Water Level Changes and Sand Transport at Pinery Provincial Park: Longterm Dune Development Implications

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Abstract

Sand transport through trough blowouts in Pinery Provincial Park responds to variations in water level. During periods of low water levels there are significantly larger volumes of sand entering the system than during high lake levels. Sand transport during the low water level period winter months is greater than the volumes moved during the summer. Continued monitoring confirms that there are variations in the patterns of erosion and accretion on the dune surface seasonally. During monitoring period, October 2001 to November 2002, a low water period, the sediment continued to be deposited on the lakeward side of the beach, while sediment closer to the dunes was eroded. The foredune lakeside surface and top continued to receive sediment, while the trough blowout throat and sides were dominated by erosion. The lee face of the trough blowout experienced net deposition. This continues a pattern documented in the first year of monitoring. This has significant implications for the dunes under climate change scenarios. Predictions of water level change for Lake Huron estimate a further lowering of water levels. The result will be a larger dynamic beach in the Provincial Parks that have beach and these trends in dune changes may allow managers to capitalize on the increased sediment supply in the management of dunes.

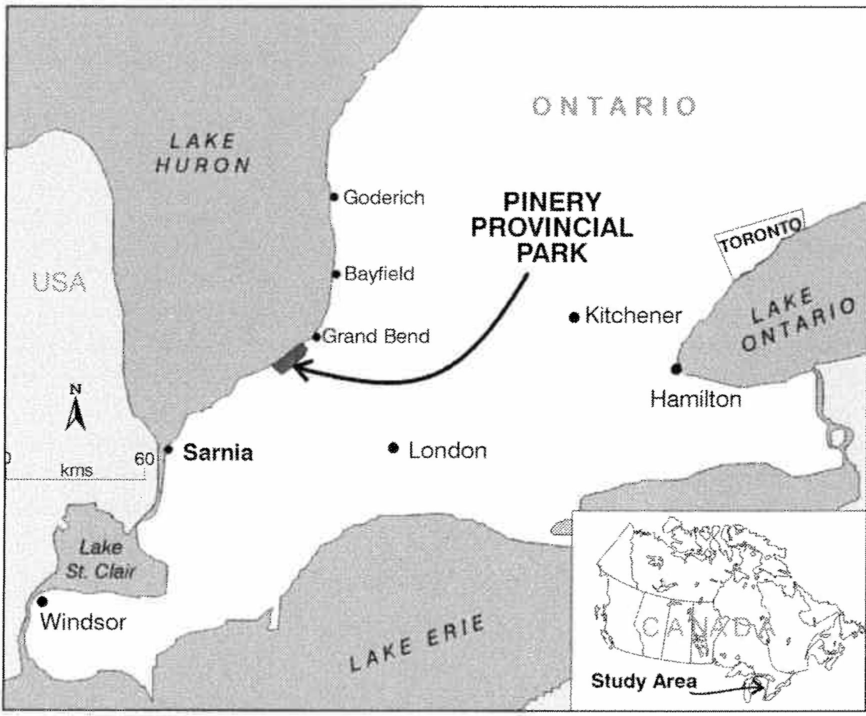
Introduction

Sand transport through the dune system at Pinery Provincial Park has been monitored since September 1993. The patterns of transport vary with the seasons having greater volumes transported in late autumn and winter and a decrease in summer. There are also variations in the patterns of transport with the changes in water level. During lower water level periods, there is an increase in the supply of sand to the beach and dune system. The purpose of this paper is to document the results of continued monitoring of sand transport and to propose an estimate as to how climate change in the Great Lakes Basin might affect the beach and dune system at Pinery Provincial Park.

Study Area

Pinery Provincial Park, located on the southeastern shore of Lake Huron (Figure 1) is a 2,532 ha natural environment park that contains a well developed freshwater coastal sand dune system (Ontario Parks, 2003). The study site is a small trough blowout, an elongate depression or hollow formed by wind erosion on a pre-existing sand deposit (Hesp and Hyde, 1996), located in the Wilderness Area of the park (Figure 2). Byrne (1997) summarized the site as a 250 m long, 20 to 70 m wide blowout that reflects the variability of wind directions at the site. The dune is typical, though more well developed, of the dunes with blowouts at Pinery Park. The trough likely began as a small blowout and eroded through the dune ridge over time. There is also a strong asymmetry to the dune, with greater erosion on the eastern side.

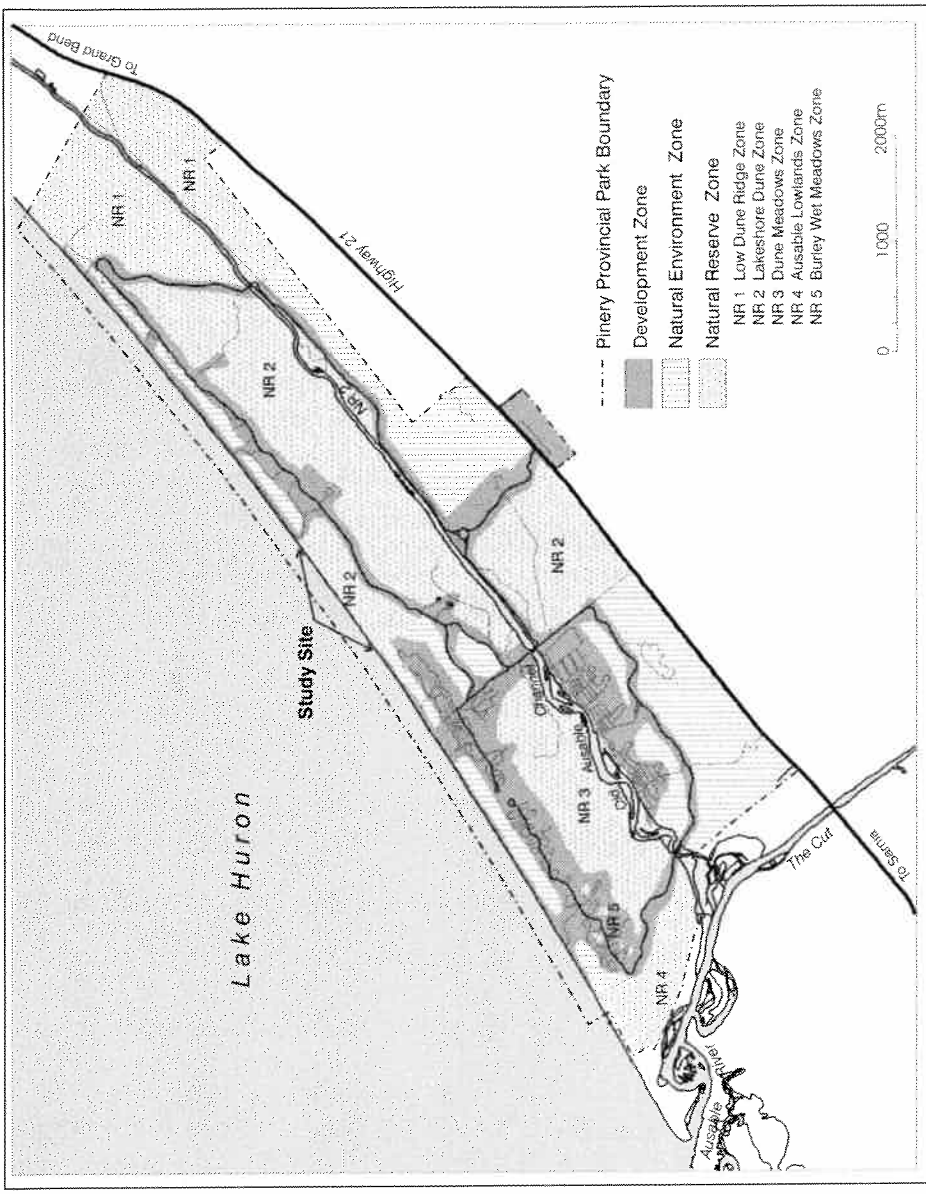
Figure 1. *Pinery Provincial Park.*



Water Level History

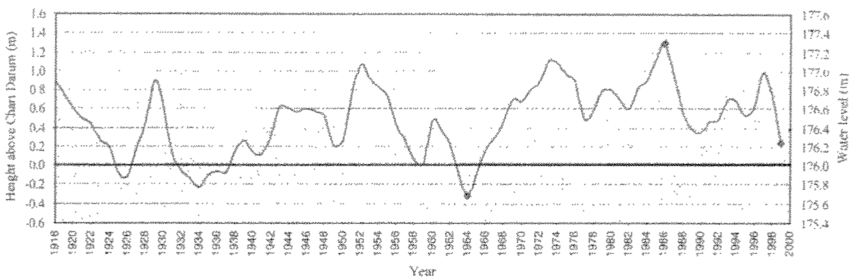
There is a natural history of water level change on the Great Lakes. Figure 3 (CHS, 2003a) illustrates the historic recorded high (1985) and low (1964) water levels. The Canadian Hydrographic Service (CHS, 2003b) documents information about the history of record of tidal levels including inland waterways. Continuous water level recording in the Great Lakes has occurred since 1906, with widespread gauging of the Lakes by 1930 (CHS, 2003b). During the period of record, there have been six periods of high water (1920, 1929, 1953, 1975, 1986 and 1998) when the recorded level was above 177.0 m asl. There have been six periods of low level (1926, 1934, 1950, 1959, 1964 and the current low level period) when water levels were lower than the IGLD 1985 datum (176 m asl). According to CHS (2003c), these fluctuations are due to high or low net basin supply of water and have no regular or predictable cycles.

Figure 2. *The study site is located in Nature Reserve 2, between the day-use area and the Dunes campground.*



Water levels also fluctuate on shorter time scales. Each year, higher net basin supplies in spring and summer result in the higher water level for those seasons, while the rest of the year experiences a lower net basin supply (CHS, 2003c). Highest seasonal water levels for Lake Huron occur in July and the lowest seasonal levels in February, with a range between the two levels of about 0.4 m.

Figure 3. *Lake water level history for Lakes Huron and Michigan.*



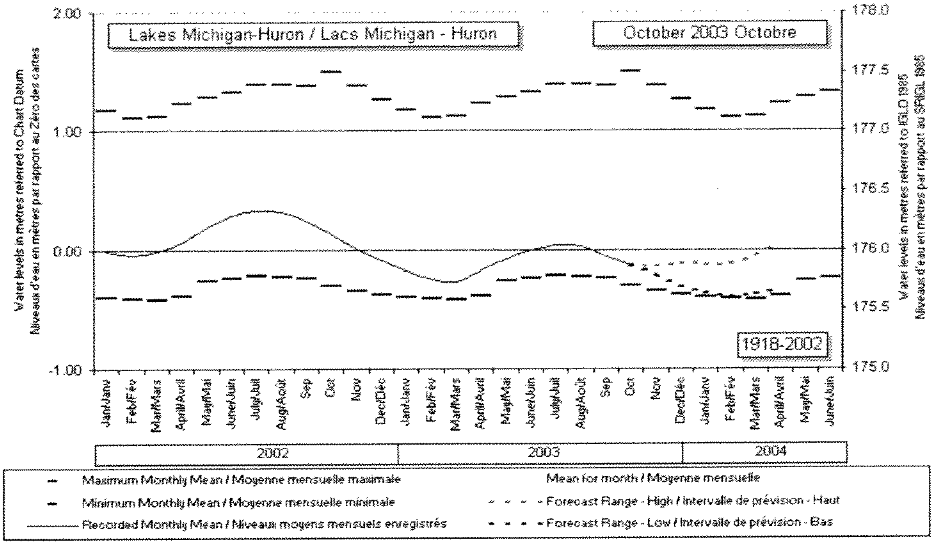
The current low water levels are approaching record low levels of the mid 1960s. Figure 4 illustrates the forecast for the next six months for the water levels on Lake Huron. The upper dashed line records the historic level for that month, the lower dashed line, the record low. Chart datum is 176.0 m referred to IGLD 1985. The monthly mean is depicted in the thicker gray line and the measured monthly mean water level is the thin black line. These graphs are updated monthly by the Canadian Hydrographic Service. The measured monthly mean ends at October for this example. The dotted lines depict the range of possible water levels for the next six months and show that the forecast for that time period lies below chart datum. The continued low water level on Lake Huron has a great influence on the dune systems at Pinery Provincial Park.

Previous Work

Byrne (1997) examined the patterns of sand transport at Pinery Provincial Park, and the ways in which these patterns change seasonally. This study was undertaken when lake levels were relatively high in the early 1990s. Byrne found that seasonal patterns of erosion and deposition varied with greater deposition in late summer and erosion in winter. Parts of the dune experienced net accretion (west side) while other parts experienced net erosion (east side). Finally, the greatest amounts of erosion and transport were occurring in the wetter and colder late autumn and winter seasons.

Byrne and Bitton (2001) and Bitton and Byrne (2002) documented the effect of the low levels through an examination of sand transport to the system. They found that the increased beach width resulted in an increase in the volume of sand that moves into the dune system. The dunes are steepening and building into the forested area landward of the established ridge. The volume of sand transported is great enough to repair breaches in the foredune.

Figure 4. *Water levels forecast (6 months).*



Methods

Sand transport in the dune here has been monitored since 1993. Earlier papers focussed on the relative rates of transport during high water levels (Byrne, 1997) and during low water levels (Byrne and Bitton, 2001; Bitton and Byrne, 2002). In the first study, Byrne installed a network of 12 erosion pins in the throat of the blowout. Bitton and Byrne installed an additional 12 pins for the second study. Additional pins were added to the lee side of the dune in 2001, bringing the number of pins to 42. Transport has continued to be monitored using erosion pins to record the changes in elevation.

More recently, a dual-frequency differential geographic positioning system (GPS) has been employed to accurately record easting, northing and elevation data for the site. Generally, this method allowed for the collection of about five thousand data points in just over an hour. These data were assessed for accuracy and entered into an interpolation software (Golden Software Surfer 8) to generate contour maps and wire frame images of the site. Images were overlaid and mathematically compared to determine areas of deposition and areas of erosion. These were then plotted on a map. Volumes of sand added or removed from areas of deposition or erosion were calculated. The changes in the surface and the calculation of the volume of sand added and removed were then used to develop a schematic of the changes in the shoreline which might occur with predicted climate induced changes in the water level of Lake Huron.

Results of Monitoring

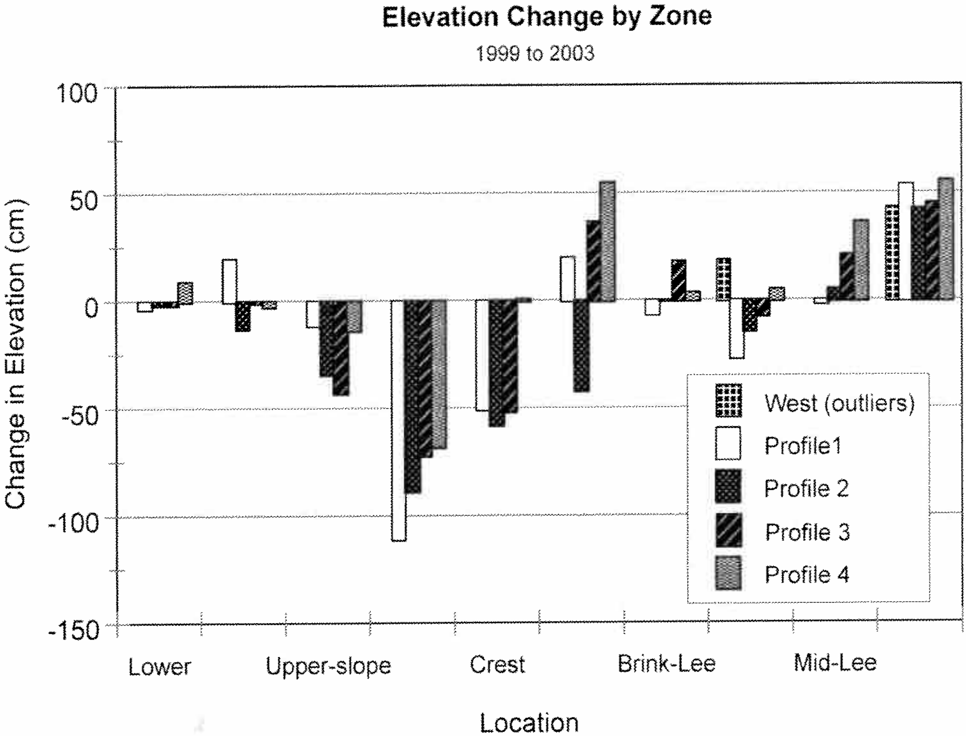
The change in elevation recorded at each of the pins ranged from -111 cm to 55.5 cm. The change in elevation is recorded in cm and represents the difference in elevation of the exposed pin between the time the pin was installed and the final recording taken on March 17, 2003. The first 12 are located on the lakeward side of the blowout and all but two of them (pins 4 and 5) have experienced erosion over the time of installation. The middle 12 pins are located higher in the throat of the blowout and have experienced greatest erosion in the lower pins (13 to 16), decreasing through the middle (pins 17 through 20) and changing to mostly accretion at the top of the blowout (pins 21 through 24).

On the landward (lee) side of the dune, accretion dominates. The change in elevation indicates that the lee slope is building up, to the point of oversteepening. Overall, the erosion pins indicate that the throat of the dune is still lowering and the lee side building. Overall, the lake side is dominated by erosion while the land side is dominated by deposition, especially the pins farthest from the water. The magnitude of erosion on the lakeward face of the dune at the bottom of the slope is small, between -1 and -12.5 cm. The magnitude of erosion increases dramatically in the higher zone of the lakeward face with between -11 and -111 cm of change in elevation. On the lee or landward side, the changes are more dramatic. Deposition dominates with some erosion. The magnitude of deposition is remarkable in that the areas on the lowest parts of the landward slope have received as much as a half a metre of deposition in just over a year.

Figure 5 presents the data as a series of long sectional profiles in the dune. There are two outliers on the western slope of the lee side of the dune that have experienced deposition. Profile 1 is on the west side of the blowout and experienced the greatest amount of erosion, especially at the upper traps level. Profile 2 just east of Profile 1, showed a similar pattern of erosion, but the surface is lowered through the brink and onto the lee side. Profile 3 shows a similar pattern as the previous two profiles, except that the volume of erosion is significantly lower. Deposition begins to dominate on the brink and lee slopes. Profile 4, the most easterly in the blowout, shows minor patterns of erosion and deposition in the lowest parts of the blowout. There is significant erosion at the brink, and then deposition dominates down the lee slope. This pattern is consistent with the previously documented effects of topographic steering of the wind in the dunes (Byrne, 1997).

Data collected using the dual frequency, differential GPS were entered into Surfer and analysed to depict the changes in the surfaces. During winter map deposition dominated on the foredune, on the west side of the blowout and on the lee slope. In summer, there was more deposition over the entire surface with erosion dominating in the throat. Figure 6 shows that over the span of a year, erosion dominated on the lakeward face of the dune and deposition on the foredune, west side and lee slopes. Overall, the surface has lowered by around 1200 cubic m of sand. Erosion dominated, but there are zones in the dune where deposition dominated and the surface increased in elevation (almost 2,800 cubic m of sand).

Figure 5. *Patterns of erosion and deposition at pins.*



Climate Change

The dune system is definitely experiencing change as a result of the lowering of the lake levels. The current water levels are approaching the historic lows. The six month prediction could see a new historic low level. The decrease in the water level has resulted in the exposure of an increased supply of sand that is available to be moved into the dune system. Indeed the foredunes are growing lakeward and the established ridge is lowering on the lakeward side, while the landward side is building upward with the sand that moves through the system. The relationship between the current low water levels and climate change is not well known. However, LHCCC (1999) reported that GCMs predict a decrease in the water level of Lake Huron by a further 1 m on average by 2090. This further decrease in water level would expose a further supply of sand for beach processes and dune building and result in a shift of the dune system lakeward. The prediction would result in a drop in both the expected new minimum and maximum levels and the new mean water levels (Figure 7). This idea is represented schematically in Figure 8. In this scenario, the 1999 and 2001 dunes profiles were measured, the 2100 profile is a "best guess" at what the dune system will look like as the foredunes continue to build lakeward, and become new established ridges. It is likely that a new foredune will develop.

Figure 6. *Erosion and deposition over surface.*

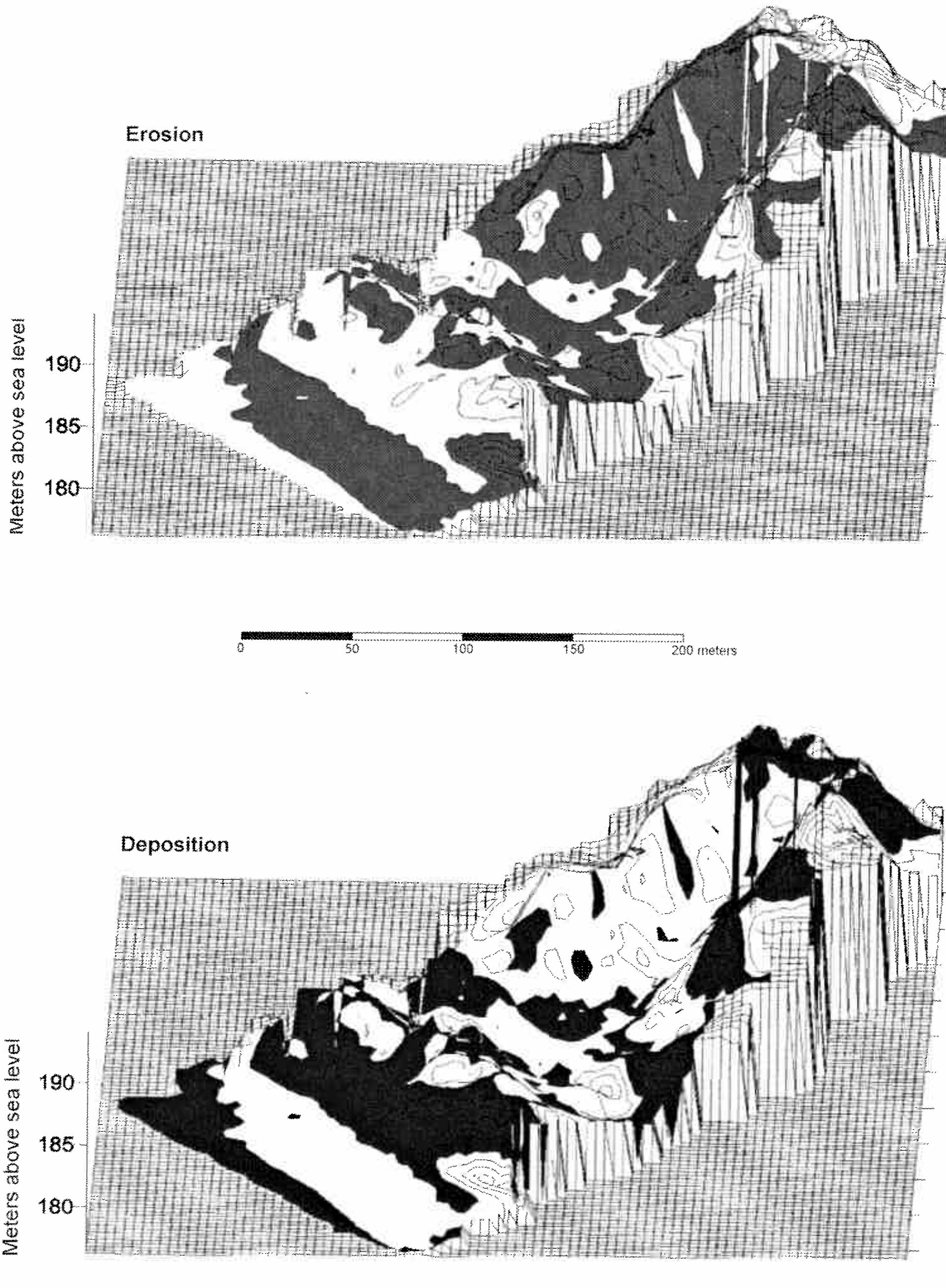


Figure 7. *Water levels forecast based on climate change.*

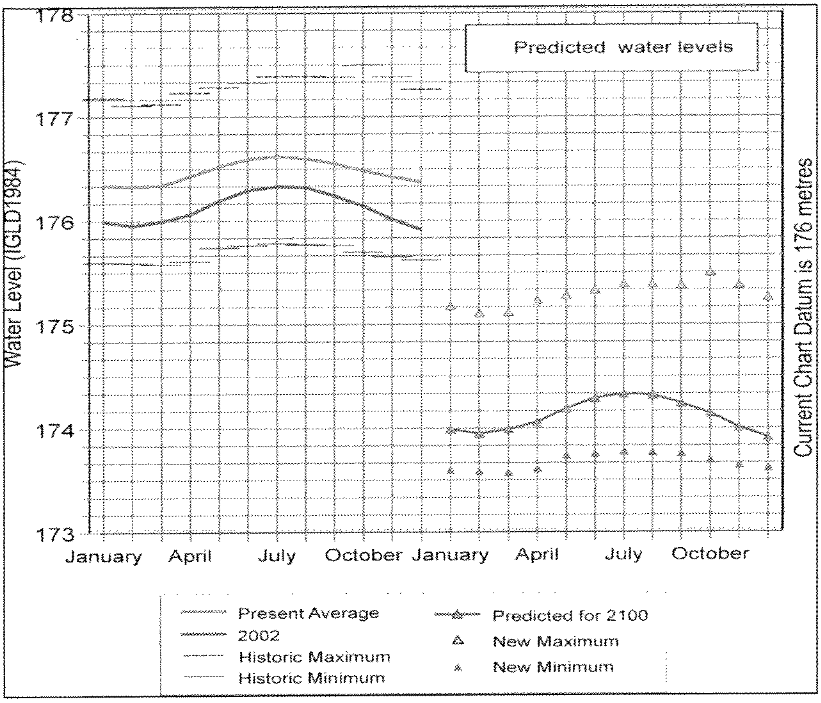
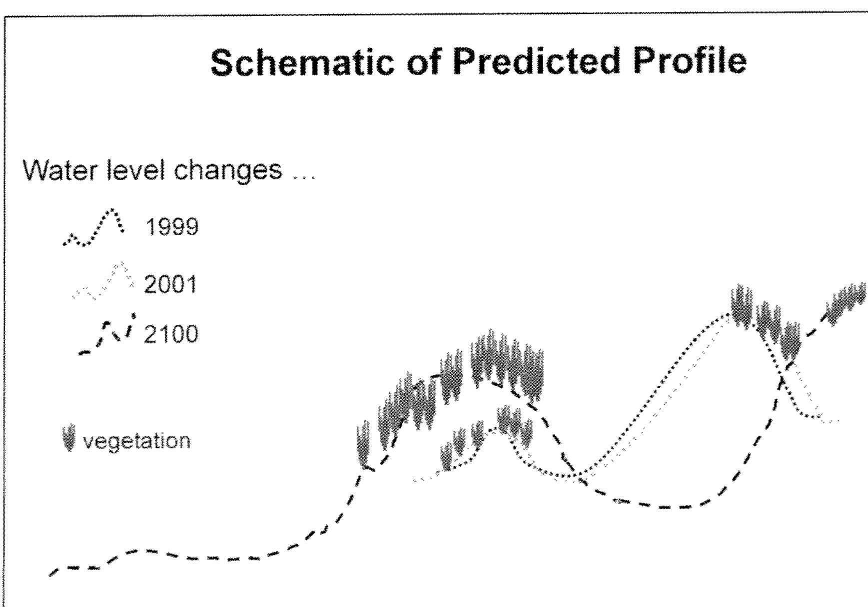


Figure 8. *Schematic representation of the effect of a 1 m fall in water level in Lake Huron at Pinery Provincial Park.*



Summary

Erosion pin evidence shows a decrease in the rate of lowering of the surface at the base of the blowout. There is continued acceleration of erosion on the upper slopes of the blowout, peaking in intensity at the crest. The lee side shows marked accretion in the lowest parts of the slope. This indicates a landward movement of the established ridge.

Mapping of the site and volumetric analysis indicates an overall erosion of the established dune. The loss of sand is into the forest landward of the dune. The foredune is building lakeward with the increase in sand supply. It is also increasing in elevation. The increases are significant enough that, with the continued supply of sand, the foredune may develop into a new established dune ridge.

References

Bitton, M. and M-L. Byrne. 2002. A Volumetric Analysis of the Changing Morphology of a Coastal Dune Blowout, Pinery Provincial Park, Ontario. Pp. 221-230. In: Lemieux *et al.* (eds.). *Parks and Protected Areas Research in Ontario 2002 - Protected Areas and Heritage Coastal Ecosystems.* Parks Research Forum of Ontario: Waterloo, ON.

Byrne, M-L. 1997. Seasonal Sand Transport through a Trough Blowout at Pinery Provincial Park, Ontario. *Canadian Journal of Earth Science,* 4: 1460-1466.

Byrne, M-L. and M. Bitton. 2001. Sand transport and water level change at Pinery Provincial Park, Ontario. Pp. 225-235. In: Porter *et al.* (eds.). *Ecological Integrity and Protected Areas: Proceedings of the Parks Research Forum of Ontario (PRFO) Annual Meeting.* Parks Research Forum of Ontario: Waterloo, ON.

CHS (Canadian Hydrographic Service). 2003a. *Historical Monthly and Yearly Mean Water Level Graphs 1918-2002.* 2003. Available: biachss.bur.dfo.ca/danp/net graphs_e.html.

CHS (Canadian Hydrographic Service). 2003b. *History of Tidal Measurements in Canada.* 2003. Available: www.lau.chs-shc.dfo-po.gc.ca/english/History.shtml

CHS (Canadian Hydrographic Service). 2003c. *Fluctuations in Lake Levels - Types.* Available: chswww.bur.dfo.ca/danp/fluctuations_e.html

Hesp, P.A. and R. Hyde. 1996. Flow dynamics and geomorphology of a trough blowout. *Sedimentology,* 43, 505-525.

Lake Huron Centre for Coastal Conservation (LHCCC) in conjunction with the University of Waterloo and the Adaptation and Impacts Research Group (AIRG) of Environment Canada. 2003. *Web page report on Climate Change impacts on Lake Huron.* Available: www.lakehuron.ca/climate/climate-change.asp.

Ontario Parks. 2003. *Pinery Provinical Park Website.* Available: www.ontarioparks.com /english/pine.html#