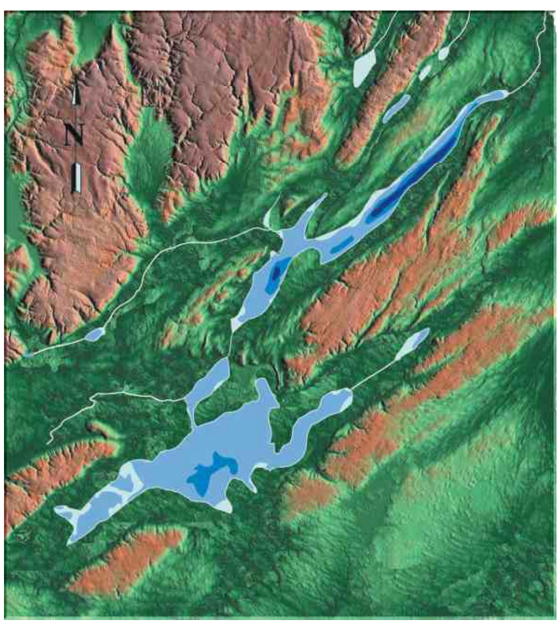
Sea Level Rise and the Bras d'Or Lakes

When undertaking repairs to the dock at Fortress Louisbourg during the restoration project begun at this historic site by Parks Canada in 1961, workers noticed ring bolts set into its wall. Although these had obviously been used to tie up boats, strangely, they were now about three feet underwater at high tide. The conclusion was inescapable; sea level was now much higher than when the fortress was built in the early eighteenth century.

Geologists are well aware of this rise in sea level and have documented this phenomenon in studies designed to shed light on the prehistoric timing and rates of sea-level change. Quite simply, the cause of this fluctuation in sea level can be attributed to ice. During ice ages the normal water cycle was disrupted as vast quantities of water fell as snow, compressed to ice and formed vast ice caps which covered most of the northern continents. Trapped as ice, this water did not return to the ocean and as a result sea levels dropped. During the last ice age, which ended about 10,000 years ago, sea level off Cape Breton was about 50 m below the its present height. As the ice retreated, lakes were formed where the land that had been scoured by the glaciers' movements. At that time, the Bras d'Or Lakes, seen below, were much smaller and connected by rivers. Then the entrance to the Lakes was about 25 metres above the sea level. As the glaciers melted water was returned to the oceans, which began to rise. About 6350 years ago sea level had risen 25 metres, at which point the ocean broke through to the Lakes. With further rise in sea level the Lakes grew in size and became increasingly salty, until saline enough to support marine life which invaded from the outside ocean. At the time the inundation of the Lakes began, the rise in sea level was in the order of 79 cm per century, but this rate declined over the past 6000 years and today is about 37 cm per century. You may wonder why sea level kept rising long after the glaciers had melted. This is because of something geologists term glacio-isostatic crustal subsidence. Although hard to believe, the earth's crust is actually quite elastic and if deformed by pressure can rebound when this pressure is released, albeit very slowly. In this case, the tremendous weight of glaciers on the continents depressed the earth's surface beneath the ice. As a result of this deformation, the earth actually bulged upwards at the margins of the ice cap to compensate. Thus with the melting and removal of ice, the earth directly beneath the ice cap gradually rose to its pre-glaciation height, whereas, the land at the periphery of the continent (ie Nova Scotia) began to subside to former levels.

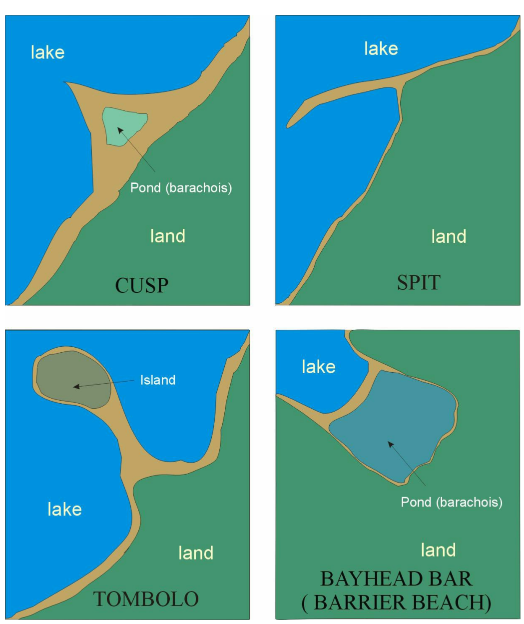


The Bras d'Or Lakes ~10,000 years ago.

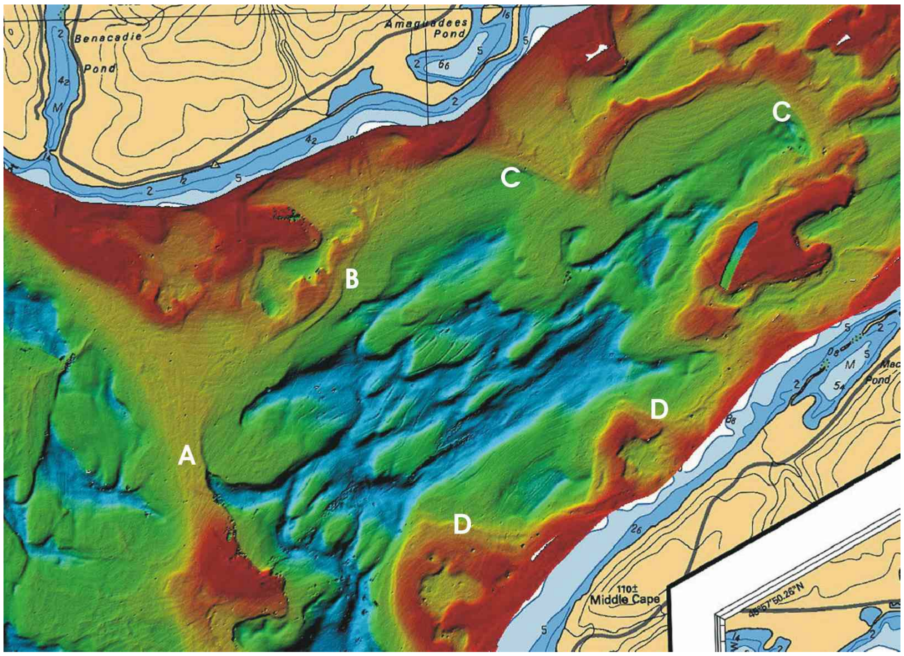
With the retreat of the glaciers in Atlantic Canada, sea level began to rise rapidly due to addition of melt waters and also subsidence of the land mass. As mentioned above, this rate of susidence of land slowed as it approached former pre-glaciation levels. However, routine measurements of sea level indicate that the rate of rise is now increasing. There is currently little doubt that this is due to global warming causing the erosion of the ice caps of Greenland and Antarctica. It has been calculated that the rate of increase in sea level will rise from the present rate of 36.7 cm per century to 60 cm per century by 2030 AD, 99.2 cm per century by 2080 AD and 115.1 cm per century by the year 2100. This means that sea level around Cape Breton will probably rise by about 76 cm (2 $^{1}/_{2}$ ft) in the next 100 years. What does this mean for the Bras d'Or Lakes?

Although the tide in Sydney Bight outside the Lakes rises and falls about 37 cm, the tidal amplitude in most of the Lakes is a mere 3 to 4 cm. The biggest drop occurs at the entrance to the Great Bras d'Or Channel, from 37 to 16 cm, and in the short distance to the Seal Island Bridge there is a further rapid decrease to 7.3 cm. The entrance to the Lakes through the Great Bras d'or Channel is too narrow and shallow to allow enough water through on a rising tide to enable the Lakes to equal the water level in Sydney Bight before the tide starts to fall again. However, the rise and fall of water in the Lakes is often far more than can be attributed to the gravitational pull of the moon and sun. Increases ten times greater than these lunar tides can be caused by an inverted atmospheric pressure effect. Simply put, sea levels are higher when low pressure systems overlie the ocean and vice versa, lower levels with high pressure. These pressure systems usually last for days and sometimes weeks. Thus when Cape Breton experiences a prolonged low pressure system the water in Sydney Bight stays higher than normal for a period of time long enough to allow sufficient water to flow into the Lakes to raise the water level far higher than that caused by a lunar tide.

The total shoreline length of the Bras d'or Lakes is 1272 km, including 285 km of island shore. This amounts to 14.4% of the total Nova Scotia coastline. A recent mapping study classified the Lake's shores into four main types; rocky (10%), unconsolidated beach and cliff (43.3%), vegetated (30.4 %) and artificial (2.6%). A further 13.7% were not mapped but were mostly vegetated or fringing beach with sloping backshore. Of these types, unconsolidated beach and cliff are the most susceptible to erosion by wave and current action. Four types of unconsolidated beach common to the Bras d'Or Lakes are illustrated to the left. These barrier forms are created by the erosion of headlands made up of glacial till. The sediment eroded from these cliffs is transported by longshore currents and deposited to add to gradually forming spits etc. When the supply of sediment is exhausted (cliffs greatly reduced by erosion) these beach forms will break down and be removed by wave action. Presently at 76 locations around the Bras d'Or Lakes, it is estimated that 39%



of these coastal barriers are in building or established phases, 43.9% are in breakdown and collapse phases, 13.4% are in a transition phase (not clear whether about to breakdown or aggregate) and 3.7% are significantly constrained by human activity. If sea level rises faster than the barrier beach forms can be supplied sediment from eroding headlands and cliffs, they will all be broken down by wave action or submerged. Sea level rise immediately post glaciation was very rapid and since there is little tide in the Lakes as we have seen and also wave action is minor



Multibeam sonar image of the entrance to East Bay off Benadacie. Red signifies shallow water and blue is deep. Submerged features are: A) tombolo, B) spit, C) bayhead barrier beaches and D) rounded cusps.

compared to the open coast, many barrier beach forms were submerged intact and can be seen on multibeam sonar images of the bottom of the Lakes.

Since unconsolidated cliffs and headlands supply the sediment for barrier beaches it is obvious they are subject to severe erosion. Measurements within the Lakes indicate that headland retreat is on the order of 0.1 to 0.3 metres per year. This would be greater if the Lakes experiences higher wave action; for instance, just outside the Lakes at the entrance to the Great Bras d’Or Channel similar measurements indicate rates of 0.4 m to 1.5 metres per year. During the next century as the rate of sea level rise increases, the rate of erosion of cliffs will also increase.

Thus it would be prudent not to build anywhere near eroding cliff tops or at at low elevations around the Lakes. Constructing habitations on or behind coastal barrier beaches, whether or not artificial protective structures are built, would seem extremely foolish, yet this is done either through foolhardiness or ignorance. An extreme example of this can be seen at Gillis

Gillis Beach, Jamesville

Beach, Jamesville where a residence has been built on a barrier beach. The house is sited on an old beach ridge behind the front and highest beach ridge. The elevation of the ridge in front is 1.0 metre above sea level and the height of the ridge upon which the house is built is 0.5 metres. Even now, as can be seen by the seaweed lines in the lower photograph, water levels have reached the top of the outer protective beach ridge. Erosion of vegetation at the crest of the ridge has caused a 'blowout' strip (middle right of photograph) and waves have actually carried seaweed and woody debris across the ridge to the other side. Water levels have no doubt reached this height due to the inverted atmospheric pressure effect as described earlier. Even without the dismal outlook on sea level change predicted by scientists for the coming century this habitation would appear to be in immediate peril. Extreme storm surge water levels accompanying tropical storm or hurricane remnants, which are expected to occur more frequently, and associated high winds and waves could easily breach this barrier beach with most unfortunate consequences. The most astonishing revelation of this unfortunate house siting is that one must assume the owner of the house received planning permission for its construction.

Basing their inferences on the drowning of prehistorical shorelines, scientists predict that complete destruction and submergence of barrier beaches may become frequent by 2030 and typical by 2045. Artificial shores are also rated as highly vulnerable and will require increased maintenance as they become increasingly ineffective in protecting backshores as sea level rises. By the end of the century, the rates of sea level rise will be in excess of 1.0 metre per century. By then the impact on the coast line of the Bras d'Or Lakes may be very severe, particularly in low lying areas.

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