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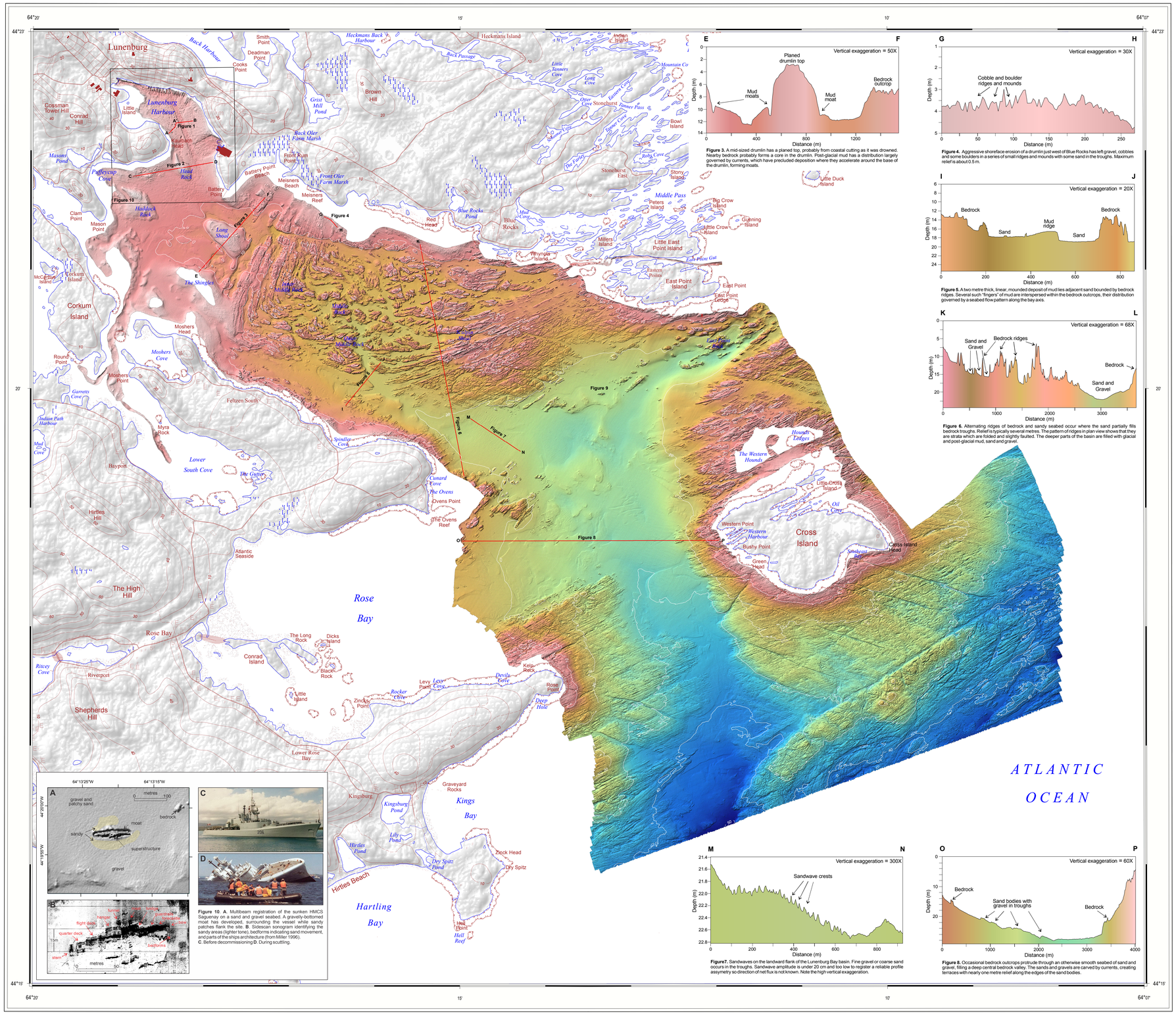





**Figure 3.** A mid-sized drumlin has a planed top, probably from coastal cutting as it was drowned. Nearby bedrock probably forms a core in the drumlin. Post-glacial mud has a distribution largely governed by currents, which have precluded deposition where they accelerate around the base of the drumlin, forming moats.




**Figure 4.** Aggressive shoreface erosion of a drumlin just west of Blue Rocks has left gravel, cobbles and some boulders in a series of small ridges and mounds with some sand in the troughs. Maximum relief is about 0.5 m.




**Figure 5.** A two metre thick, linear, mounded deposit of mud lies adjacent sand bounded by bedrock ridges. Several such "fingers" of mud are interspersed within the bedrock outcrops, their distribution governed by a seabed flow pattern along the bay axis.




**Figure 6.** Alternating ridges of bedrock and sandy seabed occur where the sand partially fills bedrock troughs. Relief is typically several metres. The pattern of ridges in plan view shows that they are strata which are folded and slightly faulted. The deeper parts of the basin are filled with glacial and post-glacial mud, sand and gravel.




**Figure 10. A.** Multibeam registration of the sunken HMCS Saguenay on a sand and gravel seabed. A gravelly-bottomed moat has developed, surrounding the vessel while sandy patches flank the site. **B.** Sidescan sonogram identifying the sandy areas (lighter tone), bedforms indicating sand movement, and parts of the ships architecture (from Miller 1996). **C.** Before decommissioning **D.** During scuttling.




**Figure7.** Sandwaves on the landward flank of the Lunenburg Bay basin. Fine gravel or coarse sand occurs in the troughs. Sandwave amplitude is under 2m and too low to register a reliable profile assymetry so direction of net flux is not known. Note the high vertical exaggeration.




**Figure 8.** Occasional bedrock outcrops protrude through an otherwise smooth seabed of sand and gravel, filling a deep central bedrock valley. The sands and gravels are carved by currents, creating terraces with nearly one metre relief along the edges of the sand bodies.





**Authors: E. L. King and D. Beaver**



**This map was produced by Natural Resources Canada in co-operation with Canadian Hydrographic Service**

*Multibeam bathymetric data collected by Canadian Hydrographic Service, 2004, 2006*

*Multibeam backscatter data compiled by Geological Survey of Canada*

*Cartography by P. O'Regan, Natural Resources Canada*

*Any revisions or additional information known to the user would be welcomed by the Geological Survey of Canada*

OPEN FILE 8177

MULTIBEAM BATHYMETRY AND SHADED SEAFLOOR RELIEF

# LUNENBURG BAY

SCOTIAN SHELF

OFFSHORE NOVA SCOTIA

Scale 1:25 000/Échelle 1/25 000

kilometres 0.5 0 0.5 1.0 1.5 2.0 kilometres

Universal Transverse Mercator Projection
North American Datum 1983
This map is not to be used for navigational purposes

Projection transverse universelle de Mercator
Système de référence géodésique nord-américain, 1983
Cette carte ne doit pas être utilisée aux fins de navigation

*Digital topographic data from Natural Resources Canada, modified by GSC (Atlantic)*

*Digital bathymetric contours in metres supplied by the Canadian Hydrographic Service and Geological Survey of Canada (Atlantic)*

*Magnetic declination 2017, 17°14.7'W, decreasing 6.9' annually*





## DESCRIPTIVE NOTES

### INTRODUCTION

This bathymetric map, in shaded relief view, is part of a three-map series of Lunenburg Bay at a scale of 1:25 000. The series also includes a colour-coded shaded sea floor acoustic backscatter strength map (OF 8176, King and Beaver, 2017) and a surficial and bedrock geology map, (OF 8138, King et al. 2017). The map is derived from multibeam bathymetric echo-sounding surveys conducted in 2004 and 2006 as a joint program between the Geological Survey of Canada and the Canadian Hydrographic Service (CHS). The bathymetric image is presented with an artificial illumination from the NE, an angle of 45° from the horizontal and a vertical exaggeration of 5X.

The map series complements oceanographic and meteorologic studies and monitoring of Lunenburg and environs (see OF 8176, King and Beaver, 2017). Lunenburg Bay is also the site of a marine park and holds both National Historic Site and UNESCO (United Nations Educational, Scientific and Cultural Organization) status for its cultural heritage, both through its build heritage and its cultural landscape and interaction with the natural environment.

### MULTIBEAM BATHYMETRIC DATA COLLECTION

Surveys were conducted in 2004 and 2006 as a joint program between the Geological Survey of Canada and the Canadian Hydrographic Service (CHS), based at the Bedford Institute of Oceanography in Dartmouth. The CHS launch CSL Plover conducted a three-day survey using the Simrad EM3000 multibeam swath mapping system and the CSL Pelican conducted two 2006 surveys, totalling 32 days, with the EM3002 system. The shaded relief image has been gridded at 2 m. The bathymetric image and map were produced in GIS (Geographical Information System) software packages to enhance the seabed relief. Presentation is with an artificial illumination from the NE, an angle of 45° from the horizontal and a vertical exaggeration of 5X.

### LUNENBURG BAY MORPHOLOGY

Lunenburg town and harbour has a characteristic glacier-influenced morphology with its round drumlins but most of Lunenburg Bay, mid-bay to the headlands, follows the same bedrock morphological trends as on adjacent land (primarily early Paleozoic slates and meta-sandstones). A shallow bedrock platform in the vicinity of Soupin Shoal, Inner, Middle, and Outer Middle Rocks dominates inner Lunenburg Bay. The east-southeast axial trend of the inner bay follows the dominant bedrock jointing trend (see also OF 8138, King et al. 2017). Bedrock outcrop dominates the shallower parts of the outer bay, seaward of "The Ovens", but the axial trend of the bay swings to SSW, influenced by a broad valley cut in the bedrock. The bedrock surface, though buried here, is slightly overdeepened as a result of glacial erosion. A topographic constriction between Rose Point and Cross Island in about 31 m water depth represents a small-scale submerged fjord-like sill, though it is buried a few metres by unconsolidated sediments. This would have acted to constrict water communication into the bay when sea-level was lower in early post-glacial times. The sill creates a central valley which has acted as a Quaternary sediment depocentre. The surficial geology and sediment distribution is governed largely by glacial processes, a post-glacial low-stand and subsequent rise, with a time of extensive salt marsh, followed by effective coastal erosion. Deposits include glacial till and pro-glacial outwash followed by post-glacial sea-level rise-influenced sands and gravels, all with comparatively smooth surfaces in contrast to the exposed rugged bedrock surface. A more complete description of the geology accompanies OF 8138 (King et al. 2017). Cross sections derived from the multibeam grid, Figures 1 to 8, highlight a variety of features and terrain character.

### ANTHROPOGENIC FEATURES

Human impact on the seabed environment is clear, especially in the harbour (Fig. 9). Dredging of muds in inner Lunenburg Harbour is evident as linear depressions with a hummocky seabed expression. Individual dredge drags are imaged at the seaward extreme of the dredged depression. The dredging operation also removed the gas in the muds, yet gas has since accumulated below the exhumed muds. This implies an active biogenic gas production. Dredging was last conducted in the late 1960's and spoils were dumped south of Cross Island but earlier operations left spoils in the outermost harbour and central bay. Isolated doughnut- shaped features where impact on the seabed has resulted in a gravel and mud mixture with a circular moat-encircled mound and central depression (Fig. 9, outermost harbour). Anchor scour traces are observed in the muds immediately north of the dredge depression at the National Sea Products wharfs. Dragger trawl marks appear on sidescan sonograms across sand and gravel deposits along the smoothest parts of the central inner bay despite periodic sand movement. A power cable to Cross Island is identified on the seabed and is locally buried and exposed across the sandy seabed (position on OF 8138, King et al. 2017).

Decommissioning of the Canadian frigate "HMCS Saguenay" (Fig. 10) was followed by scuttling under controlled conditions in June, 1994 to create an artificial reef and a recreational dive site as part of a marine park. It rises about 11 metres above the seabed and post-sinking surveying shows some settling of the vessel and scouring of sand with megaripples (indicating sediment mobility) around the wreck (Miller 1996).

### CROSS SECTIONS

Bathymetric cross-sections highlight some noteworthy features. Figures 1 and 2, from the inner and outer harbour respectively, show natural and man-made depressions in the mud. Some are floored with gravel and sand, forming cones and moats apparently developed through removal or non-deposition of muds (see OF 8138, descriptive notes). Figure 2 crosses a boulder-capped drumlin and an area of high relief mounds. These mounds are either very large boulders or an uncharacteristically rough bedrock surface morphology. Figure 3 shows the larger of a set of drumlins in the bay. It is planed off at the top when sea-level was lower. The cobble distribution suggests constructional beach spits, probably no longer active. There may have been dredging activity here also. A rough micro-topography along much of the shallow shoreface (Fig. 4) arises from gravel and boulders, locally in ridges. Fig. 5 crosses a thick mud tongue which has formed a constructional body between bedrock outcrops. More commonly mud is ponded in low-lying topography. Its distribution roughly matches what is understood about the oceanography (see also OF 8176, Fig. 3, King and Beaver, 2017). Most of the shallower part of the map area has exposed (or gravel-covered) bedrock with asymmetric ridges (weathering/erosional response to different bed compositions) between which thin sands were deposited (Fig. 6). This relief, where it occurs at sea-level, is responsible for the very convoluted coastline and ledges across the whole area east of Blue Rocks and on northern Cross Island. Where seabed currents are sufficient to move sand and there is sufficient supply, bedforms are built; Fig. 7 shows a field of small sandwaves. Where a salt-marsh was once maintained but is now flooded, small channels remain (Fig. 8). These may still direct mobilized sand periodically.

## ACKNOWLEDGMENTS


The authors would like to acknowledge R. Pickrill, GSC-Atlantic, NRCan, for coordinating the multibeam sonar survey with the Department of National Defense and Canadian Hydrographic Service (CHS). D. Beaver, GSC-Atlantic, NRCan and C. Reid, CHS small fleet, conducted the CSL Plover surveys and G. Rodger, CHS and C. Reid participated in the 2006 CHS Pelican operations. D. Beaver performed the post-survey data cleaning and he and S. Hynes produced the bathymetric images. P. O'Regan provided cartographic support. A. Normandeau, GSC-Atlantic kindly provided review.


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King, E.L. and Beaver, D., 2017. Backscatter strength and shaded seafloor relief, Lunenburg Bay, Scotian Shelf, offshore Nova Scotia; Geological Survey of Canada, Open File 8176, scale 1:25,000. doi:10.4095/299687

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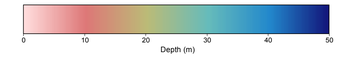


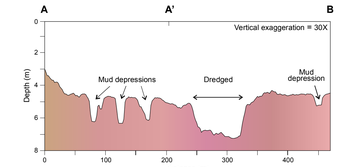


**Figure 1.** Dredging has removed a swath of mud about 100 m wide and 2 m deep. In contrast, currents are responsible for erosion or non-deposition of the mud to create isolated depressions. These may originate as pockmarks, formed through suspension and removal of the mud from methane gas escape. These coalesce in other areas to form moats around topographic highs. They may also form around moorings or other artificial seabed features.

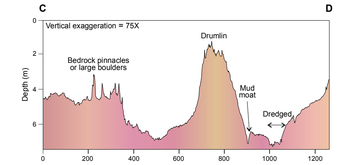


**Figure 2.** A small gravel-covered drumlin at the harbour entrance, "Head Rock" is bounded by mud on the east (right), extending as shallow as 4 m depth on the eastern shore. It is both artificially dredged and moated by currents. Sand and gravel cover the seabed on the west flank and numerous bedrock pinnacles or large boulders characterize the shallow seabed south the Kaulbach Head drumlin.

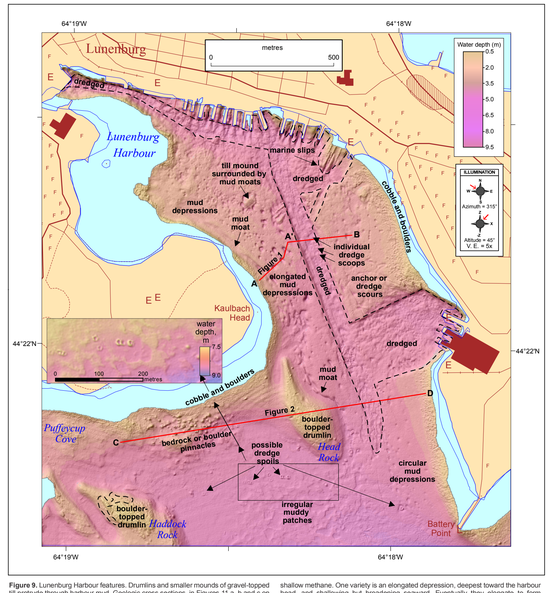


**Figure 9.** Lunenburg Harbour features. Drumlins and smaller mounds of gravel-topped till protrude through harbour mud. Geologic cross sections, in Figures 11 a, b and c on Map 8138 (King et al. 2017) show at least several metres thick mud in the harbour. It thins in less than 3 to 4 m water depth to expose gravel, cobble and boulders of the till surface at the seabed. The mud is modified locally, both naturally and by human activities. Circular mud depressions in the inner harbour may arise from current enhancement around mooring anchors or natural features such as boulders or a till mound, as the example immediately off the waterfront wharfs. They may also be nucleating as pockmarks, from mud suspension with periodic escape of the ubiquitous shallow methane. One variety is an elongated depression, deepest toward the harbour head, and shallowing but broadening seaward. Eventually they elongate to form continuous or discontinuous moats. Dredging of harbour muds has been conducted in several episodes. Individual linear scours and dredge scoops are registered. The spoils were usually transported outside the map area. Circular "doughnut-shaped" features with up to 0.5 m relief and a seabed expression of coarse sand or gravel represent individual dredge spoil drops. The central depression is typical of dredge spoils; the seabed impact apparently directs most material laterally. Seaweed varieties are common on the hard substrate and eel grass on the harbour muds.

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