

Sand Transport and Water Level Change at Pinery Provincial Park, Ontario.

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Abstract

The purpose of this paper is to document sand transport through a trough blowout during a period of low Great Lakes water levels. Measurements were made by trapping sand in Rosen style traps installed at the mouth and crest of the blowout and by measurements of surface elevation change using erosion pins. The traps were emptied every 2 to 4 weeks and compared to previous measurements taken when Great Lakes water levels were higher. The comparison illustrates that there are significantly larger volumes of sand entering the system during low levels. This information has serious implications for Park management and timing of attempts to heal breaches resulting from disturbance and human impact.

Introduction

Pinery Provincial Park, located on the southeastern shore of Lake Huron (Figure 1), contains a complex and well developed dune system that consists of a foredune ridge at the back of the beach, an established ridge landward of the foredune ridge, and four older, stable landward ridges (MNR, 1986). The established ridge generally parallels the beach and foredune ridge, however, it is cut by numerous trough blowouts that mark transport pathways for sediment through the dune system. The purpose of this paper is to document the changes that occur in the transport of the sand through the trough blowout when Lake Huron water levels change.

Previous Work

Carter (1988) stated that, of all coastal ecosystems, coastal sand dunes have experienced the greatest changes along the coast, both small scale and large scale, as a result of human impact. The largest impacts might be the deflation of an entire system, while the smaller changes could lead to the initiation of a blowout. All of the changes result from either direct impact (sand mining, cottage construction, coastal development), indirect activity (changes in up-current sand transport, recreational activity, trampling), or a combination of the two. Bagnold (1954), Hsu (1973), Svasek and Terwindt (1974), Pye (1982), Brookfield and Ahlbrandt (1983), Nordstrom *et. al* (1988), and Pye and Tsoar (1990) documented sediment entrainment and deposition by wind. Lancaster (1995) synthesized the state of knowledge for the geomorphology of desert dunes and Bauer and Sherman (1999) outlined the dynamics of coastal dunes, pointing out the need for long-term longitudinal data bases on coastal dune evolution. Hesp and Hyde (1996) documented the

dynamics and geomorphology of a trough blowout in Australia, where they found that topographic steering of winds became increasingly pronounced and corkscrew vortices prevailed, resulting in a change in location of maximum transport from the centreline to an erosional wall. Byrne (1997) documented the volumes of sand transported through a trough blowout confirming these ideas of patterns of erosion within the blowout. This study was undertaken during a period of relatively high water on Lake Huron. Water level is an important consideration in sand transport because when the levels are high, the beach is narrow and supply is limited. When water levels are low, the beach is wider and sediment supply is greater. This paper considers the need for long-term data by monitoring sand transport over time, supplying a small window on the evolution of a dune system on the Great Lakes, and presenting a comparison of two distinct time periods - high water and low water.

Study Area and Methods

The study area is located on the southeastern shore of Lake Huron in Pinery Provincial Park (Figure 1). Fisher *et al* (1987) summarized the climate of Pinery Park as being characterized by hot summers, cold winters, and rapid changes in weather in all seasons that are associated with passing mid-latitude depressions. Precipitation is spread evenly throughout the year, with slight peaks in February and March. Snowfall occurs from the end of November to the beginning of April and the mean frost-free period is 150 to 160 days with a 205 day growing season.

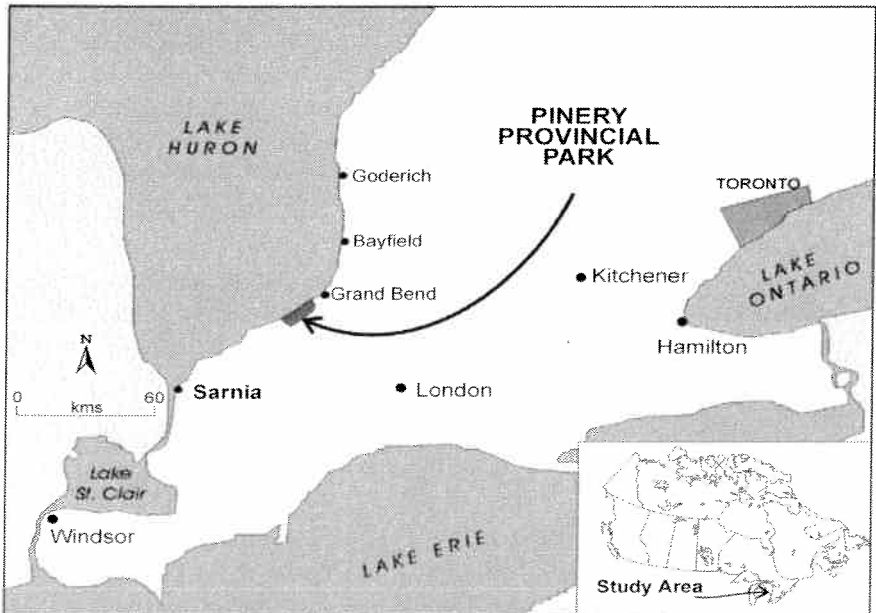


Figure 1. Pinery Provincial Park is located on the southeastern shore of Lake Huron, Ontario, Canada.

The strongest winds are from the north, west and south, while winds from the east are relatively weak. The prevailing winds, those that blow most often, are from the south and south-southwest with an average velocity of 15 kmh^{-1} measured at a height of 10 metres, accounting for 23.8% of the total winds. The dominant winds are stronger, less frequent storm winds that blow most strongly from the northwest, then west-northwest and then, north-northwest at speeds greater than 19 kmh^{-1} , but account for only 14.2% of the total wind (Figure 2). These winds blow directly onshore at Pinery and tend to occur in the fall and spring.

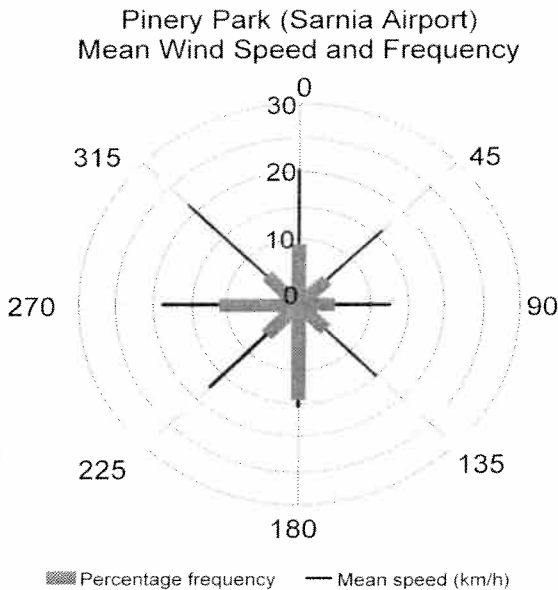


Figure 2. Windrose for Sarnia Airport, the closest Atmospheric Environment Service station to Pinery Provincial Park, shows the mean wind speed illustrated by the solid lines, is strongest winds from the northwest quadrant, directly onshore at Pinery. The percentage frequency of winds from 8 compass points is represented by the shaded line. The most frequent winds are from the south, the west, and the north. Winds from the east are relatively unimportant.

The study site is a small trough blowout located in the Wilderness Area of the park (Figure 3). As summarized in an earlier paper (Byrne, 1997), the 250 m long, 20 to 70 m wide blowout is part of a complex, digitate dune (Pye and Tsoar, 1990), reflecting the variability of wind directions at the site and 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.

Methods

Measurements of sand movement were made by trapping sand in Rosen (1978) style traps installed at the mouth and crest of the parabolic dune and erosion pins

through the throat (Figure 3). Originally, erosion pins were deployed in three arrays across the dune. The lower array was close to the lower sand traps, the middle array 25 metres up the dune, and the third array another 25 metres up the slope of the dune. A fourth array was initially set up near the upper traps, but was removed by vandals two months into the original study and could not be replaced because the ground was frozen. In the summer of 1999, three additional arrays of pins were installed at the crest of the dune.

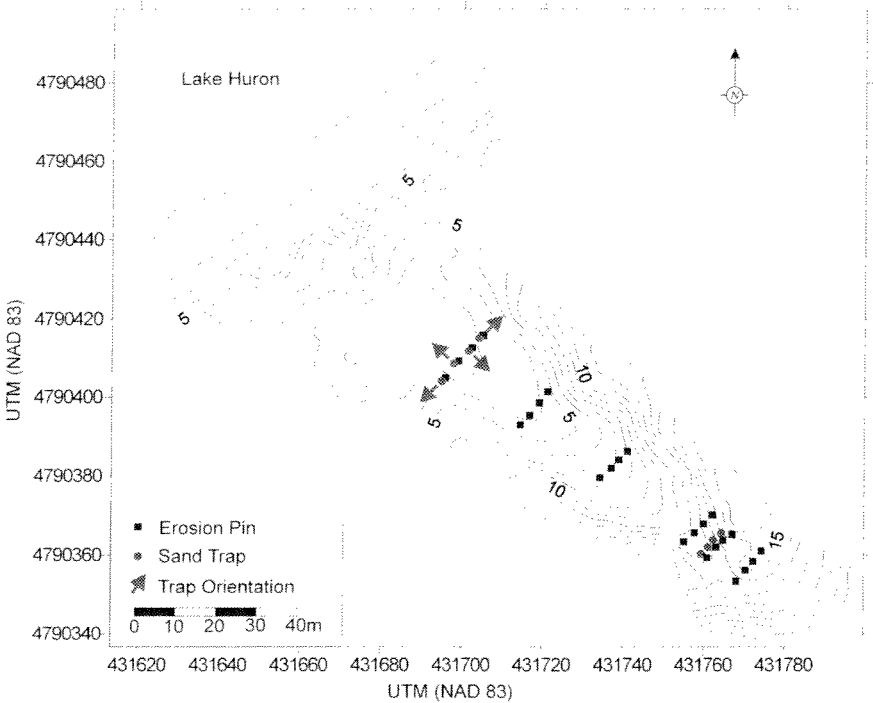


Figure 3. This topographic map shows two sets of traps, Traps 1 through 4 at the mouth of the blowout to capture sand coming into the dune, and Traps 5 through 8 at the top of the blowout to capture sand leaving the dune. Arrows indicate the direction that the trap opening is facing. For example, Trap 3 is open toward the blowout throat and captures sand transported by winds blowing offshore. Between the two sets are the lower three arrays of erosion pins. Pins 1 through 4 match with the lower traps, pins 5 through 8 are the Mid-slope array (numbering begins on the right and proceeds left), and pins 9 through 12 are the Upper-slope array. The upper arrays of pins are set up near the upper traps, and are referred to in the text as the Upper-traps array nearest the sand traps followed by the Crest array at the highest elevation of the dune, and the Brink array at the top of the steepest part of the blowout.

The lower array of sand traps was installed to measure the amount of sand being carried into the blowout from the foredune area, while the upper array was set up to measure the amount of sand transported out of the blowout. The traps were not

installed to calculate an absolute rate of transport, but rather to obtain a relative measure of the amount of sand moving past different areas of the blowout. For comparative purposes, the traps were emptied on a schedule similar to the previous study (Byrne, 1997), every 2 to 4 weeks beginning in May 1999 through to August 2000. The samples were weighed and sieved using standard techniques (Rowell, 1994; Black, 1965), and summary statistics were computed. Erosion pin measurements, taken at each visit to the park, were made from the top of the pin to a washer placed around the pin on the sand surface. For those pins where accretion had occurred between visits, thus burying the washer, the measurement was made from the top of the pin to the sand surface and then the washer was excavated. Data were tabulated and graphs constructed. The results of the low water period were compared with those of the high water period (Byrne, 1997).

Water Level Changes

Water level fluctuations are a natural occurrence on the Great Lakes. There is a long history of change that is currently documented by the Canadian Hydrographic Service (Figure 4), that shows maximum and minimum monthly means, the longterm mean for the current month, the recorded monthly mean, and the forecasted high and low ranges for the levels for the next six months. The longterm fluctuations (Figure 5), taken from the International Joint Commission (IJC) website give a graphical representation of the fluctuations that have occurred from 1918 to present. An earlier paper (Byrne, 1997) documented sand transport at Pinery from 1994 to 1996, a period when water levels were above datum (Figure 5). The data presented below were collected from a period when water levels were at or below datum (1999-2001). When water levels are higher, the beach width is narrower, as narrow as 5 to 10 metres at the highest water levels. When levels are lower, the beach width increases to over 40 metres at the current level, becoming even wider at the record lows.

Results and Interpretation

Erosion Pin Data

The erosion pin record reflects nearly two years of monitoring, spanning from June 1999 to June 2001, including 42 visits to the site. Figure 6 illustrates the spatial change of elevation at the erosion pins over the two year period.

The westernmost pin in each of the six arrays is the first group, the second group is the next pin in each array, the third group is the next pin in each array and, the fourth group is the easternmost pin in each array. Thus each group represents a profile of elevation change across the blowout. On the right side of the figure, the lowest grouping of pins is represented in the bottom of the two graphs, while the top graph portrays the upper three arrays that were installed at the beginning of this low water study. On the left of the diagram is a graph representing the previous measurements (1994-96) from a higher water period. Comparing the two periods, there is a change from erosion at all four pins at the lower array during high water to deposition at the second and fourth groups in the low water period.

Lake Michigan - Huron Water Level Forecast from May 2001

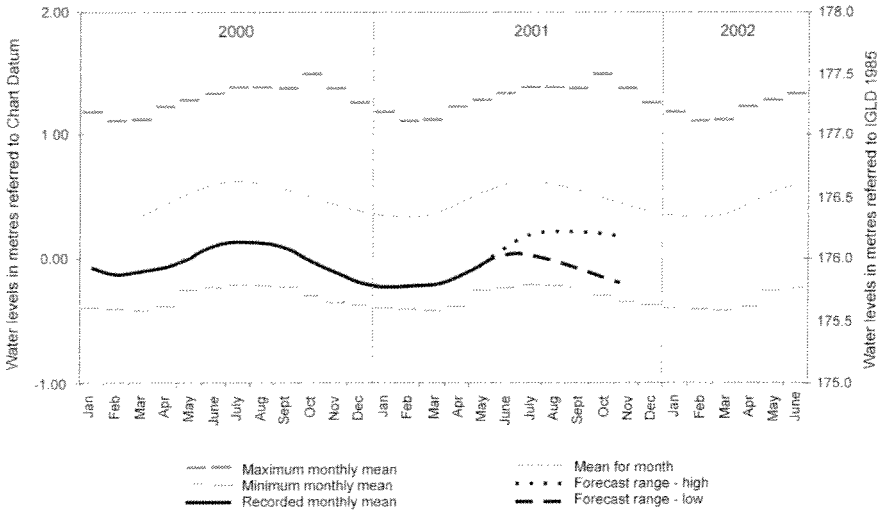


Figure 4. Lake Huron-Michigan water level record showing the record high and low levels, chart datum (IGLD 1985), the measured water level and the six month forecast level. In June 2001 the lakes are well below the datum, but forecasts show that, with rain, water level could return to datum in the near future. This graph was taken from the Canadian Hydrographic Service Website.

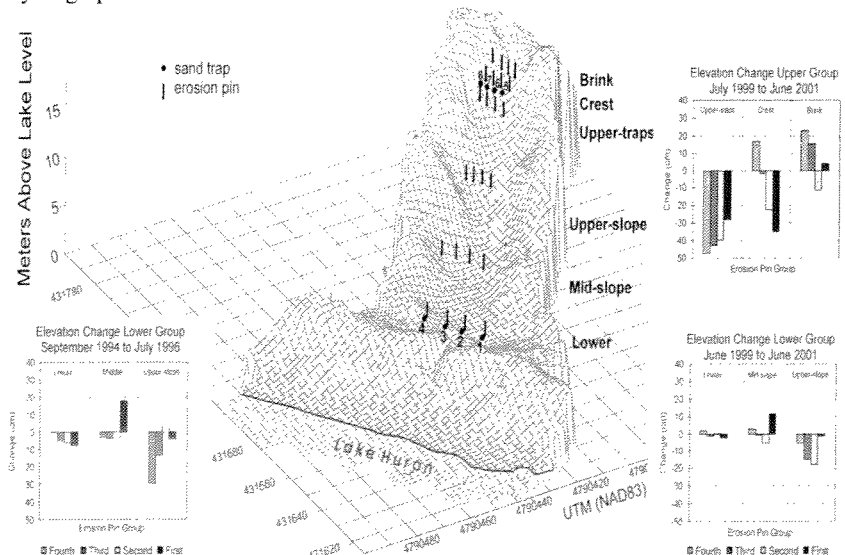


Figure 6. A three dimensional map of the trough blowout at Pinery illustrating the locations of erosion pins and sand traps. The graphs on the left and right of the diagram portray the record of change for the erosion pins. On the right are the results from this study illustrated by two graphs, one for the lower arrays and one for the upper arrays. The lower arrays can be directly compared to the lower arrays from the previous study, but the upper arrays are new for this study. On the left is the graph portraying the results from the previous, high water level study.

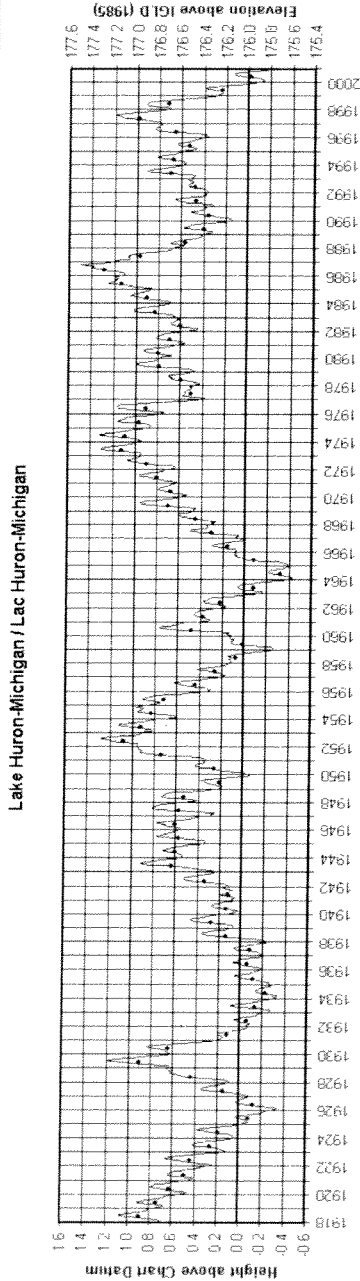


Figure 5. The longterm record of lake level change. Change of water levels is natural and can move from very high levels, like those of the mid-1980s to very low levels like those recorded in the mid-1960s. This graph was taken from the International Joint Commission Website.

In the Mid-slope area, there is again increased deposition from high to low water periods with pins in the first and fourth position receiving deposition. It is interesting to note that this deposition is occurring in these two lowest locations on the blowout. It is here that one would expect the greatest influence of a reduced water table and a potential increase in deflation. At the Upper-slope location deflation dominates in both time periods, there being no increase in elevation at this site during the low water period. The greatest deflation occurred in the centre of the blowout. Because the upper three arrays were installed in the low water period, no comparison could be made. The patterns of erosion and deposition show an overall lowering of the area close to the Upper-traps with the deflation increasing from west to east, erosion decreasing from the first to the second and third pins, and greater than 30 cm of accretion at the fourth pin. At the Brink, pin 2 showed 20 cm of deflation, while the other three pins received between 10 and 25 cm of deposition.

Sand Transport Variations

Variations in sand transported through the blowout were measured using the total amounts of sand captured in each trap for the time period from August 1999 to August 2000. The lower array again captured significantly less sand than the upper trap array. As in the previous study (Byrne, 1997), the overall movement of sand is landward rather than lakeward even though the prevailing westerly and southwesterly (summer) winds are alongshore and offshore. Traps 1 and 2 captured more sand in this study than in the previous one (Figure 7), while trap 3 captured just about the same amount. Trap 4 is the only lower trap to capture less sand during the low water period.

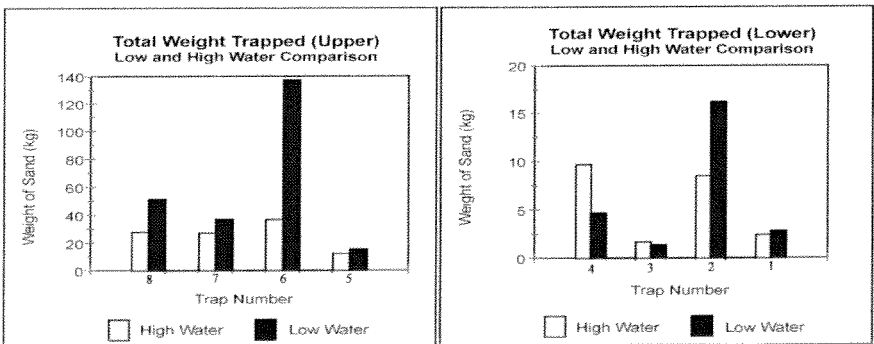


Figure 7. Weights of sand captured at Pinery from August 1999 to August 2000 compared with the results obtained from the previous study and weights collected August 1994 to August 1995. Note the scales are different on the vertical axes.

The upper trap array captured a much larger weight of sand. Note that the scales are different on the two graphs. In all four directions, there was more sand captured in the low water period than in the previous high water period. The differences between the two time periods at trap 5 and trap 7 were very small. Trap 8 received a much larger amount of sand, but the most remarkable difference was at

trap 6. This trap faces lakeward and received more than triple the amount of sand in the low water period than it had captured in the high water period.

Discussion

The patterns revealed by the erosion pin and sand trap data suggest some very important considerations for Park management. First, the pins show patterns of both erosion and accretion of sand. The greatest accretion occurred at the lowest and highest points of the blowout and toward the east side (pins 2, 4, 5, 8, 20, 23 and 24). The greatest erosion occurred at the mid-slope in the middle of the blowout and near the upper traps on the east wall (pins 1, 3, 6, 7, 9-19, and 22). From this information alone, one could conclude that the wind is simply eroding at one location, the Mid-slope, and depositing sand at another location within the dune itself, the crest. However, the overall balance of erosion pins is a negative one indicating a lowering of the surface. This lowering could possibly continue until the water table is reached.

The sand trap data (Table 1) add to this snapshot in the evolution of this part of the blowout at Pinery. The total weight of sand captured in the one year period of Low water levels is more than two times greater than that captured in the one year period of High water levels. This indicates that there is a greater supply of sand to this part of the system when the beach is wider. The increased volumes of sand captured in traps 2 and 6 support this idea. The two asterisks mark the traps which caught less sand in the low water period than in the high water period. This is likely the result of topographic steering of the wind and a change in the transport pattern as the topography changed in the vicinity of the traps.

Table 1. Weight of sand captured at Pinery at High and Low water levels (kgs)

Trap #		High Water	Low Water
4	t	9.65574	4.67
3	t	1.66893	1.3692
2		8.46758	16.1896
1		2.41349	2.794
8		27.70365	51.2043
7		36.58775	36.8548
6		27.01627	137.3029
5		12.1451	15.1951
Total		125.65851	265.5799

Why are these data important for Park managers? First this information suggests that at low water levels with an increase in beach width, there is an increase in the amount of sand that moves through the foredune and into the established ridge. In areas where there are naturally occurring blowouts, this sand actually gets to the back of the established ridge, either building the dune height, or moving the land-

ward edge of the lee slope into the forest. In areas where there is human disturbance that is creating new blowouts, this information is important in that it indicates that the low water level times are those in which the greatest volumes of sand are transported through these features. It is at this time, that the healing of disturbance is most likely to occur with planting of dune vegetation. If work is not undertaken to repair these breaches at this time, then an increase in the lowering of the surface and growth of the blowouts is likely to occur.

Summary

1. Erosion pin data at Pinery Park reveal both erosion and deposition patterns in the blowout. The net balance between erosion and deposition is negative, indicating a lowering of the surface overall.
2. Sand trap evidence indicates that there is more sand moving landward in the low water periods, more than twice that of the high water period.
3. Park managers should take advantage of this low water time to focus efforts on capturing sand in disturbed areas in order to decrease human impact.

Acknowledgements

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