§ 5.6 (d)(3)(ii) – Geology, Topography, and Soils [descriptions and maps]

(ii) Geology and soils. Descriptions and maps showing the existing geology, topography, and soils of the proposed project and surrounding area. Components of the description must include:

In this section, the emphasis will be placed on the feasibility of placing a rockfill dam at the entrance to Half-Moon Cove. The suitability of the ocean bottom to withstand vertical and horizontal loads (structural weight / seismic effects / water movement) associated with the plant's construction and operation will be the prime area of interest. In Exhibit HMC-02, a copy of the engineering analysis appears to verify the geotechnical integrity of the rockfill dam to withstand loads acting on the structure being proposed for the entrance to Half-Moon Cove. The possibility still exists to use an alternative design (i.e., tidal wall) to the rockfill dam which will be discussed in greater detail during the consultation process since a final decision has not been made on the most desirable configuration for the barrage.

Since the project will not increase the level of impoundment waters above the naturally occurring highest high tide level, the importance of the surrounding topography and soil characteristics has been reduced substantially due to the fact that surfaces above the highest high tide will not be affected by the operation of the proposed tidal power plant. The fact that the maximum velocity across tidal flats will be less than naturally occurring flows will also very slightly reduce the present erosion rate in the area between high tide and low tide. Information will be provided on terrestrial soil (slope, type, and erosion susceptibility) in order to meet FERC standards for analyzing existing conditions and potential impacts on Half-Moon Cove's design parameters.

Public information from the Quoddy Bay LNG's submittal to FERC will be referenced as part of the characterizations for this section of the pre-application document for Half-Moon Cove. Documents from the investigations conducted during the 1970s and 1980s will also be presented as part of the characterization effort [bordered by dash lines].

§ 5.6 (d)(3)(ii)(A): Geological Features

(A) A description of geological features, including bedrock lithology, stratigraphy, structural features, glacial features, unconsolidated deposits, and mineral resources at the project site;

Once again, information from the two previously referenced sources will be used to describe the basic geological features of the area around Half-Moon Cove with special attention placed on the suitability of geological features at the entrance to Half-Moon Cove to withstand project loads for the rockfill barrage. The tidal wall design will also receive the same type of engineering scrutiny if this option is selected as the most appropriate choice based on a number of factors. The following description was taken from documents written during the 1980s to summarize the geological conditions within the area of interest.

(6) Report on Geological and Soil Resources

Bedrock in the project area includes sedimentary and igneous rocks of Silurian and Devonian ages. The Eastport formation, nearest to the site, is the upper, or youngest part of the rocks of the Silurian age and outcrops mainly in a narrow belt extending from Eastport several miles to the northwest. This formation is composed of igneous Rhyolite flows, hyolite tuffs, basalt, some diabase with associated beds of shale, and minor beds of Limestone and conglomerate. These igneous rocks are dense, fine-grained and have excellent load bearing capacity.

Construction materials are available within reasonable haul distances. Quarries for rockfill for the embankment are available in the Perry and Eastport areas approximately 2-3 miles from the site. Impervious fill can be found in Carring place Cove. Filter material can be found in several nearby sites as can sources for concrete aggregate.

(i) geological features: A Department of Interior Report titled, "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development" (August 1964), presented the results of various borings taken in the Passamaquoddy Bay and Cobscook Bay area. Figure E.6.1 is a copy of an illustration which appeared in that report and which indicates the geological features of the region. The borings of particular interest are listed and identified below:

- P-42: boring taken at the site of the proposed dam to determine the depth to bedrock
- FD-2: foundation test boring for an area on the intertidal zone near the proposed dam site
- FD-1: foundation test boring taken near the dam site which serves as an indicator of the area's sub-surface profile.

The test result of the boring at the dam site showed about 4 feet of soft material, followed by increasing resistance to penetration and a refusal indicative of bedrock at 38.3 feet below mean sea level.

Overburden in the project area consists of unconsolidated surficial deposits of glacial origin, of more recent weathered granular materials, and of pest. The glacial deposits are composed of a discontinuous mantle of till, outwash materials in terraces and beaches, and silts and clays deposited in water. Sand, gravel, and talus weathered from rock outcrops are being transported to form post-glacial beaches, underwater granular deposits and stream deposits.

The project area has no known mineral resources of commercial value.

The general project area has been subjected to numerous crustal and mountain building movements and has been altered by the intrusion of large masses of igneous rock and extensive flows of volcanic rocks. The older formations were buried deeply and greatly metamorphased.

The following description (with a solid border) was recently included in the Quoddy Bay LNG application to FERC (circa 2006) since the geology of Half-Moon Cove was an important parameter in designing the LNG terminal and in placing a pipeline through Half-Moon Cove.

2.0 EASTERN COASTAL, MAINE REGIONAL, INFORMATION

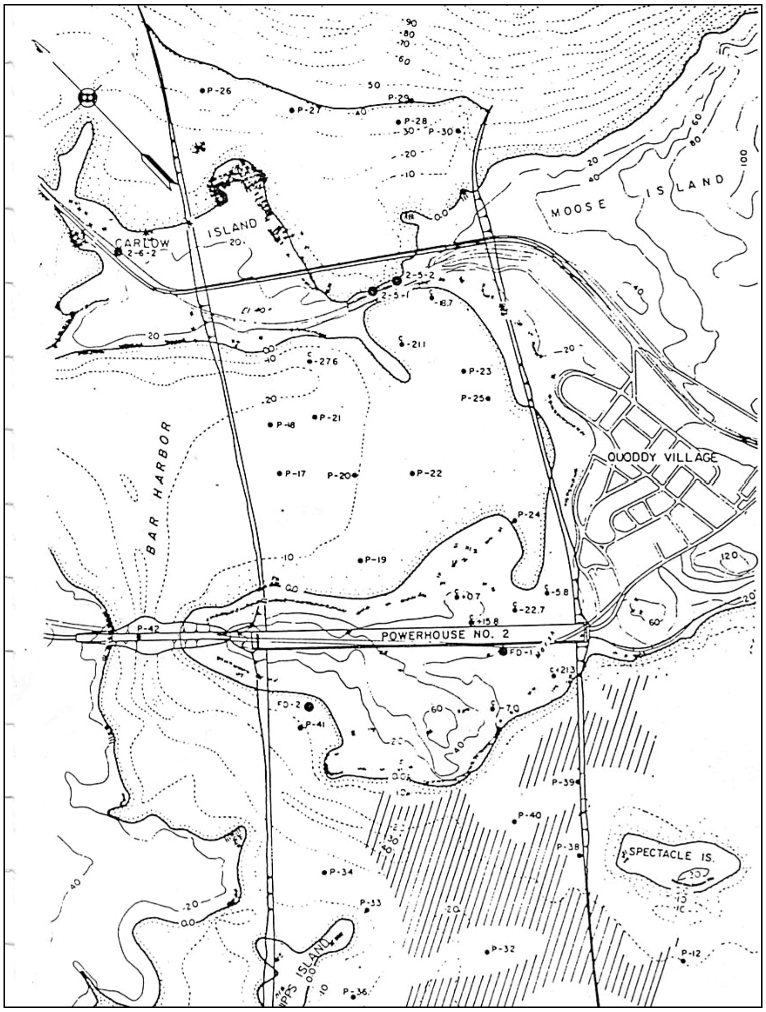
The following sections contain a brief summary of the geology of the Maine coast, in particular Eastport and surrounding areas. This information has been compiled from an extensive list of pertinent publications including articles and maps listed in Section 7.0 (FERC LNG application). Refer to these sources for more detailed information.

2.1 Geologic Setting,

Stratified rocks of Precambrian, Ordovician, Silurian and Devonian age are exposed in the Passamaquoddy Bay area (Gates, 1984). Locally in the Eastport area, rocks of lower Silurian to lower Devonian age (400 -- 440 million years ago) are exposed. During this time, marine volcanic and sedimentary rocks formed in a subsiding, extensional tectonic regime. Deformation of these rocks during the Acadian orogeny created complex tbld and fault structures. In the immediate and surrounding area of the planned LNG facility, bedrock is of the Eastport Formation. Rocks of the Eastport Formation consist of basahic rhyolite, andesite lavas and coarse pyroclastics alternating with silicic tuff breccias, ash flows, volcanic domes and shallow diabase and gabbro intrusions (Gates, 1977). The volcanic rocks in this area may be as thick as 7 kilometers, thinning rapidly to the east and west. Glaciation transformed much of the landscape of Maine between ca. 14,000 and I 1,000 B.P. (Belknap and Shipp, 1991). During glacial ice sheet advances, bedrock was scoured and carved, eroding the landscape and transporting material during ice movement. Retreating ice sheets deposited sediments in the form of till, eskers, glacial fluvial and glacial marine sediment. Sediment grain sizes can be as large as boulders, found in till deposited near the ice margin, and as fine as clay, deposited in tills, drumlins or distal marine environments.

A study by Belknap and Shipp (1991) used high-resolution seismic reflection profiling to characterize glacial stratigraphy of offshore coastal Maine. Their protocol was to identify stratigraphic units based on the character of their bounding surfaces, intensity of acoustic contrasts, and intensity, frequency and geometry of internal reflections.

From an earlier investigation on the potential of tidal power development which considered the placement of a powerhouse directly east of the now proposed dam location, the following data was presented at the site in question as referenced above:



[1] Probe P-42 performed at entrance to Half-Moon Cove as part of plans to install a powerhouse and adjoining tailrace to an area directly to the east of the area if the proposed tidal power project (Tidewalker Associates).
[2] Half-Moon Cove is identified as "BAR HARBOR" in this illustration.

Figure HMC-10: Historic Explorations at Proposed Dam Site (1964)

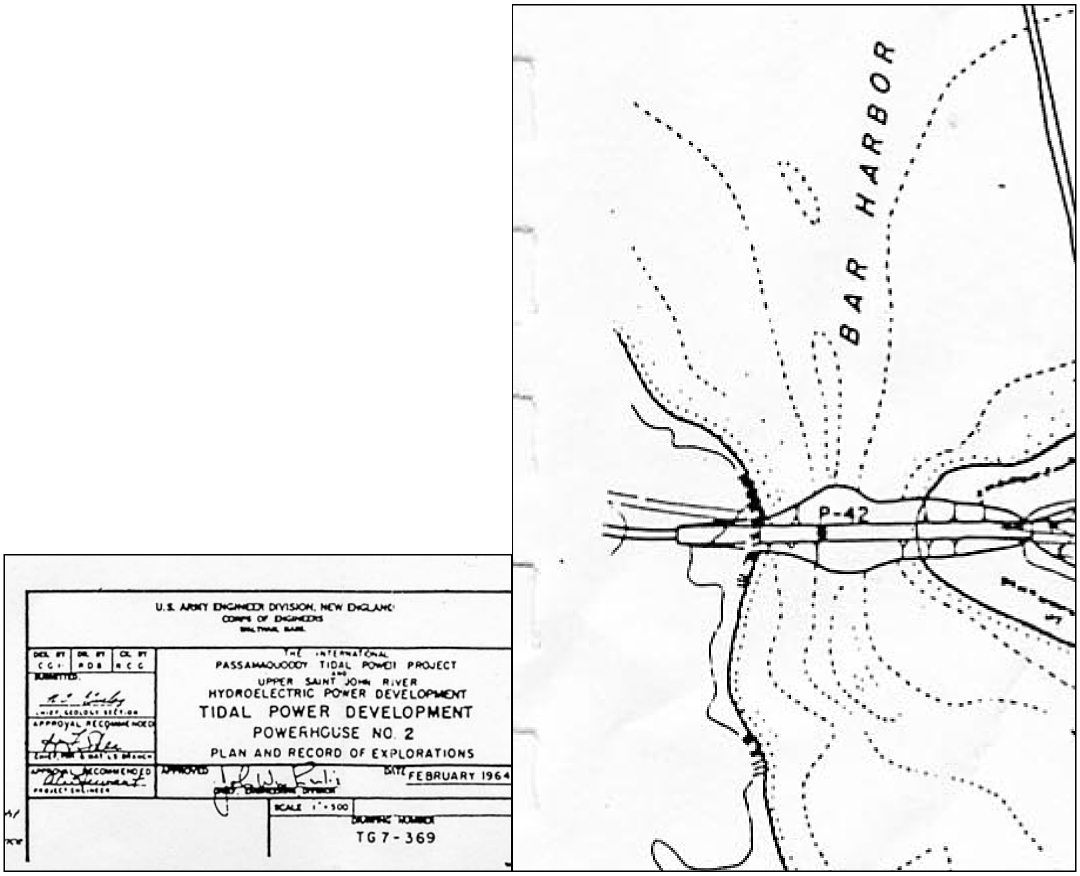


Figure HMC-11: Expanded View of Dam Site
U.S. Army Corps of Engineers (1964)

Probings were made by dropping 1.625” (OD) drill rods using a 343 pound drop weight with a free fall of about one foot. Refusal denoted by absence of vertical movement after two hundred blows. The following information was provided for probe No. P-42 at the deepest depth at the entrance to Half-Moon Cove as measured with respect to mean sea level:

DEPTH [FT]	NUMBER OF BLOWS
32	5
36	35
38	45
42	REFUSAL

The actual profile of entrance is illustrated in tidal current measurements taken at the site (Exhibit HMC-03). Borings from Maine Department of Transportation during the construction of the old toll bridge (circa 1920) provides a profile of the bedrock at the project site.

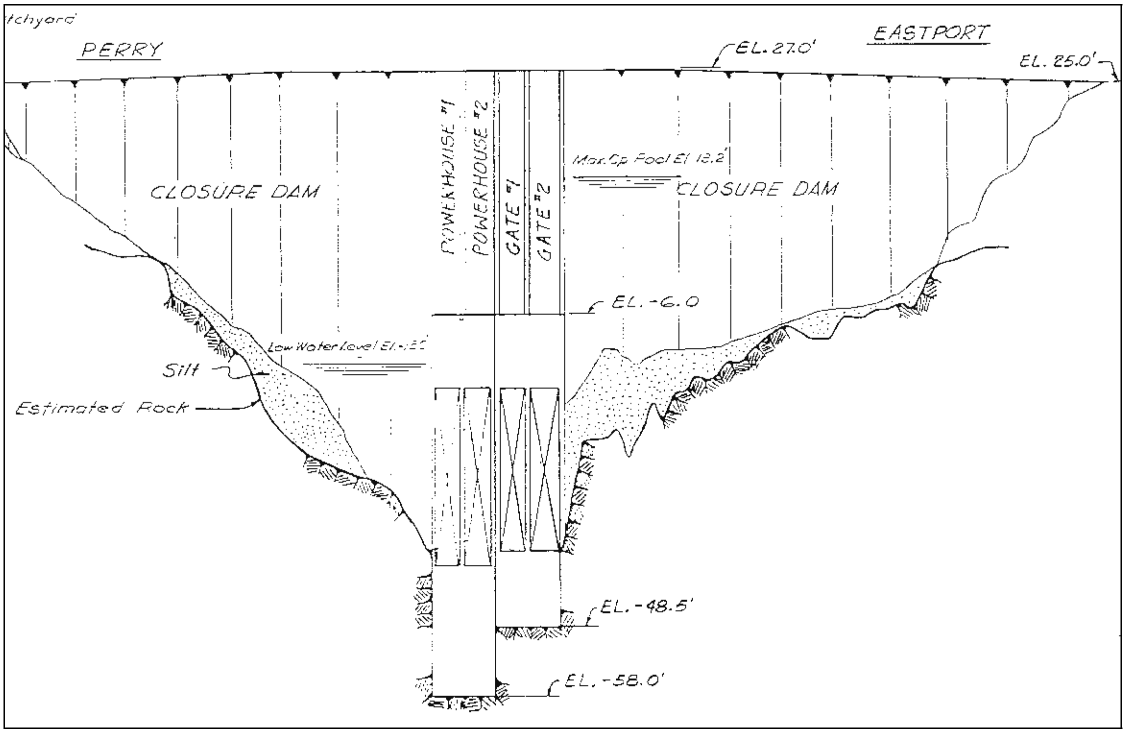


Figure HMC-12: Cross-sectional View of Entrance to Half-Moon Cove With Project Elements [Geological Contour from Maine DOT (circa 1920)]

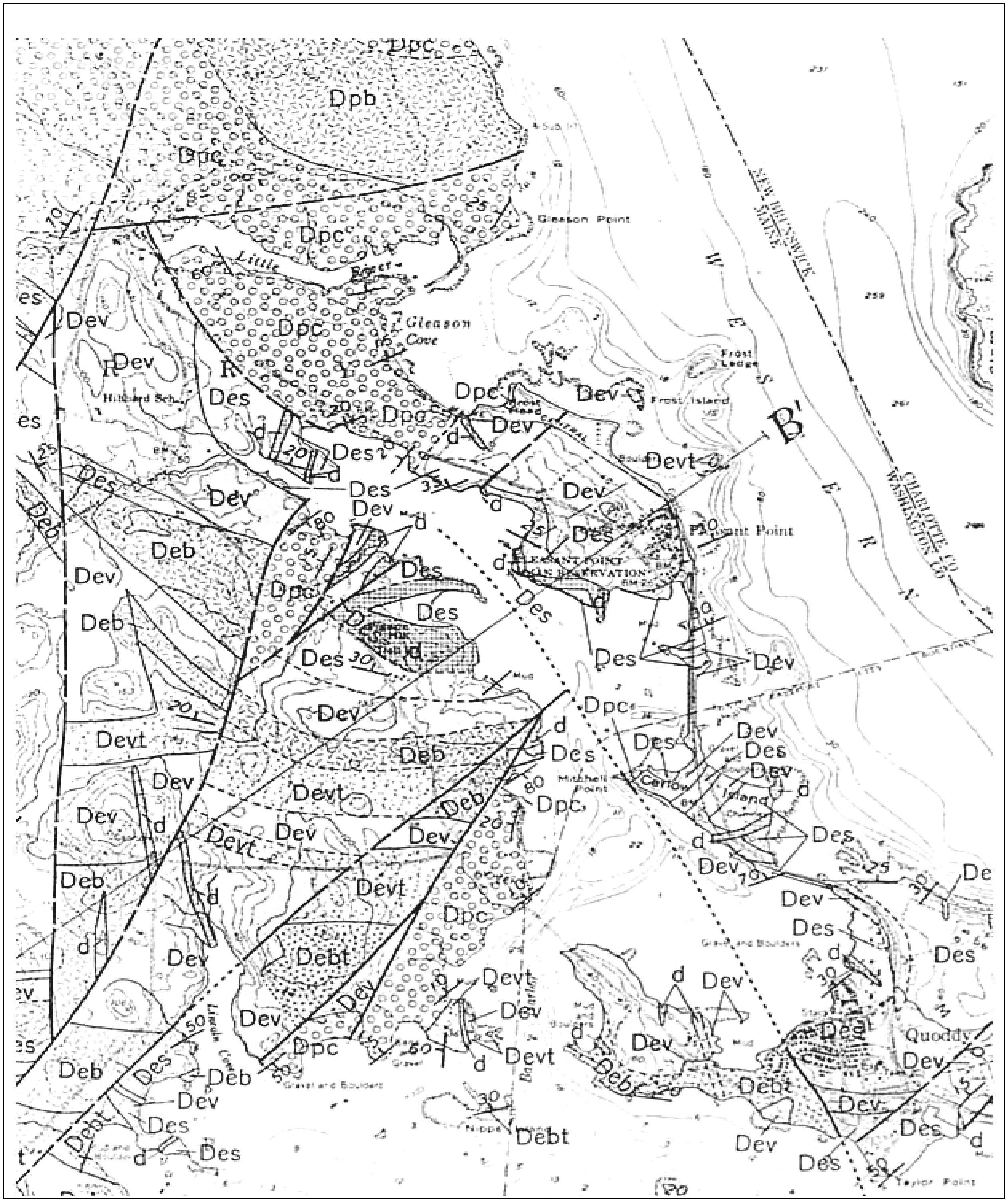


Figure HMC-13: Geologic Formation, Maine Geological Survey (1975), Eastport Quadrangle (1975)

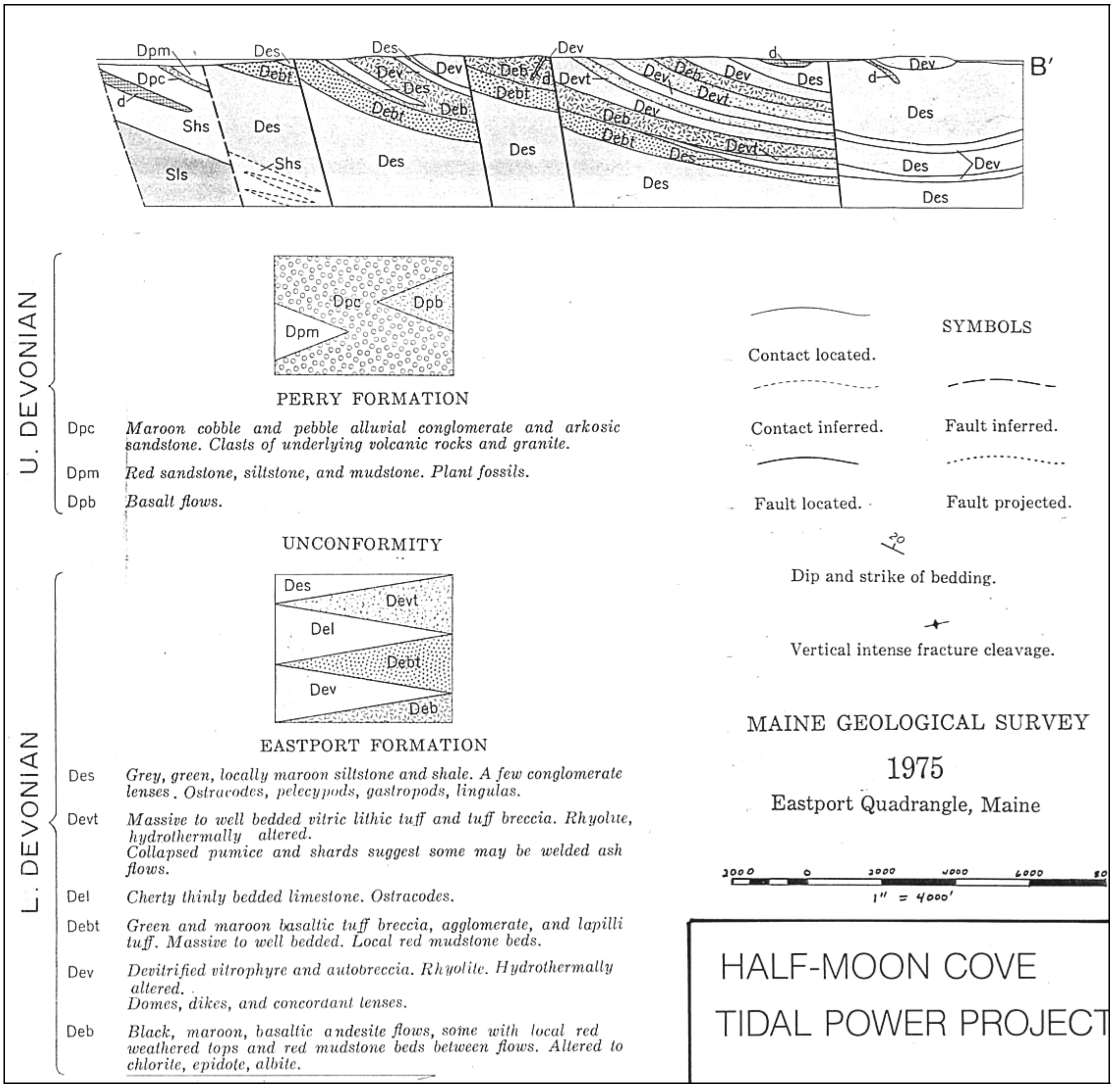


Figure HMC-14: Legend for Geological Features Depicted in Figure HMC-0X, Eastport Quadrangle

§ 5.6 (d)(3)(ii)(B): Project Soils

(B) A description of the soils, including the types, occurrence, physical and chemical characteristics, erodability and potential for mass soil movement;

Soils within and near the project area are depicted in Figures HMC-0X along with a description and expanded view of the entrance to Half-Moon Cove in Figure HMC-11.

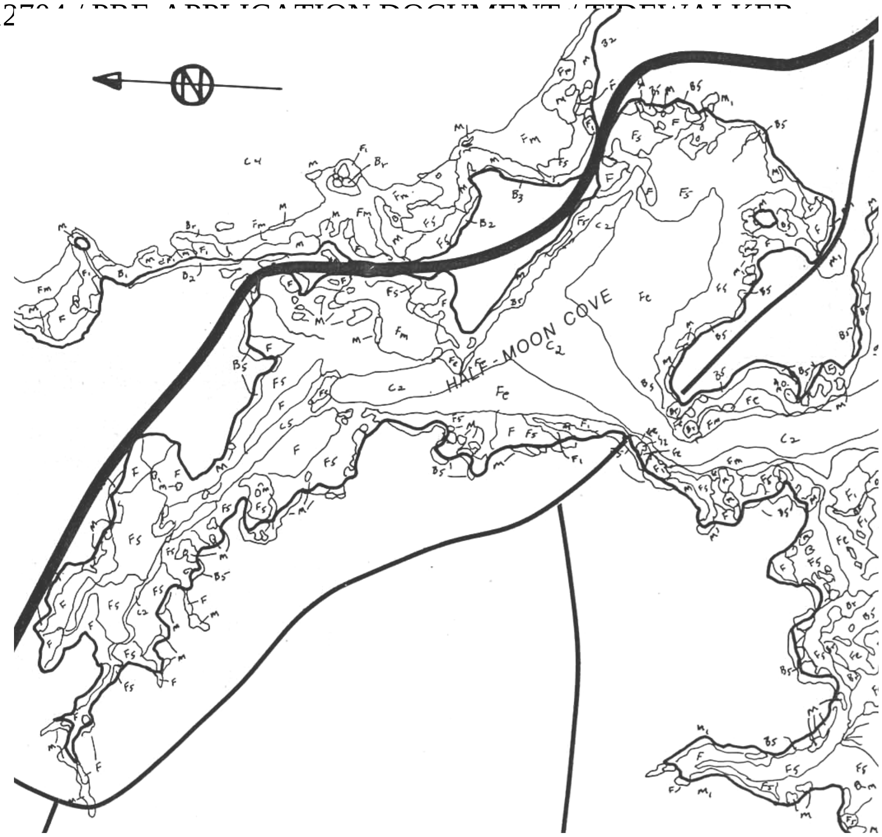
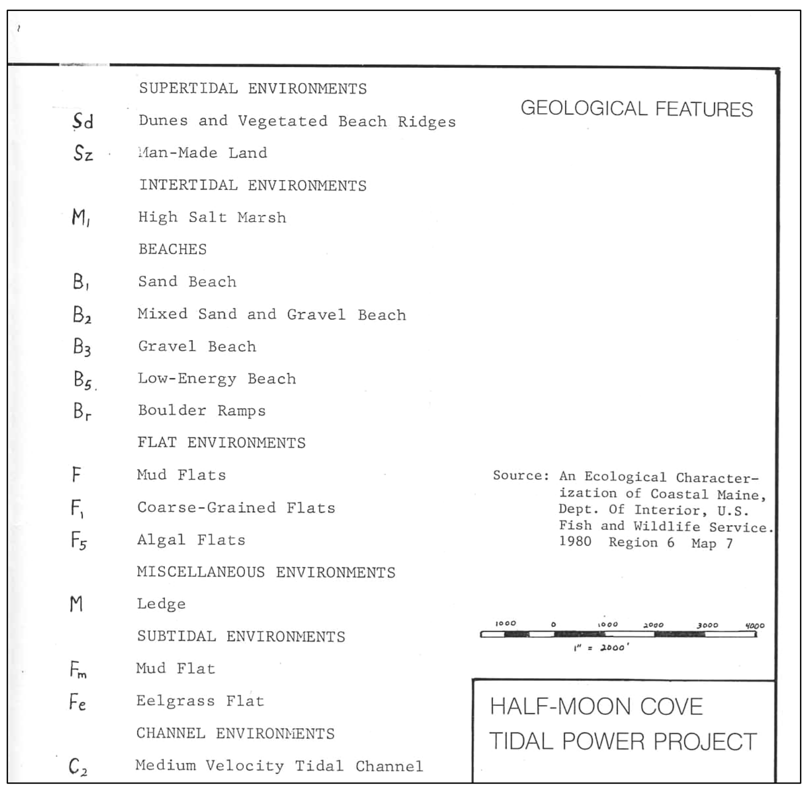
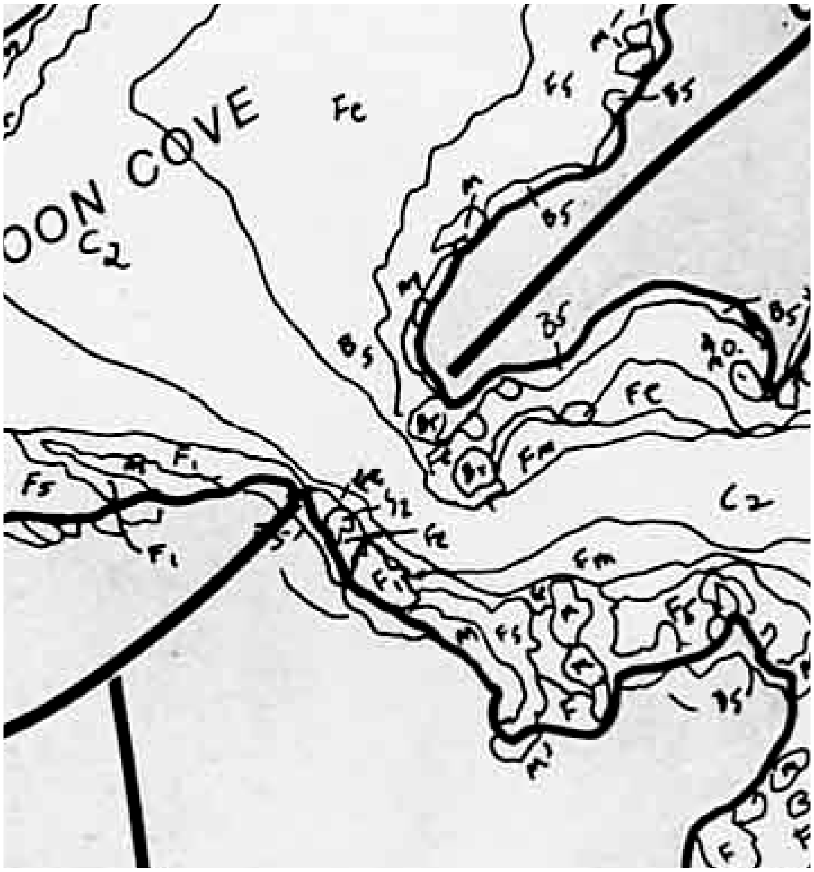


Figure HMC-15: Supertidal, Intertidal, Subtidal, and Channel Environments, U.S. Fish & Wildlife Services (1980) – Legend Below

C_4 - Estaurine Channel
C_5 - Estaurine Flood Channel

Tidal Creeks





[1] 1200’ Across Opening
[2] Average Tidal Range Equal to eighteen feet

Figure HMC-16: Expanded View of HMC-15 at Entrance to Half-Moon Cove

§ 5.6 (d)(3)(ii)(C): Reservoir Characteristics

(C) A description of reservoir shorelines and streambanks, including:
(1) Steepness, composition (bedrock and unconsolidated deposits), and vegetative cover; and
(2) Existing erosion, mass soil movement, slumping, or other forms of instability, including identification of project facilities or operations that are known to or may cause these conditions.

Once again, a description of the soils in question appears below along with maps and legends summarizing the nature and characteristics of the soil. The operation of the proposed dam will not have an impact on the stability of the soil in an around the basin.

(ii) description of soils: The soil characterization of the area bordering Half-Moon Cove is depicted in Figure E.1.1 as prepared the Maine Soil and Water Conservation Commission. Since the impoundment will not be raised above the normal high tide level, this terrestial region will not be affected during construction or operation. (see Table E.1.1)

The intertidal zone has been characterized as muddy. The over burden description which appeared earlier in this section characterizes this region. Erosion will be much less severe in this case than for projects that create an elevated reservoir since the intertidal zone is periodically flooded and drained during a normal tide cycle. The intertidal zone also has an established marine cover which can easily adapt to a modified tidal regime without excessive erosion.

(iii) geological hazards: The topics relevant to this discussion are Earthquakes and Siltation. In the case of Half-Moon Cove, the Passamaquoddy Bay area has been relatively free of earhtquakes during recent times. Minor tremors have occured from time to time as the rocks adjust to differences in internal stresses. These small adjustments, if occuring at Half-Moon Cove would not be sufficient to adversely affect the stability of the structures. Apparently, recovery from compression of the earth surface due to glaciation is essentially completed in the tidal power area.

Siltation problems refer to the increased movement and subsequent deposit of suspended and loosely-packed particles. This effect relates to the character of the existing geological composition and thereby pertains to potential impacts on the environment and on the project's economic lifetime. In this instance, the sedimentation problem is not considered to pose unacceptable.

(iv) geological and soil resources impacts: The impacts for the geological and soil resources are listed below for the construction and operation phases:

a. construction
-several terrestial sites will supply material (e.g.; gravel, armor stone) for the rockfill dam; each site when identidied will have to be individually evaluated with respect to their suitability as a quarrying or mining site.
-site preparation for the Perry side of the barrage would involve a different set of concerns than the Eastport segemnt due to the use of cofferdam construction versus "dumping in the wet"; the Perry barrage would be constructed in the dry and would follow a systematic method of overburden removal and material placement which would therefore produce a negligible amount of sedimentation; the removed overburden would be placed in a suitable terrestial landfill as designated in the 404 application.

- on the other hand, the Eastport embankment will be constructed without the erection of a cofferdam; construction of the Eastport dike under wet conditions will require the removal of the overburden in order stabilize the structure for possible earthquake loads; the reduction of erosion and the associated possibility of sediment deposition will be handled either by the use of sill curtains on the Eastport side of the project site or the removal of the overburden during the time when the cofferdam on the Perry side; the actual construction of the Eastport embankment will done in a manner which minimizes the exposure of erodable material to tidal currents (see Exhibit C); the environmental effect of erosion and sedimentation for this phase of construction is considered minimal, short-term, and localized to the dam site
- the powerhouse would be constructed behind the cofferdam; rock excavation would amount to 7900 cu. yd. for the powerhouse, 5000 cu. yd. for the gate structure, and 3400 cu. yd. for the staging areas; suitable tailrace and headrace sections will also be prepared behind the cofferdam; the rock excavated for the powerhouse will be used for material for the rockfill embankment,
- the rockfill dam is comprised of a marine clay core which will be dredged from a suitable nearby source; conditions setforth in the section 404 permit from the Corps of Engineers will define the precise method of dredging and excavation,
- construction activities will not endanger a seismic reaction due to the site's geological characteristic and due to the project's size,

b) plant operation

- once the plant is placed in operation, the terrestial geology will remain unchanges; the normal high tide level will not be exceeded and will, therefore, not pose any degradation problems to the impoundment's shoreline; the higher mean tidal range within the impoundment will have a negligible effect on the geological substructure as related to a possible increase in the amount of salt water intrusion,
- the question of seismic loading has been addressed by the Chas. T. Main engineering company; their analysis appears in the accompanying report (supplemental information); Chas. T. Main considered the most sensitive structure; i.e., Eastport embankment, for their analysis under the most critical hydrostatic loading conditions; public safety hazards related to the project's failure have been dismissed due to the fact that any flooding would not reach beyond the normal high tide level on either the basin or sea side,

- the marine burden not removed during construction phase near the turbine's discharge area will experience increased erosion during the first few years of operation; however, the existence of reversible site will quickly stabilize the erosion effect in this area; this localized and temporary effect will not significantly alter the marine environment.

v. mitigation of impacts

The mitigation of impacts to soil and geologic resources has been discussed earlier in Sec. 3 (§ iii), Exhibit E. Erosion and sedimentation as a result of construction activities will be prevented to the maximum extent possible by conformance with erosion provisions in Environmental Quality Handbook for Erosion and Sediment Control published by the Maine Soil and Water Conservation Commission. Other related mitigative measures will also be defined during the permitting process for Corps' Section 404 excavation and dredging permit.

Procedures for the operation of the project will also include provisions to maintain a regular regime of filling and emptying Half-Moon Cove in order to ensure that the modified environment will experience consistent operational parameters.

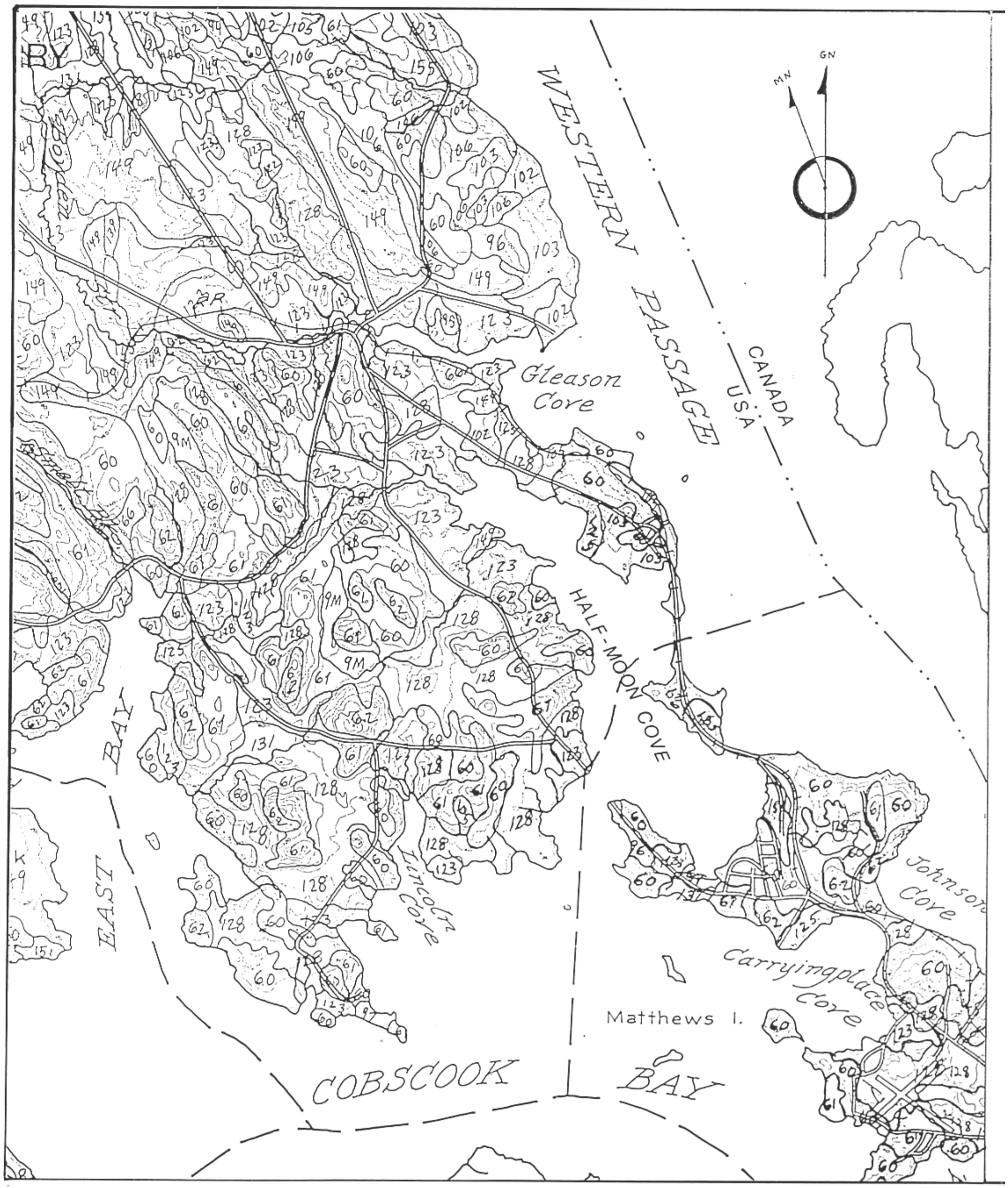


Figure HMC-17: Soil Types Bordering HMC – Legend and Characteristics Listed Below

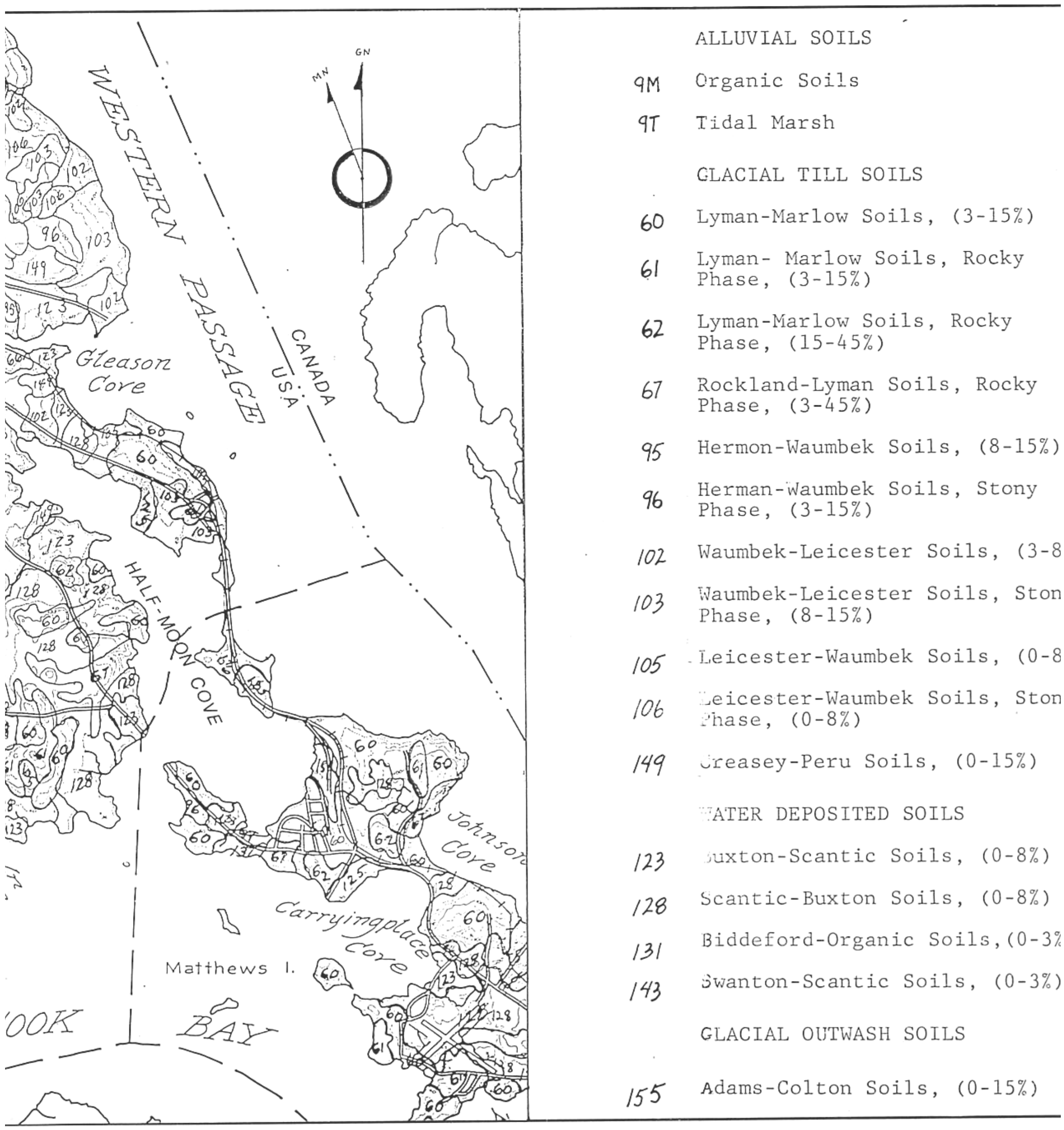


Figure HMC-18: Soils Types Bordering Half-Moon Cove [Maine State Planning Office / Soil Conservation Service]

SOIL CATEGORIES

ALLUVIAL SOILS

9M	ORGANIC SOILS
9T	TIDAL MARSH

GLACIAL TILL SOILS

60	LYMAN - MARLOW SOILS, 3-15 % SLOPES
61	LYMAN - MARLOW SOILS, ROCKY PHASE, 3-15 % SLOPES
62	LYMAN - MARLOW SOILS, ROCKY PHASE, 15-45 % SLOPES
67	ROCKLAND - LYMAN SOILS, ROCKY PHASE, 3-45 % SLOPES
95	HERMON - WAUMBEK SOILS, 8-15 % SLOPES
96	HERMON - WAUMBEK SOILS, STONY PHASE, 3-15 % SLOPES
102	WAUMBEK - LEICESTER SOILS, 3-8 % SLOPES
103	WAUMBEK - LEICESTER SOILS, STONY PHASE, 8-15 % SLOPES
105	LEICESTER - WAUMBEK SOILS, 0-8 % SLOPES
106	LEICESTER - WAUMBEK SOILS, STONY PHASE, 0-8 % SLOPES
149	CREASEY - PERU SOILS, 0-15 % SLOPES

WATER DEPOSITED SOILS

123	BUXTON - SCANTIC SOILS, 0-8 % SLOPES
128	SCANTIC - BUXTON, 0-8 % SLOPES
131	BIDDEFORD - ORGANIC SOILS, 0-3 % SLOPES
143	SWANTON - SCANTIC SOILS, 0-3 % SLOPES

GLACIAL OUTWASH SOILS

155	ADAMS - COLTON SOILS, 0-15 % SLOPES

Table HMC-19: Soil Characteristics and Slopes for Area Bordering Half-Moon Cove

APPROXIMATE PROPORTION OF SOIL TYPES IN EACH ASSOCIATION	
LYMAN-MARLOW	55% LYMAN, 25% MARLOW, 20% PERU, RIDGEBURY
ROCKLAND-LYMAN	60% ROCK LAND, 30% LYMAN, 10% MARLOW, PERU
HERMON-WAUMBEK	60% HERMON, 25% WAUMBEK, 15% CANAAN, LEICESTER
WAUMBEK-LEICESTER	60% WAUMBEK, 30% LEICESTER, 10% HERMON, CANAAN
LEICESTER-WAUMBEK	60% WAUMBEK, 20% LEICESTER, 20% WHITMAN, ORGANIC, HERMON, CANAAN
CREASEY-PERU	70% CREASEY, 20% PERU, 10% MARLOW, RIDGEBURY, LYMAN
BUXTON-SCANTIC	60% BUXTON, 25% SCANTIC, 15% SUFFIELD, RAYNHAM, BELGRADE
SCANTIC-BUXTON	65% SCANTIC, 20% BUXTON, 15% SUFFIELD, BELGRADE, BIDDEFORD, HOLLIS
BIDDEFORD-ORGANIC	70% BIDDEFORD, 20% ORGANIC, 10% SCANTIC, SWANTON, SHALLOW TO BEDROCK SOILS
SWANTON-SCANTIC	50% SWANTON, 35% SCANTIC, 15% ELMWOOD, BUXTON, ORGANIC, SHALLOW TO BEDROCK SOILS
ADAMS-COLTON	70% ADAMS, 15% COLTON, 15% DEERFIELD, DUANE, WALPOLE

Table HMC-20: Additional Soil Characteristics for Soil Bordering Half-Moon Cove

SOIL TYPE	SLOPE	DRAINAGE	DEPTH TO BEDROCK (IN)	PERMEABILITY	POTENTIAL FROST ACTION	K VALUE (ERODABILITY)
ADAMS	0-15	EXCESSIVE	>60	VERY RAPID	LOW	0.17
BIDDEFORD	0-03	VERY POOR	>60	VERY SLOW	HIGH	0.32
BUXTON	0-25	MODERATE WELL TO SOMEWHAT POOR	>60	VERY SLOW	HIGH	0.49
CREASEY	3-35	SOMEWHAT EXCESSIVE	< 20 TO > 60	MODERATELY RAPID	MODERATE	0.20
HERMON	3-35	SOMEWHAT EXCESSIVE	> 60	RAPID	LOW	0.17
LEICESTER	0-08	SOMEWHAT POOR	> 60	MODERATELY SLOW	HIGH	0.17
LYMAN	3-35	SOMEWHAT EXCESSIVE	< 20	MODERATELY RAPID	MODERATE	0.20
ROCK LAND	8-35	EXCESSIVE	< 20	MODERATELY RAPID	LOW TO MODERATE	-
SCANTIC	0-08	POOR	> 60	SLOW	HIGH	0.49
SWANTON	0-03	SOMEWHAT POOR	>60	SLOW	HIGH	0.32
WAUMBEK	3-05	MODERATELY WELL	>60	MODERATELY RAPID	HIGH	0.17

IMPORTANT PROPERTIES OF SOILS IN

Table HMC-01: Soil Characteristics for Shoreline Bordering Half-Moon Cove