TIDAL CURRENTS AT THE SAINT JEAN ESTUARY

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Introduction

Near the tip of Canada's Gaspé Peninsula, the Saint Jean estuary mixes with the Baie de Gaspé. Two spits, the Haldimand Spit (north) and the Douglastown Spit (south), have developed, closing off estuary to the ocean save for a 100 meter inlet. The Saint Jean river empties approximately 1.5 million cubic meters of water into the estuary each day. River flow and tidal currents have combined to build up the marsh and sand flats near the estuary inlet. Figure 1 shows the inlet and its accompanying tidal shields.

Tidal currents dominate water movement at the inlet and study of those currents provides information about the forces shaping the ever-shifting shields and marshes. For this study the currents passing through the inlet were measured directly and those flowing some distance from the inlet were recorded using buoys. In a Eulerian fashion current readings were taken from a bridge traversing the inlet for the duration of a tidal cycle. Later in a Lagrangian fashion, buoys were dropped near the limits of the ebb and flood shields and tracked by theodolites.

The Tidal Prism

Since work took place during half moon or neap tide, the semidiurnal high tides did not differ greatly from one to the other. Channel depth measurements were taken at 10 meter intervals across the bridge and the cross-sectional cells were summed for the inlet mean cross-sectional area. Calculations showed this area to be 320 m^2. During measurements however, strong velocities pushed the depth ballast down current, which ensured that cell-area calculations would exceed the actual cross-sectional area by up to 3 m^2 in the center.

At 9:30 June 23 current meters were lowered from the bridge at 10 meter intervals to 0.6 water depth, which gives the average velocity. Measurements were taken at one hour intervals until 20:30. Water height data show that a maximum high tide occurred at 9:15 and another at 22:00. These times were entered into the tidal cycle data as endpoints.

The velocities across the bridge can be contoured against time as shown in figure 2. Figure 3 shows the contours smoothed to fit fourth power polynomials and drawn in three dimensions. The volumes under the surfaces are equal to the total discharge for ebb and flood tide respectively. Note from figure 2 that the flood tide shows a narrower channel and a shorter period of peak discharge velocities. Flood tide shows the fastest velocity, 0.93 m/s, at the 45 meter mark. The locations of highest velocities suggest that flood currents use the channel some 10 meters south of the 45 meter mark for ebb currents. Also note that at slack tide 16:45 south currents are moving into the estuary and north currents are still moving out of the estuary. This in-between state best indicates that ebb currents enter the north side of the inlet and flood waters preferentially use the south.

As a possible test for accuracy in this project, Obrien (1976) showed with high precision that the cross-sectional area of tidal inlets is a unique function of their tidal prism, and that the prism behaves in a linear relationship with the inlet cross-sectionl area according to the equation:

$$P = A_e(5.0 \times 10^4) \qquad \text{where P and } A_e \text{are expressed in feet}$$

The mean cross-sectional area measured on 6/20/92 multiplied by 5×10^4 and the prism on 6/23/92 were 159,000,000 ft^2 and 202,000,000 ft^2. The prism deviated from the area product by 27%.

The River Discharge

Discharge data can used to calculate the river discharge for this estuary. For coastal inlets with no river input and only tidal flow, the ebb discharge should equal the flood discharge, minus any effect from evaporation or seepage. With an estuary, however, a river adds water to the system, so that at the estuary mouth the ebb discharge should exceed the flood discharge by an amount equal to the river's discharge and any solar or seepage effects. Figure 4 shows the total discharge curve for the tidal cycle. Integration of the total discharge curve gives a 3,840,000 m^3 ebb discharge, 2,670,000 m^3 flood discharge, and a 1,170,000 m^3 net discharge. Jeff Cook, who studied the river near its mouth, calculated that the river could discharge 867,000 m^3 in 12 hours and 45 minutes. The bridge calculation exceeds the river calculation by 203,000 m^3 or 35%.

The Shore Channel System

Buoys were placed near some of the major channels during both flood and ebb tide. Figure 5 shows the paths of three buoys during mid-flood. Notice how the a and b buoys assume a straight approach to the inlet. The absence of any curve or wobble in the paths suggests that forces are pushing on either side of the buoys and forcing a straight-line approach. Such approaches may indicate Langmuir circulation caused by strong winds. Since Langmuir (1938) first observed the vortex motion in ocean currents, Langmuir circulation has been observed many times, particularly among breaking waves. Thorpe (1992) found that water moves in a relatively stable pattern of "parallel vortices," between which, in the intercellular convergence, flotsam collects and travels separate from adjacent inter-cell boundaries until the circulation pattern dissipates. Jerome Smith (1992) comments on an observation from Langmuir (1938): When the wind blows "water lines" can be seen that are found to be lines of linear convergence and down welling on either side. Furthermore surface currents reach maximum speed along these lines. Photographs from the bridge show a number of these lines, which are strongly associated with Langmuir circulation. It is unknown whether wind speed reached 13 m/s which Smith found to be the minimum for Langmuir circulation generation in the ocean (Smith 1992).

In the south, buoy c moves contrary to the incoming east winds and travels in a protected longshore channel. It is not surprising that it does not show the straight-line approach of the other two. All three buoys, after passing under the bridge at the 35 meter mark, entered the flood shield channel and eventually grounded on the marsh. The buoys show that the flood waters deposit sediment at the north side of the marshes. The velocity contours for buoys a and b show a gradual acceleration to the mouth followed by an equally rapid deceleration in the estuary. Note that if Langmuir circulation is in action these velocities are maxima for surface currents. Also note that the buoys pass under the bridge at 35m, the distance for maximum velocities during eulerian bridge measurements. See figure 6.

The Estuary Channel System

Figure 7 shows the paths of a number of buoys that were dropped during mid-ebb tide. Due to a powerful north wind all buoys were eventually blown off course. In the southwest, however, buoys a and b give evidence for a channel. Flood buoys showed that flood currents use and deposit sediment in this channel. The ebb buoys show that ebb currents are responsible for undercutting the marsh. Buoy a shows that accelerating ebb currents are responsible for undercutting the marsh along its northern boundary. Buoy c shows a short stretch of the main estuary channel that extends as far back as the river mouth to the west. Due to wind conditions no buoys were dropped in the relatively slow south channels, which drain the marshes. Velocites in both the southwest and the northwest channels fluctuate around 0.5 m/s.

Conclusions

A contour map of velocities shows that flood waters move fastest 35 meters from the inlet south and that ebb waters move fastest at 45 meters suggesting that ebb currents use the northern half of the inlet and flood currents use the southern half. Flood buoys confirm that flood currents pass along the inlet's south edge and exit into a southwest. Eulerian depth and velocity measurements suggest that 3,840,000 m^3 exit the inlet during ebb tide, 2,670,000 m^3 enter during flood tide giving a 1,170,000 m^3 net discharge, which according to theory equals the river discharge. An inaccurate depth profile takes some responsibility for error between river and bridge team discharge calculations. Obrien's equation and the river team's estimate of the river discharge suggest that bridge measurements were approximately 30% inaccurate. Inside the estuary ebb currents move from three major channels S, SW, and NW. Buoys indicate that the SW channel is also the flood discharge channel, and slowing velocities confirm that deposition takes place. Ebb currents from that channel are cutting into the north side of a marsh. Such behavior indicates both that the channel is shifting and that ebb currents are outstripping flood tide deposition there. Outside the estuary, observations and buoys suggest that flood currents may approach the inlet from the north and east as spiraling vortices exhibiting Lagrangian circulation.

References

Langmuir, I., 1938. Surface Motion of Water Induced by Wind. Science, v. 87, p. 119-23.

Nichols, Maynard M. and Rober B. Biggs, 1985, in Coastal Sedimentary Environments, ed., Richard A. Davis Jr., New York: Springer-Verlag, p 77-186.

Smith, Jerome, 1992. Observed Growth of Langmuir Circulation. Journal of Geophysical Research: Oceans, v. 97 n. C4, p. 5651-64.

Thorpe, S.A., 1992. The Break-up of Langmuir Circulation and the Instability of an Array of Vortices. Journal of Physical Oceanography, v. 22, p. 350-60.

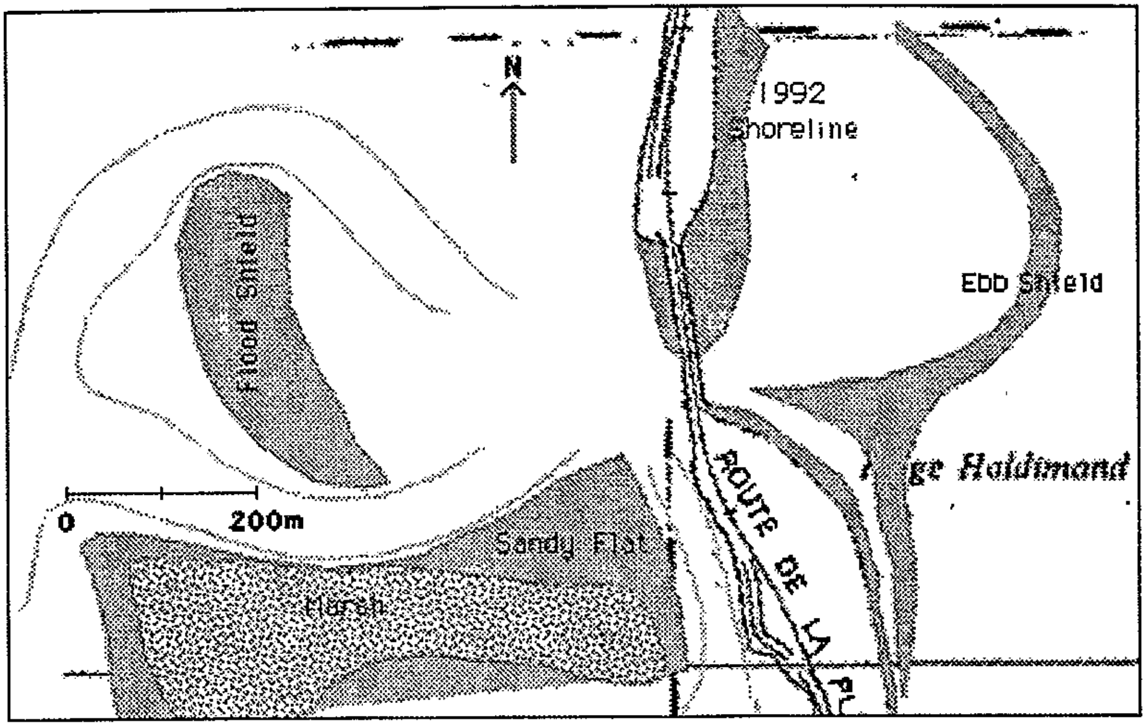


Figure 1. The Saint Jean's tidal inlet

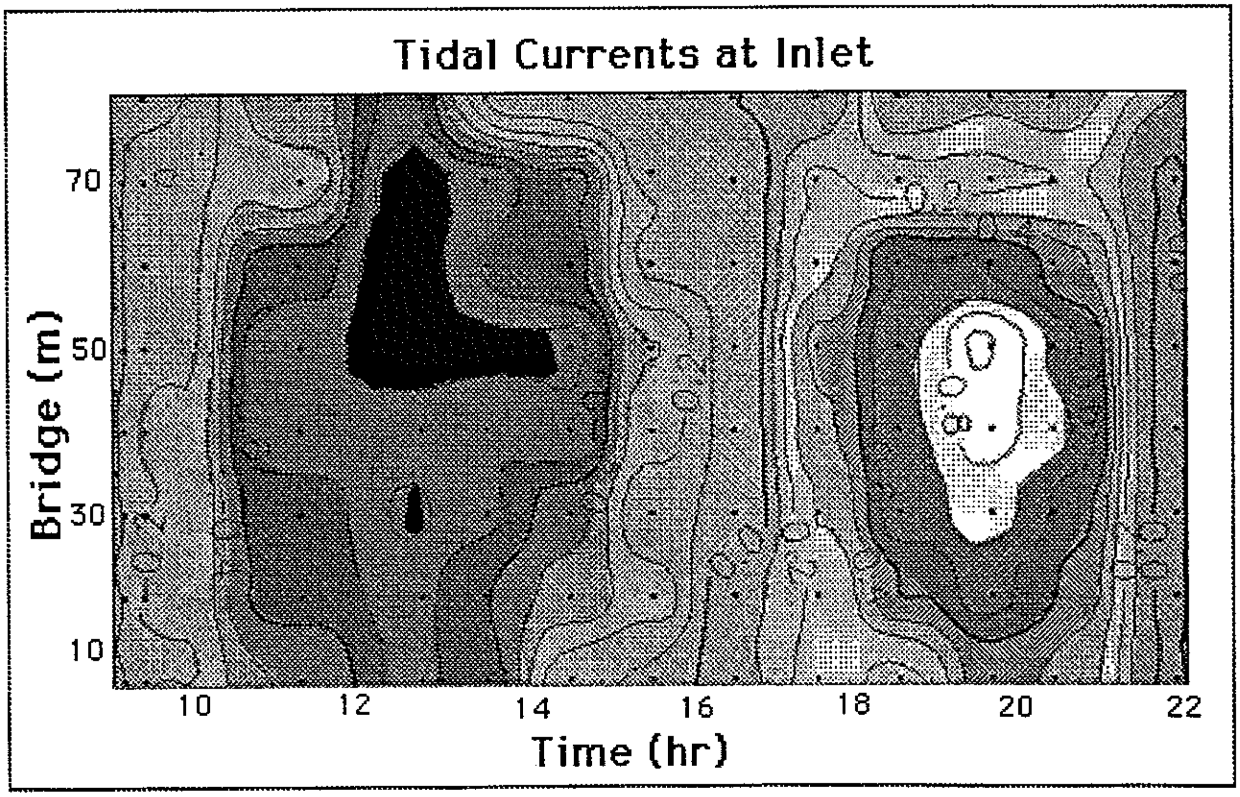


Figure 2. Velocity contours (m/s) at the inlet.
Contour interval is 0.1 m/s.

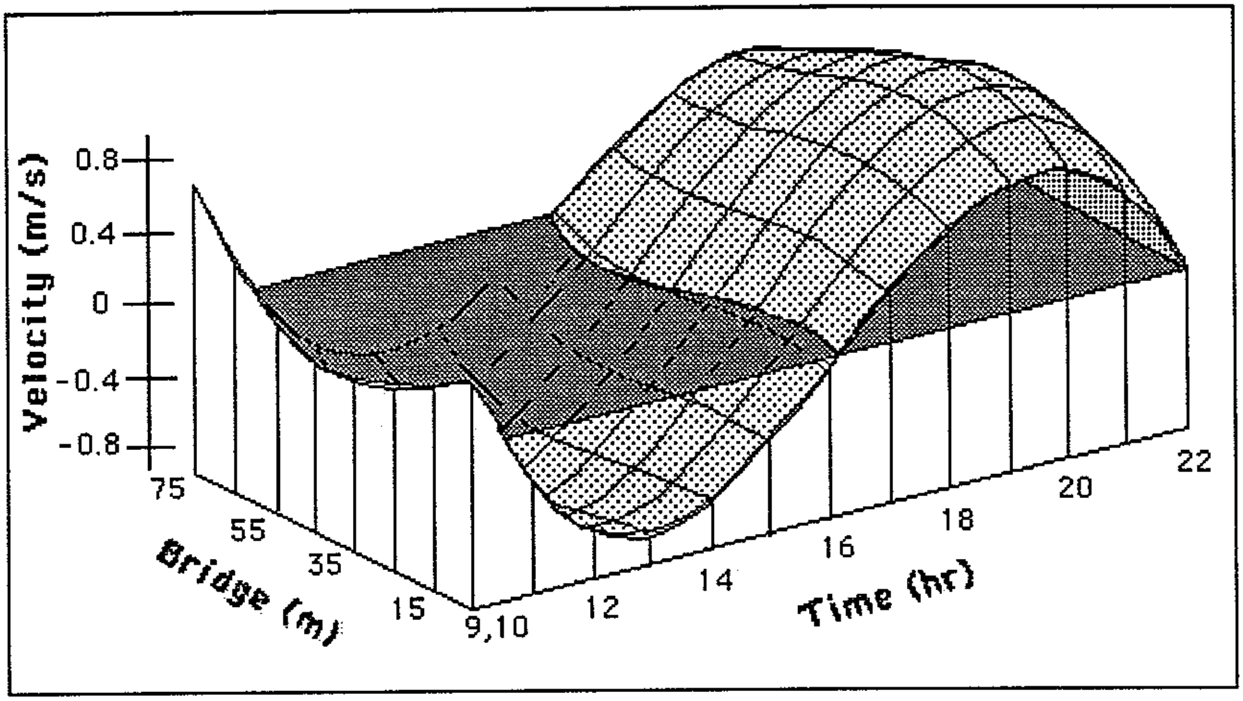


Figure 3. The shape of the tidal prism

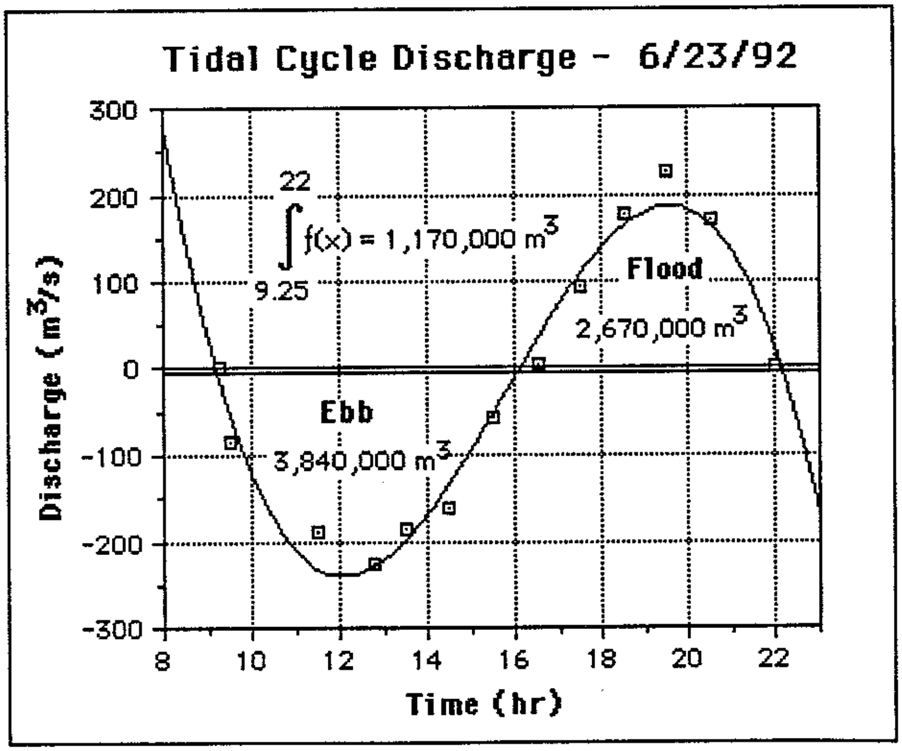


Figure 4. The total discharge curve. The river's discharge is expressed as the integral from 9.25 to 22

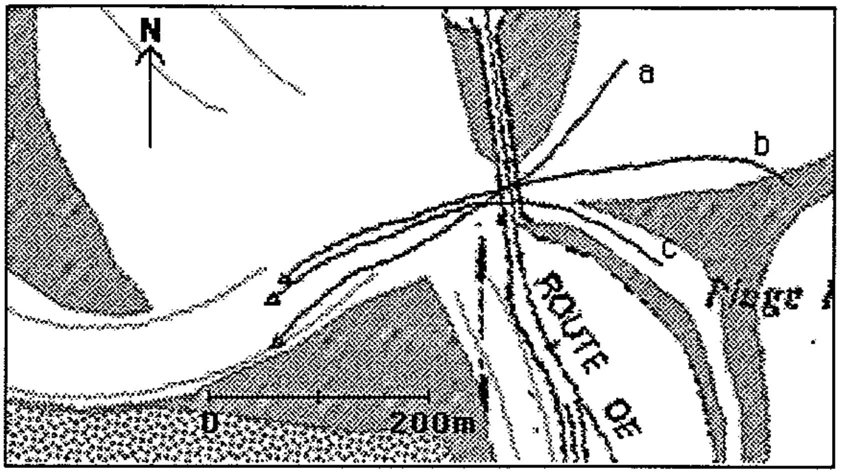
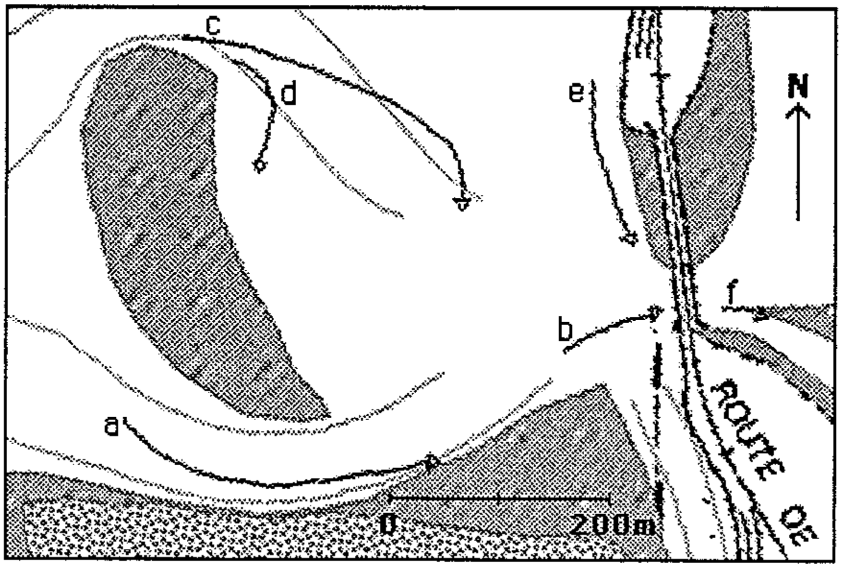


Figure 5. Buoy paths during flood tide

Figure 6. Buoy paths during ebb tide
There are high winds from the north



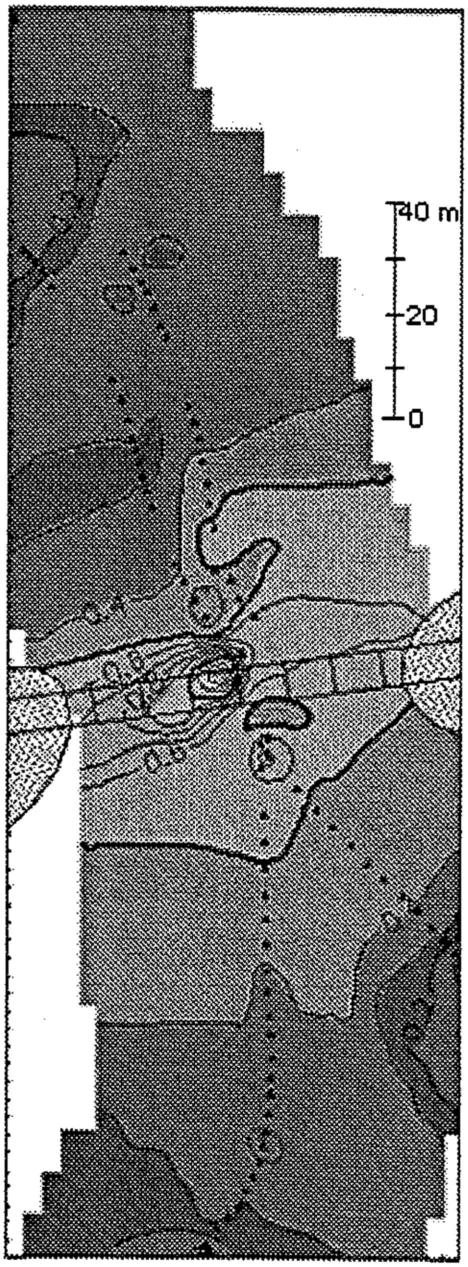


Figure 7. Velocity contours
of flood buoys a and b.
Contour interval is 0.1 m/s

MAPPING AND STUDYING SEDIMENTARY AND VEGETATIVE ENVIRONMENTS IN A SALT MARSH IN THE SAINT JEAN ESTUARY, QUEBEC

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INTRODUCTION AND SITE DESCRIPTION

The study was conducted on a marsh on the south shore of Gaspe Bay in easternmost Quebec, Canada. The marsh of interest is located at the mouth of the Saint Jean River, protected from Gaspe Bay and the Gulf of Saint Lawrence to the west by the Douglastown Spit. The estuary is located in a mixed energy mesotidal portion of the coastline, in which the marine influence into the estuary is a near balance of wave and tide energy. This environment is characterized by the relative stability of the estuary, large ebb and flood tidal deltas, and "drumstick"-like spits caused by long-shore current action.

The goal of the project was to map the surficial sedimentary and vegetative zones on the marsh, and from there explain the evolution of the marsh/spit system. The Douglastown Marsh has distinctive regions of vegetation, from which the evolution of the salt marsh can be deduced. A topographic map of the marsh could also be produced; because of the low topography of the marsh, slight differences in elevation could provide important information on the evolution of the marsh.

FIELD AND LABORATORY METHODS

Mapping the vegetative and sedimentary regions was done using a combination of resources in addition to observations made in the field. Air photos of the estuary, the Magellan Global Positioning System, computer imaging programs, microscopes, and a Topcon GTS-2B infrared laser theodolite all were used in the production of a surficial map and a topographic map of the marsh.

Black and white air photos from the Canadian Geological Survey dating 1948, 1961, 1962, and 1976 were scanned into a Macintosh computer and compared to show differences in tidal channel migration. While working with GeoCanvas version 3.04, the 1976 air photo image was used as a backdrop/reference while drawing a map of the marsh showing the different stages in marsh evolution (Figure 2). Topographic data taken from theodolite readings were entered into MicroSoft Excel and Surface 3 computer programs to produce a contour map and a three-dimensional model of the salt marsh.

Shallow trenches were dug in several areas of the marsh that were representative of tidal flat, incipient, low, high, and mature marsh environments. These zones were determined by observation of differences in types of vegetation growing in the areas. Sediment samples were taken and later analyzed under a microscope to show variations in sediment colors, shapes, and sizes. This would provide clues to possible migration of the marsh, as well as provide information as to whether the sediments were of marine or fluvial origins.

Precise locations of the trenches that were dug were made using the Magellan GPS. The Magellan system also enhanced accuracy of the location of boundaries of the different vegetative and sedimentary environments on the marsh.

OBSERVATIONS

Since the estuarine environment is inhabited by plant species uniquely adapted to the brackish waters and daily inundations by the tides, vegetation provided a useful tool in identifying zones of different maturation levels in the marsh. The marsh was divided into areas of beach and dunes, tidal flats, low/incipient marsh, and high/mature marsh.

The beach and dune areas were inhabited mostly by *Ammophila breviligulata* (American Beach Grass) and *Lathyrus japonicus* (Beach Pea), common in sandy beach and dune environments. The low marsh was characterized by the growth of *Spartina alterniflora*, small patches of *Salicornia bigelovii* (Bigelow glasswort), and scattered *Limonium angustatum* (Sea-Lavender) plants. These types of flora are characteristic of intertidal zones exposed only