Published online June 29, 2007

Soil/Landscape Relationships in a Mesotidal Maine Estuary

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Submerged sediments represent an important component of near-shore coastal systems. Soil scientists have begun to study subaqueous soils from a pedological perspective, and conceptualize these soils as organic or mineral materials, having the ability to support rooted plants, which are submerged by estuarine, marine, or lacustrine water for a period of time such that their pedogenesis reflects an environment dominated by submergence. The objective of this study was to describe and classify subaqueous soils of a shallow, mesotidal, Maine estuary and identify the relationship between soil properties and landscape position. A detailed bathymetric map was created for the study site using a fathometer, Global Positioning System (GPS), tide gauges, surveying equipment, and Geographic Information System (GIS) software. The bathymetric map was used to identify the slope for each landscape unit and the mean water depth above each landscape unit. Slopes in the study range from 1 to >25%. Water depths above the soil surfaces are between 0.1 and 21.0 m at mean sea level (MSL). Soil samples were collected to depths between 1.0 and 5.5 m below the soil surface using a bucket auger, McCauley peat auger, or vibracoring device. Seven soil landscape units and 10 soil map units were differentiated from one another according slope class, geomorphic position, depositional environment, and soil characteristics. Most of the soil parent materials in the estuary are fine-textured sediments. This work is the first estuary soil survey completed in Northern New England.

Abbreviations: AVS, acid volatile sulfides; CC, coastal cove; CCD, deep coastal cove; CH, channel; CRS, chromium reduced sulfides; CS, channel shoulder; estuary edge; FMT, fluvial-maritime terrace; MS, mussel shoal; MSL, mean sea level; OM, organic matter; RES, recent estuary sediment; S, sands; SCC, shallow coastal cove; SFD, submerged fluvial delta; SFS, submerged fluvial stream; SiCL, silty clay loam; SiL, silt loam; SL, sandy loam; SM, submerged marsh; TC, total carbon; TE, terrestrial edge; TIC, total inorganic carbon.

Estuarine environments occupy the boundaries between terrestrial and marine systems and are located at the confluence of fresh and salt waters. These ecosystems provide habitat for mammals, birds, fish, invertebrates, and a variety of plant species. Housing and business development along estuarine shores and recreational and economic activities within estuarine waters can have major impacts on the estuarine system. Potential impacts include eutrophication, increased turbidity, and habitat loss (Short and Wyllie-Echeverria, 1996; Roman et al., 2000; Deegan, 2002; Hughes et al., 2002; Keats et al., 2004). Changes in the environment, such as sea level rise, also have an impact on estuarine environments (Stevenson et al., 1986; Koch and Beer 1996;). Erosion and submersion of tidal marshes and shorelines are two consequences of rising sea level (Ward et al., 1998; Simas et al., 2001) that may lead to the deposition of mineral and organic material into estuarine systems.

Scientists from a broad range of disciplinary specialties have studied estuarine and coastal ecosystems. Examples of previous estuary studies include investigations of vegetation and faunal interactions (Heck et al., 1995; Mattila et al., 1999), hydrology (Fitts, 2002), vegetation assemblages (Odum et al., 1974; Fonesca et al., 1982, 1998), and descriptions of the physical substrates in estuarine environments (Timson, 1976; Shipp et al., 1985). However, until recently, soil scientists rarely studied the sediments of estuaries.

In the last decade, the USDA's definition of soils changed to include environments that are permanently submerged (Soil Survey Staff, 1999). Since then, some soil scientists have studied the sediments of shallow subtidal lagoons and described them from a pedological perspective. The pedological approach involves characterizing the physical (color, texture, compressibility), chemical (pH, salinity, sulfides, cation exchange), and biological (plants and animals) properties of the benthic substrates and describing them using the terminology commonly used for soils. Once the benthic materials and underlying sediments are described as soils, investigators can identify the relationships between the soils and their position on the landscape (Demas et al., 1996; Demas and Rabenhorst, 1999, 2001; Bradley and Stolt, 2002, 2003). An understanding of these relationships enables land managers to identify the best location for specific land uses (e.g., shell fish production, dock placement) and to better predict the potential impact of proposed changes (e.g., dredging, marina development) on subaqueous soils and the ecosystems they support. This study is an investigation of the relationship between soil properties and landscape position, slope class, and depositional environment in a mesotidal estuary in Maine.

Soil Sci. Soc. Am. J. 71:1323–1334
doi:10.2136/sssaj2006.0224
Received 13 June 2006.
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SITE DESCRIPTION

The Taunton Bay estuary is a small (1329 ha), shallow, inland-bay estuary representative of Maine's Island-Bay Coast geomorphic province. The Island-Bay Coast province includes 47% of the state's 4800 km coastline (Kelley, 1987). Mean tidal range is 2.7 m and mean spring tidal range is 3.4 m. Taunton Bay is connected to Frenchman's Bay via the Taunton River. Frenchman's Bay is an open bay north of Penobscot Bay along Maine's Atlantic Coastline. A small amount of marine water also enters Taunton Bay through a historic (19th century), anthropogenic, mostly filled-in, channel connecting Taunton Bay to Young's Bay, another subestuary of Frenchman's Bay to the southwest. Fresh, surface water inputs to the Taunton Bay estuary come from many, small, perennial and intermittent streams.

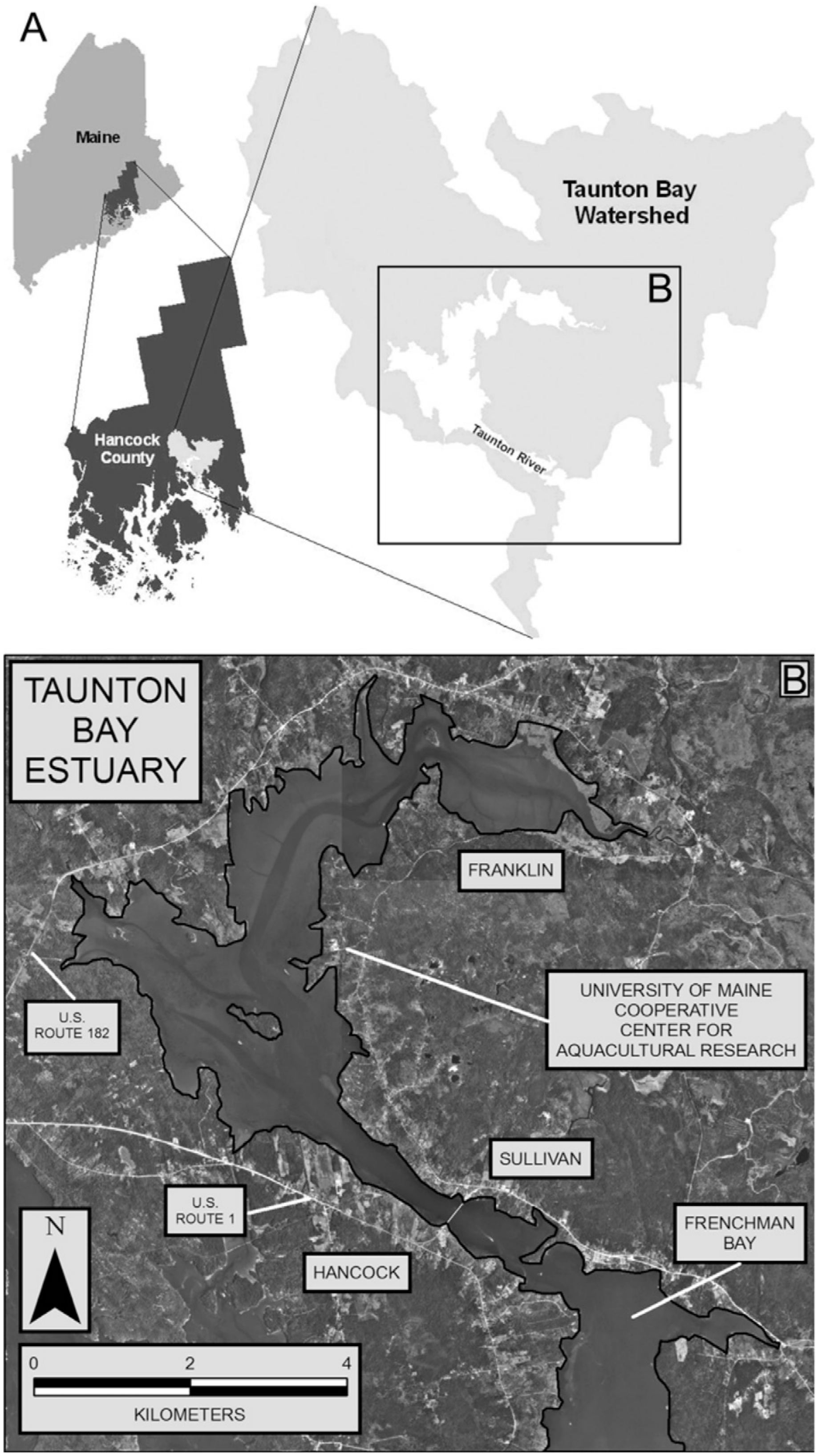

Fig. 1. Maps presenting the location of the study site. A. Location of Hancock County in Maine, Taunton Bay watershed in Hancock County, and Taunton Bay estuary within the Taunton Bay watershed. B. Towns, roads, and coastline of the Taunton Bay estuary.

The Taunton Bay estuary is located in Hancock County, Maine (Fig. 1A). The estuary is bisected by long, narrow channels up to 21 m in depth below MSL. None of these channels have ever been dredged. A low bridge prevented access to commercial fishing vessels across the Taunton River that connected the Hancock and Sullivan since the 1920s (Fig. 1B). When the low bridge was replaced with a higher bridge in 1996, the State imposed a moratorium on the dragging of fishing nets in Taunton Bay. As a result, anthropogenic disturbance of the soil surfaces in the estuary has been limited to the harvesting of worms and bivalves by local residents. This study site for this research is a 589-ha section of the Taunton Bay estuary system (Fig. 2).

The 34,000-ha watershed contributing to the Taunton Bay estuary is rural; with a low density of homes, businesses, and roads. There are no municipal wastewater treatment plants or industrial facilities that discharge water to the estuary. The watershed is mostly forested, with a small percentage of area used for agriculture. The relatively pristine character of the watershed and estuary makes this site an excellent place to study estuary soil–landscape relationships.

Parent materials of upland soils in this watershed include glacial till, glaciofluvial sand, and gravel on outwash plains, glaciomarine, and glaciolacustrine sediments in the coastal lowland, and recent (late Holocene) alluvium in river valleys (Johnson, 1999; Thompson and Borns, 1985). The glaciomarine sediments in coastal Maine were deposited between 14,000 and 11,500 yr before present (Dorion et al., 2001) and are referred to as the Presumpscot Formation (Bloom, 1960). These sediments have silty clay textures (Johnson, 1999) and blue gray colors ranging from 5G 5/1 to 5B 8/1 (Kollmorgen Instruments Corporations, 2000).

MATERIALS AND METHODS

Bathymetry

Bathymetric data for Taunton Bay were collected with a Garmin168 GPS/Sounder combination unit with the transducer mounted to the stern of a boat. The boat traveled along transects within the estuary that were approximately 35 m apart. A Toshiba laptop computer equipped with Nobeltec's Visual Navigation Suite software which included digital marine charts for Taunton Bay (Nobeltec Corporation, 2002), were used to identify the general location of the boat in the Bay during data collection. The GPS/Sounder collected depth, latitude, and longitude measurements every 2 s while the boat was traveling an average speed of 7 knots. The location of each data collection point was visible on the computer screen immediately after data collection. A total of 13,900 data collection points (Fig. 2) resulted in an average of 22 data collection points per hectare.

During bathymetric data collection, the water surface elevation changed as a result of tidal fluctuations. To account for these changes, time analogous data was collected from three YSI 6000 water level measurement (tide) gauges. The tide gauges were placed approximately 2.4 km apart from one another. One gauge was placed near the upstream end of the Taunton River channel (TG1), the second one was placed in Egypt Bay (TG2) and the third (TG3) was placed in Taunton Bay, just beyond the perimeter of the study area (Fig. 2). The location of each gauge was identified using the GPS. A certified USDA-NRCS surveyor determined tide gauge elevation.

Each tide gauge recorded water depths at 15-min. intervals. Using the elevations, the data from each gauge was calibrated to MSL (between high and low tide) set to the North American Vertical Datum of 1988 (NAVD88). Each bathymetric data point was corrected to MSL for the moment it was collected using a three variable inverse weight distance calculation routine. The equations used to make these corrections are as follows:

Distance of each sample point from three tide gauges:

$$\sqrt{(\mathrm{Se} - \mathrm{TG1e})^2 + (\mathrm{Sn} - \mathrm{TG1n})^2} \qquad [1]$$

$$\sqrt{(\mathrm{Se} - \mathrm{TG2e})^2 + (\mathrm{Sn} - \mathrm{TG2n})^2} \qquad [2]$$

$$\sqrt{(\mathrm{Se} - \mathrm{TG3e})^2 + (\mathrm{Sn} - \mathrm{TG3n})^2} \qquad [3]$$

Weighted distance from each tide gauge:

$$\frac{1}{\sqrt{(\mathrm{Se} - \mathrm{TG1e})^2 + (\mathrm{Sn} - \mathrm{TG1n})^2}} \qquad [4]$$

$$\frac{1}{\sqrt{(\mathrm{Se} - \mathrm{TG2e})^2 + (\mathrm{Sn} - \mathrm{TG2n})^2}} \qquad [5]$$

$$\frac{1}{\sqrt{(\mathrm{Se} - \mathrm{TG3e})^2 + (\mathrm{Sn} - \mathrm{TG3n})^2}} \qquad [6]$$

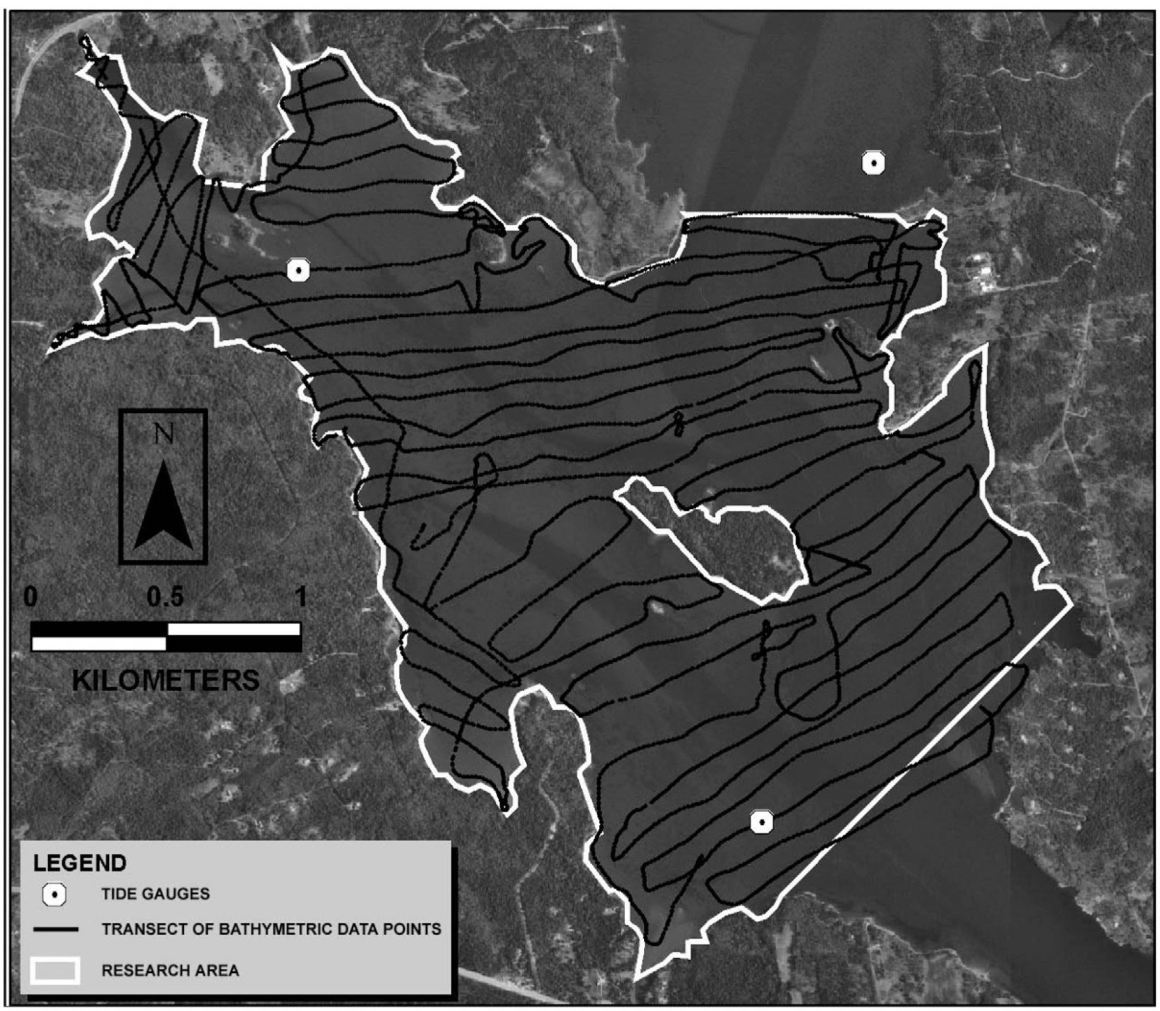

Fig. 2. Perimeter of the study area and locations where latitude, longitude and depth measurements were collected in Taunton Bay estuary. The three circles identify the locations of the tide gauges. The base map for the figure is the 1996 USGS digital orthophoto quad for this portion of Hancock County, Maine.

$$\text{Weighted Sum} = \frac{1}{\sqrt{(\text{Se - TG1e})^2 + (\text{Sn - TG1n})^2}} + \frac{1}{\sqrt{(\text{Se - TG2e})^2 + (\text{Sn - TG2n})^2}} + \frac{1}{\sqrt{(\text{Se - TG3e})^2 + (\text{Sn - TG3n})^2}} \quad [7]$$

$$\text{Calculated depth at MSL} = (1/\text{Eq. [1]})(\text{Dtg1}) + (1/\text{Eq. [2]})(\text{Dtg2}) + (1/\text{Eq. [3]})(\text{Dtg3})/\text{Eq. [7]} \quad [8]$$

$$\text{Correction factor} = \text{Eq. [8] - Ds (m)} \quad [9]$$

where Se equals the easting of a bathymetric data point, Sn equals the northing of a bathymetric data point; TG1e, TG2e, TG3e equals the easting of tide gauges 1, 2, and 3, respectively; TG1n, TG2n, and TG3n equals the northing of tide gauges 1, 2, and 3, respectively; Dtg1, Dtg2, and Dtg3 equal the depth of tide gauges 1, 2, and 3, respectively; and Ds equals depth of a bathymetric data point. Inverse distance weighting and triangulated irregular network (TIN) extensions of ArcGIS (ESRI Corporation, 2004) were used to create the bathymetric map from the adjusted depth values.

Landform Delineation

Landforms were delineated by identifying differences in photo tone, water depth at MSL, slope class, and position on the landscape. The distinctly darker color of submerged streams and the estuary channels in the 1:7920 rectified, Digital Ortho-Photo Quad (DOQ) (produced by the USDA-FSA Aerial Photography Field Office in 1998, available at: www.fsa.usda.gov/Internet/FSA_File/catalog.txt, verified 9 May 2007) facilitated delineation of these subaqueous landforms. Lighter colors were indicative of shallower portions of the estuary, where the subaerial and subaqueous soils meet. The slopes of these landforms were identified using the slope tool on the geospatial toolbar in ArcView GIS (ESRI Corporation, 2004). The landforms were further characterized by depth of soil surface below MSL.

Soil Sampling Techniques

Soils were collected using hand held augers (24 pedons) and a vibracorer device (31 pedons). Firm soils with *n* values (bearing capacity of mineral soils) < 0.7 were collected with a bucket auger. Loose, fluid soils with *n* values > 0.7 were collected using a McCauley peat sampler. The *n* value is a unit-less measure that characterizes the bearing capacity of the soil and is also representative of the approximate water, clay, and humus content in the soil (by weight) under field conditions (Pons and Zonneveld, 1965). The *n* value was determined by hand in the field (Schoeneberger et al., 2002). The *n* values > 1.0 are considered high, those < 0.7 are considered low.

The maximum depth sampled using the soil auger was 150 cm; maximum depths sampled using the McCauley peat auger were 300 cm. The coordinates for each sampling location were identified with the GPS. Areas with soil surfaces > 3 m below the water surface at MSL were excluded from the study because the soils at this depth are those along the walls and the bottom of the estuary channels, making them difficult to sample with the equipment available.

Auger samples were described in the field according to the National Soil Survey Center (NSSC) guidelines (Schoeneberger et al., 2002). Each soil sample collected for laboratory analysis was placed in a plastic bag, sparged with N_2 gas, and stored in a cooler with ice. The coolers were transported to the laboratory, and frozen within 6 h of collection.

A vibracorer (Hoyt and Demarest, 1981), oriented vertically, was used to collect soil cores to depths as great as 550 cm without significantly disturbing soil morphology. The tool vibrated a 7.6-cm diam. aluminum tube into the soil so that it sampled the profile perpendicular to the water surface. Sampling ended when the aluminum tube stopped penetrating the soil by its own force. The tubes were extracted from the sediment using a chain-fall, and sealed with an airtight cap at the lower end. The excess aluminum pipe was cut near the surface of the soil, and the second end of the core was capped. Thirty-one soil cores were collected using the vibracoring device. The lengths of these cores ranged from 1.0 to 5.5 m. When individual core lengths were >2.75 m, the cores were cut into sections, sections were labeled, and all cut ends were capped. Cores were transported to the University of Maine, Orono and stored in a walk-in cooler at 4°C.

Laboratory Analysis

Soil cores were removed from cold storage and cut in half along the long axis using a circular saw. The open, split cores were described and sampled in the laboratory according to the NSSC guidelines (Schoeneberger et al., 2002). Soil pH was measured for each horizon within 200 cm using a 1:1 ratio of soil to deionized water. Soil conductivity was determined by measuring the conductivity of a saturated paste of moist soil and deionized water (National Soil Survey Center, 2004). Subamples of the soils collected with augers were analyzed for total C content (TC) by thermal partitioning method (EPA 440.0) using a Leco CN-2000 combustion analyzer (Leco Corp., St. Joseph, MI). Organic matter (OM) was burned off another subsample in a muffle furnace at 550°C. The muffled residue is then analyzed to determine total inorganic C (TIC), and presented as a percentage of the unmuffled sample. Organic C content was calculated as difference between TC and TIC. Combustion temperature for both TC and TIC analysis is 1350°C (Midwood and Boutton, 1998). The percentage of OM of these horizons was calculated by multiplying the measured organic C concentration by 1.72 (Pons and Zonneveld, 1965). Samples from horizons within the top 100 cm of auger and vibracore samples were (moist) incubated and the pH monitored for 8 wk to determine if the soil materials met the requirements for sulfidic materials according the method described by Soil Taxonomy (Soil Survey Staff, 2006).

Horizons from the top 25 cm of vibracores were also analyzed for acid volatile sulfides (AVS) and chromium reducible sulfides (CRS) following a procedure similar to the methods described by Cline (1969) and Ulrich et al. (1997). Between 0.5 and 1.5 g of moist soil from each horizon was placed in individual 150 mL serum bottles. A sulfur trap (a 10 mL tube containing 2.5 mL 11% O_2–free zinc acetate) was placed in each serum bottle. The bottles were then sealed and purged of oxygen using N_2 gas. Using a syringe, 12 mL of O_2–free 2 *M* HCl was added to each bottle, and bottles were gently shaken overnight at 150 rpm. The sulfur traps were removed after 12 h and the zinc acetate was analyzed for AVS. Fresh traps were placed in the same bottles, which were again sealed and purged of O_2 using N_2 gas. Next, 4 mL of 12N O_2–free HCl and 8 mL Cr^{2+} were added by syringe and the bottles were shaken for 12 h, the trap was removed and the zinc acetate was analyzed for CRS. Zinc acetate solutions were analyzed on a Bausch & Lomb Spectronic 2000 spectrophotometer (Bausch & Lomb, Inc. Rochester, NY) at 670 nm calibrated with standards made from $Na_2S{\cdot}9H_2O$ in 11%

zinc acetate. All samples were diluted as necessary to stay within the linear range of the calibration curve (Cline, 1969).

Soil profiles collected in each map unit were classified according to the Keys to Soil Taxonomy (Soil Survey Staff, 2006) and the proposed amendments to Soil Taxonomy developed to accommodate subaqueous soils (Stolt, 2006).

RESULTS

Bathymetry and Slope

The bathymetry for the study area is presented in Fig. 3. The base map is the portion of the Hancock, ME DOQ that includes Taunton Bay. Each contour interval represents surfaces with equivalent depths below MSL. The surface elevation for three quarters of the study area (431 ha) is between 1.0 and 2.0 m below MSL and has a mean depth of 1.3 m. The channel bottoms range in depth from 3.5 to 21 m below MSL, and have a mean depth 8.6 m below MSL. The shallowest locations in the estuary are those nearest to shorelines.

Slopes in the study area range from 0 to 27%. This range in slopes was separated into five different slope classes. Level landscapes with 0 to 0.5% slopes are in slope Class A, and occupy 9% of the study area. Nearly level landscapes; those with slope between 0.5 and 1%, are in slope Class B, and occupy 16% of the study area. Approximately 43% of the study area has slopes between 1 and 3% (slope Class C). Portions of the study area with slopes between 3 and 5% (slope Class D) occupy 17% of the area. The areas with slopes greater than 5% are in slope Class E.

Landscape Units

Seven subaqueous landscape units were mapped in the study area. Table 1 presents the landscape units, the area of the study site they occupy, their slope range, slope class, the water depth above the soil surface at MSL, and the depth to the underlying Presumpscot Formation. All but one of the landscape unit names are derived from the common geomorphology terms used to describe similar landforms in a subaerial landscape. The one exception is the terrestrial edge (TE) landscape, which occupies the areas along the edges of the estuary (Fig. 3).

The TE landscape has been submerged by rising sea level in the last several hundred years (Osher et al., 2007). The slopes of the TE are nearly level (<0.5%) and soil surface depths are 0.5 m

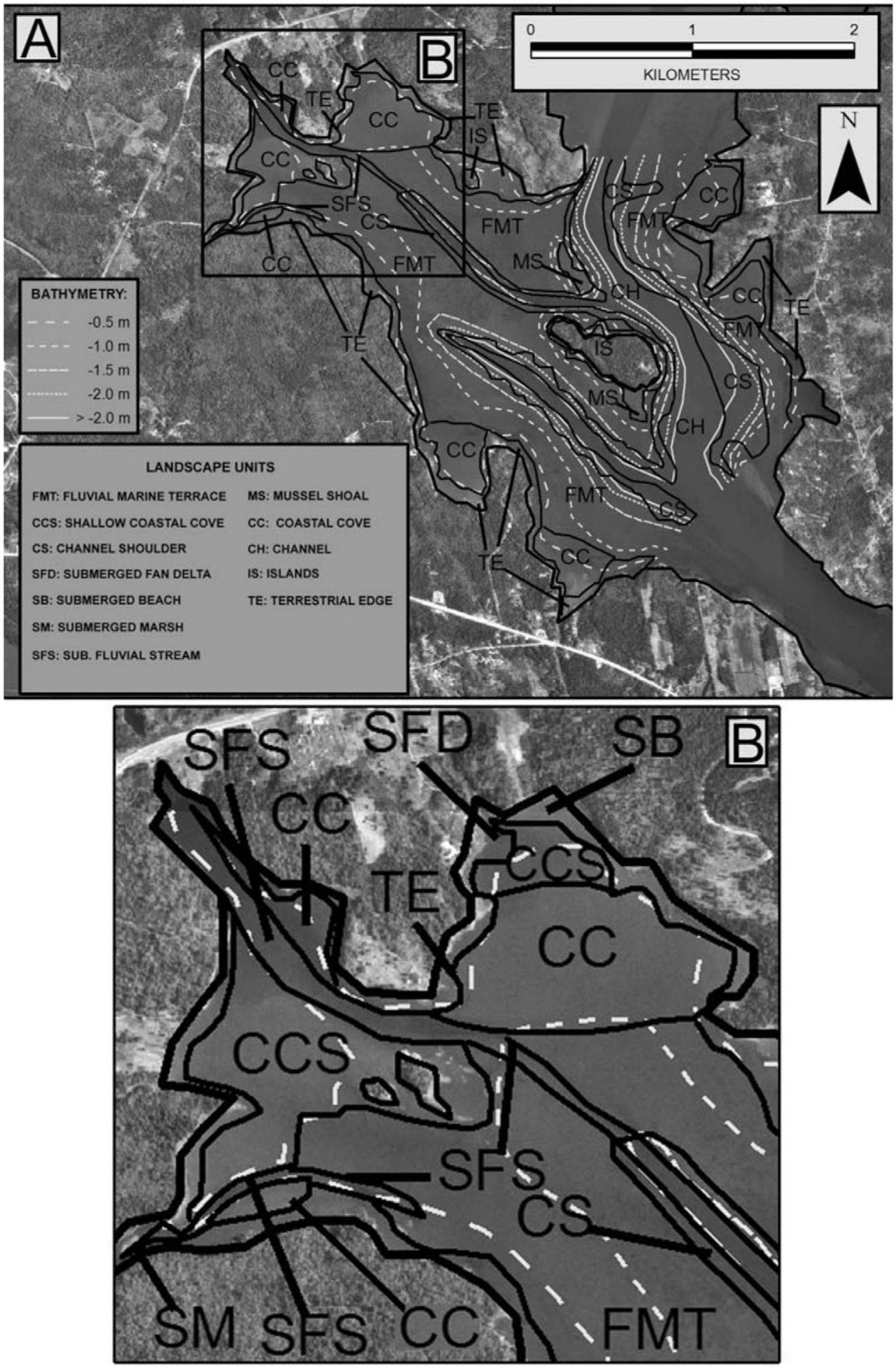

Fig. 3. Landscape units, bathymetry and soil map units of the Taunton Bay estuary. A. Landscape units (black lines) and bathymetry (white lines) in the soil-landscape study area. Each white line represents contours with equivalent depths below mean sea level. The contour intervals are 50 cm to a depth of 2 m. The 2 m line represents all surface greater than 2 m depth. B. Soil map unit delineations within Terrestrial Edge; Submerged Beach, Submerged Delta, Submerged Marshes and Streams, and Shallow and Deep Coastal Coves and other landscape units present on the western portion of the study area.

Table 1. Soil landscape unit name, percent area, slope range, slope class, water depth above the soil surface at mean sea level, and the depth to the underlying Presumpscot Formation.

Landscape unit	Area	Slope	Slope	Water depth†	Depth to PF‡
	%	Class	%	m	m
Terrestrial edge	8	A	0.5	0.5	0.5–2.0
Coastal cove	16	B	0.5–1.0	0.5–1.0	1–3.0
Submerged fluvial stream	5	B	0.5–1.0	0.5–1.0	>1.4
Mussel shoal	1	B	0.5–1.0	0.5	>5.0
Fluvial marine terrace	43	C	1.0–3.0	1.0–1.5	2.5- > 6.0
Channel shoulder	18	D	3.0–5.0	1.5- 3.0	>3.0
Channel	15	E	>5.0	>3.0	ND§

† Depth from the water surface to the soil surface at mean sea level.

‡ Presumpscot Formation, a glaciomarine deposit underlying the estuary.

§ Not Determined.

below MSL. The TE is intertidal; soil surfaces are exposed at low-low tide. The parent materials of the surface 20 to 40 cm of all soils in the TE are recent (late Holocene) estuarine sediments (RES). Below these sediments, some of the subsoils contain submerged and buried upland soils. Submerged and buried soils in the TE landscape unit include soils of beach, marsh, and stream delta landforms. Because the aerial extent of each of these submerged landforms is small, the entire zone along the estuary edge (EE) was mapped as a single landscape unit. The Presumpscot Formation is encountered in the TE landscape unit at depths between 0.5 and 1.5 m below the soil surface.

The Coastal Cove (CC) landscapes are sheltered from the force of the surging tides that flow along the estuary channels. In the Taunton Bay estuary, the narrowness of Taunton River channel causes the water to flow into and out of the estuary with more force than if the tides had no physical restriction. (Fig. 1B). Slopes in the CCs range between 0.5 and 1.0%. The top 100 cm of these soils are composed of RES. The Presumpscot Formation is encountered between 1 and 3 m in most locations.

The submerged fluvial stream (SFS) landscape unit is long and narrow. It extends from the mouths of the watershed's freshwater streams to the start of the estuary channels, bisecting the TE and CC landscape units. Only the portion of the SFS that shares its boundary with the TE is exposed at low tide.

The fluvial-marine terrace (FMT) landscape unit is located in the central portion of the bay and occupies 43% of the study site. The elevation of the soil surface is 1.0 to 1.5 m below MSL. The slopes are between 1 and 3%. The shallowest slopes occur closest to the shorelines and the greatest slopes occur closest to the channel edges. The majority of the landscape is below 1.0 and 1.5 m of water at MSL. The microtopography of this and almost all of the other landscape units is flat with little undulation (Fig. 4).

The Mussel Shoal (MS) landscape units are located within the FMT, and adjacent to the Channel Shoulder (CS) landscapes (Fig. 3A, 4). The MS landscapes units are formed by the growth of blue mussel (*Mytilus edulis*) upward into the water column. The MSs are as much as 1 m higher in elevation than the FMT, and like the FMT, have nearly level slopes. Their surfaces of the MS have complex microtopography created by the mussel community. There is a variation of approximately 5 cm height across distances as small as 3 cm across.

The CS landscapes are associated with and are located beside the deep channels in the Bay (Fig. 3A and 4). Slopes range from 3 to 5%, with the greatest slopes along the boundary of with the channel (CH) landscape unit. The majority of the landscape has surface depths between 1.5 and 3.0 m below MSL.

The CH that carry water into and out of Egypt and Taunton Bay are up to 21 m deep (Fig. 3A). The slopes in the CH landscape unit range from 5% at the CS and toe slopes to 27% on the channel wall backslopes. Acoustic reflectance observations completed by the Maine Department of Marine Resources (S. Barker, pers. com., 2002) indicate that surface textures of the channel bottoms are a mixture of coarse sand and gravel in the deepest channel zones and mud (silt loam) in the shallower channel zones.

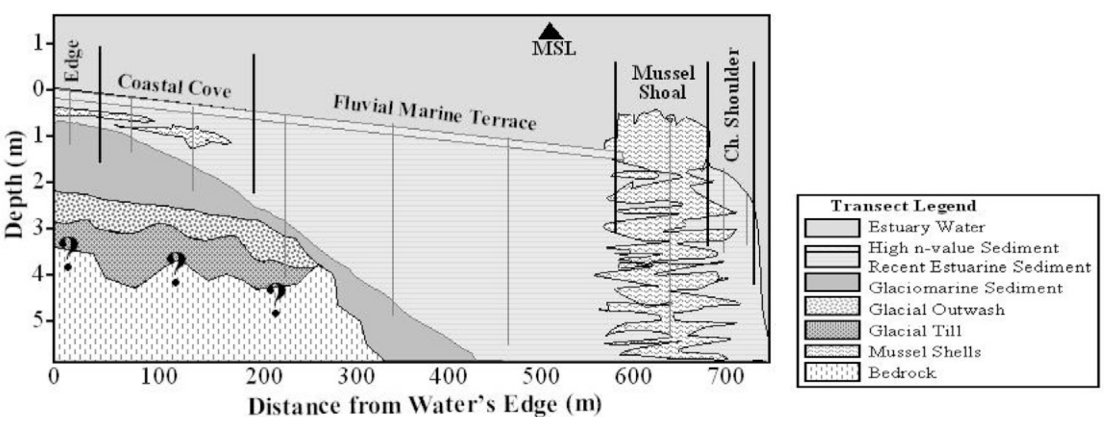

Fig. 4. Schematic cross-section illustrating the presence and stratigraphy of parent materials along a hypothetical soil transect from the water's edge to the center of the estuary channel in Taunton Bay estuary. The black vertical lines on the transect define where one landscape unit ends and the next begins. Where space is limited in the figure, landscape unit names are abbreviated. "Edge" refers to the Terrestrial Edge landscape unit. The Channel Shoulder landscape unit is abbreviated "Ch. Shoulder." The thin, gray vertical lines on the transect indicate the locations where vibracore-derived soil morphology data was used to generate the figure. The question marks at the interface between the bedrock and the glacial till are used to illustrate that while this sequence of parent materials is known to occur, this sequence was not observed in any of the profiles sampled for this study. The glaciomarine sediment parent material in this figure is also referred to as the Presumpscot Formation.

Soil Map Units

Twelve soil map units were identified in the study area. The soil map unit names, the landscape unit where they occur, the area they occupy, and their surface and control section textures are presented in Table 2. The physical and chemical characteristics of representative profiles are presented in Table 3.

The submerged marsh (SM) soils (Fig. 3B) contain a buried silty clay loam (SiCL) layer over organic horizons. The organic horizons are between approximately 175 and 190 cm depth. They contain pieces of undecomposed vegetation (*spartina* sp.) indicative of salt marshes. In profile 19 (Table 3), the abrupt boundary at the surface of the buried marsh has a layer of shells above it. The organic horizons are over a buried upland soil (an Inceptisol) that formed in the bluish gray Presumpscot Formation. The horizons in this buried Inceptisol contain redox concentrations and depletions indicative of the poorly drained (subaerial) soils commonly formed in glaciomarine parent materials.

Table 2. Differences in percent area, slope, textures, depths below mean sea level, and depth to the Presumpscot Formation for the Landscape units of Taunton Bay estuary.

Soil map unit name	LSU	Area	Texture† ‡		Core§	Length¶
		%	0–25 cm	25–100 cm	#	cm
Submerged marsh	TE	1	SiL	SiL	19	256
Submerged beach	TE	2	SiL	xsh,gr S	16	136
Submerged fluvial delta	TE	1	SiL	S	8	113
Terrestrial edge	TE	4	SiL	SiL	22	119
Submerged fluvial stream	SFS	2	SiL	SiCL	28	171
Shallow coastal cove	CC	6	L	SiL	10	112
Deep coastal cove	CC	8	SiL	SiL	13	197
Fluvial marine terrace	FMT	43	SiL	SiL & SiCL	23	336
			SiL	SiL & SiCL	18	322
			SiL	SiL & SiCL	4	440
Mussel shoal	MS	1	vsh Si	sh SiL	3	540
Channel shoulder	CS	17	SiL	SiL	24	202
			SiL	SiL	30	386

† S, Si, C, & L = sand, silt, clay and loam.

‡ g = 15–35% gravels, vg = ≥ 35%, sh = 15–35% shells, vsh = ≥ 35%, and xsh = ≥ 60% shells.

§ The vibracore number for the profile representative of this soil map unit.

¶ Length of the vibracore from which the representative profile was described.

The Submerged Beach (SB) soils (Fig. 3B) consist of RES deposited over sandy gravelly and sometimes shell-strewn beaches. The surface and near surface horizon textures are RES with silt loam (SiL) textures. At the base of the RES there is a sandy loam (SL) transitional horizon. In profile 16, this horizon begins at 31 cm. At 47 cm, broken shells dominate the buried, sandy textured beach surface horizon. The underlying horizons are gravelly sands, in which the gravels are only slightly larger than 2 mm in diameter. Monosulfidic materials are present in the surface of Profile 16 (Table 3) and in greater than half of the submerged beach profiles described.

Soils of the submerged fluvial delta (SFD) are characterized by SiL horizons as much as 35 cm thick over sands (S) and loamy coarse sands (LCS). The coarse textured horizons are gray, grading to olive colors. The OM contents of these horizons are the lowest of any horizon in the estuary. The S horizons are over SiL marine sediments. The two parent materials are separated by SL or loamy sand (LS) transitional horizons. The transitional horizon begins between 85 and 105 cm. The matrix color for this layer varies from olive to dark reddish brown and the SiL horizons below it are gray. The dark reddish brown color of the transitional horizon is assumed to be indicative of the presence of oxygenated groundwater moving through these coarse textured materials. In much of Hancock County, outwash deposits directly overlay the Presumpscot Formation (Borns, 1977). Rainfall moves through the outwash and quickly reaches this relatively impermeable layer, and flows down gradient along its surface. In the uplands, this water emerges as springs where the marine sediment intersects the soil surface.

The TE includes soils in which a layer of RES is burying upland soils and soils in estuary sediments deposited over and beside rock outcrops at the EE. These soils have SiL surface and subsurface textures. Most of these soils have black or very dark gray colors (N2.5 and N3) in horizons within 0 to 25 cm of the soil surface (Table 3). The odor of the soils when exposed to the air, the colors of the soils, and the presence of AVS are indicative of monosulfidic materials (Fanning et al., 1993). Terrestrial edge soils may contain thin horizons with sandy textures, shells, or high OM contents, but the predominant parent material of the upper 1 m of these soils is Holocene estuarine sediments. In Profile 22, there is a shell-rich horizon between the 34- and the 49-cm depth. The Presumpscot is encountered at 86 cm below the soil surface. In most of the TE soils, the Presumpscot begins at depths of 1 m or greater.

Soils mapped as SFS have higher OM contents than other soils in the estuary. The OM content in surface horizons (to 30 cm) is similar to OM in adjacent TE soils. With their SiL textures, the parent materials of these surface horizons is RES. Below 30 cm, SFS profiles contain more OM than other soils of the estuary, and OM contents fluctuate, decreasing and then increasing irregularly with depth (Jespersen and Osher, 2007) as would be expected in soils formed in fluvial deposits. Most of the fluvial horizons (34–148 cm in profile 28) have fine-loamy textures and gleyed matrices. At the base of the RES, the SFSs tend to have a horizon with a SL texture. Parent materials of the soils below the fluvial deposits are dark grayish green glaciomarine sediments. In profile 28, the Presumpscot Formation is encountered 146 cm from the soil surface.

Like many of the soils in Taunton Bay, shallow coastal cove (SCC) soils are formed primarily from RES. However, rather than having SiL surface textures, these soils have loam (L) textured surface horizons to approximately 25 cm in depth. Some of the estuarine sediments contain inarticulate shells and some have thin horizons containing greater than 15% crushed mussel and/or soft-shell clam (*Mya arenaria*) shells. The surface horizons of the SCC soils are dark gray (N4) in color. Like the majority of the soils in this estuary, they also contain monosulfides. In these soils, the Presumpscot Formation is encountered within 100 cm of the soil surface.

Deep Coastal Cove (CCD) soils have loamy surface horizons to depths between 7 and 15 cm over SiL textured horizons extending to >1 m in depth. These soils have AVS concentrations indicating the presence of monosulfides (Table 3). The soils smell of H_2S when exposed to the air, and surface horizons (to 15 cm) are

Table 3. Morphology and soil characteristics representative of most of the soil map units.

Horizon	Depth	Bndry	Sand	Clay	Coarse Frag.	Shell Frag.	Munsell Color	pH	Incub. pH; 8w§	AVS	CRS	EC	OC	Parent Material‡
	cm			————-%————						ug g^{-1}	ugg^{-1}	dS m^{-1}	g kg^{-1}	
							Submerged Marsh (SM); profile 19							
A†	0–7	G	ND	ND	0	0	10Y 4/1	ND	ND	31.2	103.1	39	3	RES
Cg1	7–29	G	18	20	0	0	10Y 4/1	6.8	3.9	4.3	123.1	39	2	RES
Cg2¶	29–51	G	56	25	0	0	10Y 4/1	6.8	ND	ND	ND	31	2	RES
Cg3	51–82	C	14	20	0	0	10Y 5/1	7.1	ND	ND	ND	22	2	RES
Cg4	82–129	G	9	29	0	0	5Y 5/1	7.1	ND	ND	ND	11	2	RES
2Agb1	129–151	C	24	20	0	0	2.5Y 4/2	7.3	ND	ND	ND	11	2	RES
2Agb2†	151–176	C	8	17	0	0	5Y 3/2	7.1	ND	ND	ND	11	12	INTM
3Oeb	176–180	C	ND	ND	0	0	N 2.5	7.2	ND	ND	ND	10	15	INTM
3Oab	180–190	G	ND	ND	0	0	N 2.5	7.0	ND	ND	ND	13	34	MRSH
4Agb	190–199	A	3	37	0	0	5Y 2.5/1	7.0	ND	ND	ND	11	38	MRSH
4Bwb	199–204	C	18	12	0	0	5B 5/1	7.2	ND	ND	ND	9	2	GMS
							Submerged Beach (SB); profile 16							
CAg†	0–8	G	19	21	0	< 1.0	N 4	6.6	3.8	23.6	45.6	38	23	RES
Cg1	8–19	C	27	25	< 1.0	2	N 4	6.6	3.8	7.1	50.7	36	26	RES
Cg2	19–31	G	29	21	2	0	5Y 4/4	6.4	3.9	0.0	111.3	37	23	RES
Cg3	31–47	A	52	16	5	< 1.0	5Y 4/1	7.2	3.9	ND	ND	32	15	RES
2Ab	47–63	A	93	0	35	70	N 4	8.1	3.9	ND	ND	17	15	SH&BCH
2C1	63–130	A	98	0	35	0	N 4	8.2	ND	ND	ND	10	< 1	BCH
2C2	130–139+	–	98	0	35	0	10Y 4/1	7.9	ND	ND	ND	17	< 1	BCH
							Submerged Fluvial Delta (SFD); profile 8							
A†	0–1	C	ND	ND	0	0	2.5Y 4/3	ND‡	ND	ND	ND	ND	18	RES
Cg1†	1–9	C	9	29	0	0	N 3	7.1	3.6	4.9	25.3	ND	17	RES
Cg2	9–18	A	29	25	0	5	N 4	7.0	3.6	1.1	25.1	24	< 1	RES
2C1¶	18–45	A	97	3	0	0	N 5	6.9	4	0.0	155.7	13	< 1	ALV S
2C2¶	45–76	C	96	0	0	0	N 4	6.8	ND	ND	ND	11	< 1	ALV S
2C3	76–94	A	97	2	0	0	N 5	6.8	ND	ND	ND	11	< 1	ALV S
2C4	94–105	C	98	2	0	0	5Y 4/4	6.8	ND	ND	ND	11	< 1	ALV S
2C/3C	105–113+	–	63	4	20	0	5Y 4/3	6.6	ND	ND	ND	< 1	< 1	RES
							Submerged Fluvial Stream (SFS); profile 28							
Ag1†	0–7	C	4	22	0	0	N3	6.7	3.8	15.6	68.7	36	29	RES
Ag2	7–24	G	4	28	0	0	N2.5	6.9	3.8	3.2	75.4	36	31	RES
Cg	24–34	C	4	30	0	0	N4	7.0	3.6	4.3	109.7	35	27	RES
2Cg1	34–43	C	63	18	4	10	10Y4/1	7.0	3.6	ND	ND	29	15	ALVM
2Cg2	43–70	C	17	33	0	trace	10Y4/1	6.6	3.6	ND	ND	24	13	ALVM
2Cg3	70–78	C	12	40	0	0	10Y4/1	6.7	ND	ND	ND	24	13	ALVM
2Cg4	78–108	G	24	38	0	15	10Y4/1	6.8	ND	ND	ND	23	15	ALVM
2Cg5	108–114	G	18	28	0	2	10Y4/1	6.9	ND	ND	ND	17	9	ALVM
2Cg6	114–135	G	16	28	2	3	10Y4/1	6.6	ND	ND	ND	15	2	ALVM
2Cg7	135–148	C	18	29	trace	0	10Y4/1	6.7	ND	ND	ND	14	1	ALVM
3AbCg	148–160	A	15	34	trace	0	10Y4/1	6.8	ND	ND	ND	15	< 1	GMS
3Cg1	160–164	C	16	43	trace	0	10Y3/1	6.6	ND	ND	ND	13	< 1	GMS
3Cg2	164–171	–	19	46	0	0	10GY3/1	6.9	ND	ND	ND	12	< 1	GMS

Table 3. Cont'd.

Horizon	Depth	Bndry	Sand	Clay	Coarse Frag.	Shell Frag.	Munsell Color	pH	Incub. pH; 8w§	AVS	CRS	EC	OC	Parent Material‡
	cm		%							ug g^{-1}	ugg^{-1}	dS m^{-1}	g kg^{-1}	
							Deep Coastal Cove (DCC); profile 13							
Ag†	0–13	C	26	25	trace	0	N 3	7.0	3.8	2.4	8.3	33	24	RES
Cg1†	13–22	G	12	21	trace	0	10Y 4/1	7.0	3.8	0.7	13.8	33	24	RES
Cg2	22–44	G	15	16	trace	0	10Y 5/1	6.7	3.6	0.0	10.2	ND	25	RES
Cg3	44–78	G	8	8	0	5	10Y 5/1	6.6	3.6	0.0	13.0	29	19	RES
Cg4	78–109	C	11	12	0	10	10Y 5/1	6.8	ND	ND	ND	26	14	RES&SH
Cg5	109–124	C	42	9	0	5	10Y 5/1	6.9	ND	ND	ND	22	14	RES
CAb	124–134	C	–	–	0	5	10Y 4/1	6.7	ND	ND	ND	17	16	RES
2Ab†	134–143	A	22	30	0	0	5Y 3/2	6.6	ND	ND	ND	17	13	RES&OM
3Cg1	143–158	A	6	68	trace	0	5BG 4/1	6.9	ND	ND	ND	17	11	GMS
3Cg2	157–175	C	9	47	0	0	10BG 5/1	7.2	ND	ND	ND	10	8	GMS
3Cg3	175–184	C	9	25	0	0	10BG 5/1	7.8	ND	ND	ND	9	7	GMS
3Bwgb	184–193+	–	3	44	0	0	10BG 5/1	7.7	ND	ND	ND	9	9	GMS
							Fluvial Marine Terrace (FMT); profile 4							
ACg†	0–24	G	18	26	0	0	10Y 4/1	6.3	3.9	3.3	123.2	36	26	RES
CAg†	24–40	G	16	30	trace	0	10Y 5/1	6.9	3.8	1.7	89.0	35	23	RES
Cg1†	40–66	C	19	13	trace	4	10Y 5/1	7.1	3.8	ND	ND	35	21	RES
Cg2	66–83	C	19	25	0	trace	5Y 4/1	7.1	ND	ND	ND	34	19	RES
Cg3†	83–113	G	14	26	0	6	5Y 4/1	7.3	ND	ND	ND	33	22	RES
Cg4	113–162	G	9	30	0	3	10Y 4/2	7.1	ND	ND	ND	33	23	RES
Cg5	162–201	C	12	30	0	0	5Y 4/2	6.9	ND	ND	ND	36	19	RES
Cg6	201–249	G	11	42	0	8	5Y 4/2	7.3	ND	ND	ND	33	24	RES&SH
							Mussel Shoal (MS); profile 3							
Ag1†	0–24	C	11	4	0	40	N 3	7.5	3.4	15.6	165.7	38	36	SH&RES
Ag2†	24–35	C	9	31	0	10	N 3	7.4	3.7	25.6	187.6	35	31	RES&SH
Ag3	35–41	C	15	17	0	30	N 3	7.5	3.7	ND	ND	33	35	SH&RES
Cg1	41–50	A	8	34	0	10	N 4	7.2	3.7	ND	ND	34	24	RES&SH
Agb	50–55	A	4	8	0	80	N 4	7.3	ND	ND	ND	31	35	SH&RES
Cg1′	55–64	G	8	38	0	10	10Y 4/1	7.2	ND	ND	ND	30	22	RES&SH
Cg2†	64–78	G	8	17	0	10	10Y 4/1	7.3	ND	ND	ND	28	26	RES&SH
Cg3†	78–111	C	21	8	0	5	10Y 4/1	7.4	ND	ND	ND	28	31	RES
Cg4†	111–121	G	38	0	0	0	10Y 5/1	7.4	ND	ND	ND	27	18	RES
Cg5	121–126	C	56	16	0	0	10Y 5/1	7.7	ND	ND	ND	25	12	RES
Cg6	126–134	C	32	25	0	10	10Y 5/1	7.3	ND	ND	ND	27	20	RES&SH
Cg7†	135–154	C	59	0	0	5	10Y 5/1	7.3	ND	ND	ND	24	18	RES
Cg8	154–157	G	23	25	0	0	10Y 5/1	6.9	ND	ND	ND	22	20	RES
Cg9	157–164	G	46	25	0	5	10Y 5/1	7.3	ND	ND	ND	23	14	RES
Cg10	164–171	C	31	20	0	0	10Y 5/1	7.4	ND	ND	ND	19	17	RES
Agb2	171–196	C	50	25	0	20	10Y 5/1	7.2	ND	ND	ND	17	22	SH&RES
Agb3	196–205	C	51	20	0	40	10Y 5/1	7.2	ND	ND	ND	15	22	SH&RES

† Horizons had *n* values > 1.0.

‡ RES = recent estuarine sediment, INTM = intertidal muds, MRSH = marsh, GMS = glaciomarine sediment, BCH = beach, ALV S = sandy alluvium, ALVM = stream alluvium, SH = shells.

§ pH of soil after 8-wk moist incubation at room temperature.

¶ Horizons between the 20- and 50-cm depths with *n* values < 0.7.

black or very dark gray (N2.5 and N3). Shell layers are common. In profile 13, the horizon at 78–109 cm contained more than 15% inarticulate shells. Below that, a SiL horizon with few (5%) shells was over a partially eroded, buried, OM rich, A horizon formed from RES deposits. This horizon is directly above the Presumpscot Formation. In most profiles collected in this map unit, the RES parent materials extended to approximately 1.5 m below the soil surface before encountering the Presumpscot.

Fluvial-marine terrace soils have RES parent materials to at least 2.0-m depth. Surface horizons in these soils have SiL textures and subsurface horizons have SiCL textures (Table 2). Nearest to the EEs, glaciomarine sediments were encountered between 2.3 and 3.6 m. In most core samples, when the Presumpscot Formation was encountered during collection of a soil core, the density of this glaciomarine sediment layer prevented the vibracorer from moving deeper than a few centimeters. One exception to this was Core #18, in which a layer of blue-gray SiCL glaciomarine sediment was encountered between a 236- and 271-cm depth. Below this layer, there are layers of glacial outwash and glacial till to the 297-cm depth. Core #18 ends with a few centimeters of glaciomarine sediment that appears to have been exposed to air enough to develop redoximorphic features.

Soils mapped as MS have very shelly horizons (>60% shells) at the soil surface. In these horizons, the fine earth fraction is silty; with one horizon between 20 and 50 cm that has <8% clay (Table 3). Most of the shells are blue mussels, and most of the mussel shells are articulate (whole). Deeper in the profile, shell layers are interlayered with SiL horizons composed of RES. Some of the SiL horizons contain (<15%) crushed shells. AVS data for MS surface horizons (Table 3) indicate the presence of monosulfides. Horizons to 55 cm depth all have colors (N3 and N4) often associated with monosulfides (Fanning et al., 1993). Presumpscot Formation was not encountered within 5.0 m of the surface in the two profiles cored to that depth.

Channel Shoulder (CS) soils have SiL textures in surface and subsurface horizons. AVS data for horizons to a 35-cm depth identified the presence of monosulfides. The dominant parent material is RES. However, at various depths in the profile, the shell-free SiL horizons are interlayered with extremely shelly SiL horizons. Most of the shells are in life position. In some shell horizons, crushed shells occupy up to 15% of the horizon volume. The Presumpscot Formation, when encountered, is at depths >3 m below the soil surface.

Soil Classification

All of the soils in the estuary are Aquents (Soil Survey Staff, 2006). The majority classify as Sulfaquents because they contain sulfidic materials within 50 cm of the soil surface. The submerged delta, submerged beach, and SCCs all have *n* values of <0.7 or have <8% clay in some horizon between the 20- and the 50-cm depth. As a result, these soils classify as Haplic Sulfaquents (Table 4). The soils of the submerged beach and submerged delta classify as Haplic Sulfaquents because of their low clay contents. The SCC soils classify as Haplic because of the presence of a low *n value* horizons between 40 and 50 cm.

The SM, SFS, DCCs, FMTs, and nonvegetated CS all classify as Typic Sulfaquents. The Typic Sulfaquents located in the portions of the landscape that are continually submerged; FMTs, MSs and CSs; have fine-silty family particle size textures. With the exception of the SM soils, the soils of the TEs and coastal coves (SCC and DCC), which are exposed at some or all low tides, have coarser family particle-size textures than the continually submerged soils.

Soils located on the CS in the few areas where *Zostera marina* (eelgrass) vegetation covered >50% of the soil surface did not classify as Sulfaquents because the pHs of horizons between the soil surface and 50 cm did not drop below 4 after 8 wk of moist incubations. Without sulfidic materials within the top 50 cm, these soils classify as Typic Endoaquents. The profile representing the TE classifies as a Sulfic Endoaquent, because it contains sulfidic materials between 50 and 100 cm from the soil surface.

DISCUSSION

Parent Materials

The majority of the soils in the Taunton Bay estuary are formed from recent estuarine sediment. The primary source of these fine-grained parent materials is the erosion of the SiCL glaciomarine Presumpscot Formation. The soils formed from this thick, silty, and SiCL textured layer tend to be poorly drained. Some of these soils are located on the bluffs along the shoreline of Taunton Bay. Recent sea-level rise has caused wave erosion of the soils along the estuarine/TE and the destabilization of the bluffs (Kelley, 1987). The eroded material then becomes the sediment source for the adjacent estuary. The sediment that is deposited on the portion of the FMT exposed at low tide is resuspended at high tide. In this way, the tide facilitates sediment movement and redeposition within the estuary. The sea level rise-related erosion also contributes to the addition of coarser-textured sediments to the estuary, by erosion of soils formed from coarse parent materials; specifically glacial outwash and glacial till. The coarser sediments are too heavy to be resuspended by the tidal flows, and, for the most part, are not redistributed throughout the estuary. In CCs, where the ratio of estuary perimeter length to estuary area is largest, coarser sediments have accumulated enough in the shallow areas to create the coarsest textured surface soils in the estuary (Table 4).

The fine textured parent materials of these soils are significantly different than the materials that are typically encountered along the Atlantic coast of southern New England (Folger, 1972a, 1972b) and further south in the USA. The coarse-textured coastal lagoon soils of Rhode Island (Bradley and Stolt, 2003) and Maryland (Demas and Rabenhorst, 2001) are in embayments bounded by dune dominated barrier islands and spits. Erosion of these features by storm surges and overwash events contributes large volumes of sandy sediments to the lagoons. In Maine, the lack of barrier beaches along the central and northern part of the coast limit the sand contributed to estuaries from the marine environment.

Figure 4 is a schematic cross-section illustrating the arrangement of soil parent materials along a hypothetical transect from the water's edge to the center of the estuary channel. The thick vertical lines identify the portions of the cross-section in each map unit. The name of each map unit is located between pairs of these lines. The thin vertical lines identify the locations where the profile data (Table 3) was used to identify the depths for each parent material encountered in the soils of that map unit. Bedrock outcrops were encountered at shallow depths beneath some cores collected from the EE. The large and small islands in the estuary are also bedrock outcrops. The question marks at the bedrock/unconsolidated material interface in Fig. 4 identify what is known about the stratigraphy below the depths where soils were collected for this research. The thin lines on the figure illustrate the points on the figure where horizon and parent material depths were based on observations from the cores and auger samples collected.

Table 4. Classification of the predominant soils in each map unit to the family level.

Soil map unit	Soil taxonomic classification: Family particle size	Subgroup	Proposed subgroup
Submerged marsh	fine-silty, mixed, non-acid	Typic Sulfaquent	Sulfic Fluviwassents
Submerged beach	coarse-loamy/sandy, mixed, non-acid	Haplic Sulfaquent	Sulfic Psammowassents
Submerged fluvial delta	sandy, mixed, non-acid	Haplic Sulfaquent	Sulfic Psammowassents
Submerged fluvial stream	fine-silty, mixed, non-acid	Typic Sulfaquent	Sulfic Fluviwassents
Terrestrial edge	coarse-loamy, mixed, non-acid	Sulfic Endoaquent	Sulfic Haplowassents
Shallow coastal cove	coarse-loamy, mixed, non-acid	Haplic Sulfaquent	Haplic Sulfiwassents
Deep coastal cove	coarse-silty, mixed, non-acid	Typic Sulfaquent	Typic Sulfiwassents
Fluvial marine terrace	fine-silty, mixed, non-acid	Typic Sulfaquent	Typic Sulfiwassents
Mussel shoal	fine-silty, mixed, non-acid	Typic Sulfaquent	Typic Sulfiwassents
Channel shoulder†	fine-silty, mixed, non-acid	Typic Sulfaquent	Typic Sulfiwassents
Channel shoulder‡	fine-silty, mixed, non-acid	Typic Endoaquent	Typic Haplowassents

† Not vegetated.

‡ Vegetated.

In Fig. 4, the surface horizons of most map units are presented as a continuous low-density layer that appears to occupy a similar depth across several soil map units. In the estuary itself, the high *n* value surface materials varied in depth from 2 to 7 cm. As shown in Fig. 4, high *n* value surface materials were not observed in the soils of the MSs or CSs. The soil surface textures in the estuary are primarily SiL. Soils nearest to the estuary/TE have higher sand contents than the surface soils of the FMTs, CSs and MSs. The surface horizons of the CCD soils are finer textured than those of the SCC, but still coarser than surface textures of the FMT soils.

Organisms

Silty surface horizons are found in the soils of the MS. This appears to be a result of the organisms themselves: the mussels inhabiting the shoals grow above the surrounding FMT landscape surface. In this position, they intercept and harvest fine particles from the water column. Also, by being located near the CSs, they are far from sources of coarse textured sedimentary materials. By both preferred landscape position and means of obtaining nutrients, the organisms are facilitating the genesis of finer textured soils than are found in the rest of the estuary.

The shoals have formed in association with the large island located near the confluence of the estuary channels. This position ensures the mussels will have access to water and nutrients moving into the estuary from marine sources and that sediment particles will be regularly flushed from the mussels by the high-energy channel waters. The deep cores collected in these shoals contained shell layers throughout, illustrating that the general location of the mussel populations has not changed much over time. The shell horizons bounded by shell-less horizons in these cores illustrates that the area occupied by these organisms has expanded and contracted regularly over time. Some of the expansions of the mussel community stretched into the adjacent CS soils, indicating an expansion of the shoal toward the channel. In contrast, cores collected in the soils of the FMT, collected on the side of the shoal distal from the channel contained no shell-dominated horizons at depth.

In the CS soils, the vegetation may be controlling the chemistry, and associated classification of the soils. In locations on the CS in which eelgrass densities are greater than 50%, no sulfidic materials were detected. Where eelgrass cover is <50%, incubation of the soils identified the presence of sulfides, but other soil characteristics were similar. The difference in chemistry between vegetated and unvegetated soils could be a result of the oxygen transported to the rhizosphere by the eelgrass rhizomes (Penhale and Wetzel, 1983). However, the rhizospheres of the vegetated soils, where the sulfides are oxidized to sulfates (Holmer and Nielsen, 1997) are more than 50 cm deep. It is unclear why the soils do not contain sulfidic materials below their rhizospheres. Due to the lack of sulfidic materials, these soils classify as Endoaquents, while the unvegetated soils on the CS landscape classify as Sulfaquents (Table 4).

Between 1996 and 2000, prior the start of sampling, the eelgrass in the Taunton Bay estuary experienced an 85% population decrease (die-off). By 2003, the year the soils were sampled, the channel shoulders were the only landscape position with healthy populations of eelgrass. The majority of the soils in the estuary classified as Sulfaquents (Table 4). This result suggests that when the estuary is again vegetated with eelgrass, the soil will probably not have sulfidic materials and therefore maintain its classification as Sulfaquents.

Classification

With the increase in the number of investigations of soils beneath coastal waters, the limitations of the present suborders of Entisol for classifying subaqueous soils are becoming evident. The subaqueous soils committee of the NCSS has proposed a new suborder ('Wassents') for soils that are permanently saturated by water. The last column of Table 4 presents the classification of Taunton Bay's estuary soils using the changes to Soil Taxonomy proposed for subaqeuous soils. The criteria for the subgroup and great group classes of Wassents (sulfic, haplic, typic, psammentic) are similar to the criteria for those classes where they appear elsewhere in Soil Taxonomy. One exception is in the proposed Wassent suborder, where Psammowassents appear higher in the key than Sulfiwassents. (In the established key for Aquents, sulfaquents are higher in the key than Psammaquents.) This difference illustrates the importance of soil texture in the use and management of estuarine soils.

ACKNOWLEDGMENTS

This project was supported by National Research Initiative Competitive Grant Number 2003-35107-13885 from the USDA Cooperative State Research, Education, and Extension Service. Other funding for the support of this project was received from ME Sea Grant, the Maine Agricultural and Forest Experiment Station, and a University of Maine Faculty Equipment Grant. Nick Brown, Director of the University of Maine's Center for Cooperative Aquaculture Research provided logistics including a local base of operations, a place to moor our research boat, and thoughtful conversation. State Conservationist Joyce Schwaretzendruber and State Soil Scientist Wayne Hoar of the USDA NRCS Bangor State Office provided professional assistance including the work of the certified surveyor. Jennifer Jespersen assisted with organization of the field and laboratory data for the soils of Taunton Bay and provided thorough editorial reviews on previous versions of this manuscript. Peter Leach assisted with the creation of the figures. University of Maine undergraduate students Lauren LeClerc ('04), Emily Berry ('05), and John Boucher ('04) assisted in the field and laboratory.

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