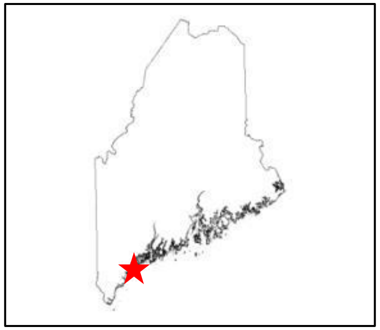
Geologic Site of the Month

May, 2007

The Patriots' Day Storm at Willard Beach, April 2007



43° 38' 43.14" N, 70° 13' 38.92" W

Text by
Peter A. Slovinsky

Introduction

The recent Patriots' Day storm battered numerous sections of the Maine coastline for several days with high waves and strong winds. Offshore wave heights reached over 8 meters (26 feet) on April 16. The storm also coincided with astronomically high tides; predicted tides were exceeded by approximately 0.75 m on April 16, indicating that a storm surge of about 2.5 feet occurred at the height of the storm.

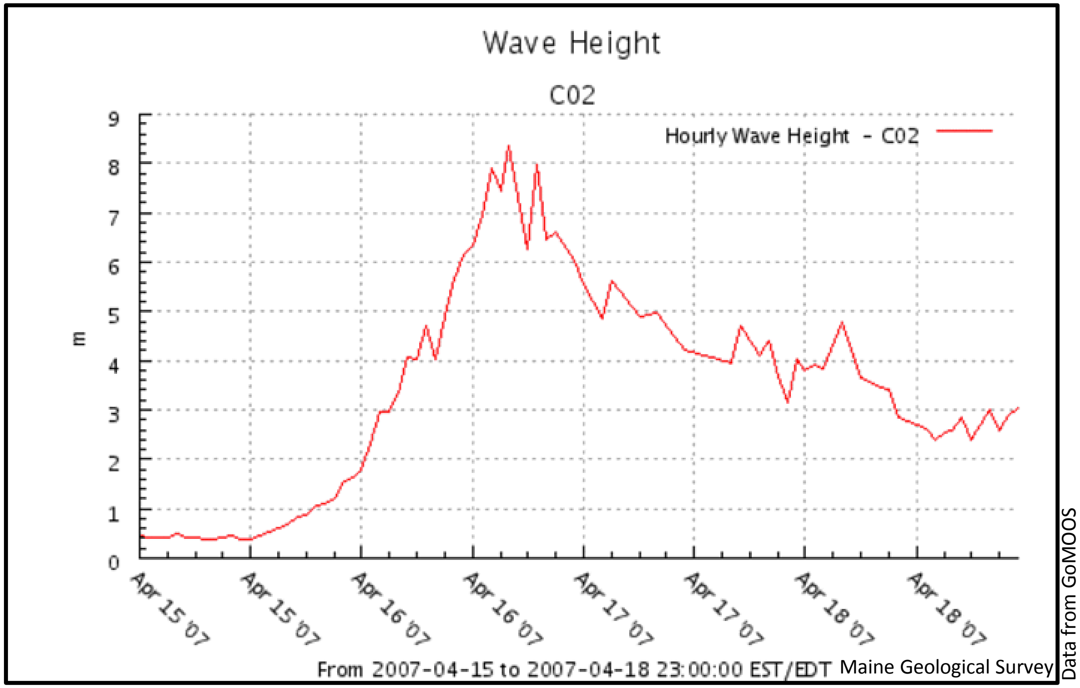


Figure 1. Graph of ocean wave heights recorded in Casco Bay at the Gulf of Maine Ocean Observing System Buoy C02. Wave heights are in meters and build in less than 24 hours from under a meter on April 15, 2007 to over 8 meters early on April 16, 2007. Wave heights gradually decline over the next two days to 3 meters.

Patriot's Day Storm

The twice daily rise and fall of the tides is shown as predicted by the National Oceanic and Atmospheric Administration (NOAA) in blue. The rise and fall (range) of the tide is larger than the mean due to "spring tide" conditions forced by the gravitational pull of the moon and sun; these astronomically high tides were the largest of the year. The second tidal line (red) is a plot of the observed tide. The storm produced a surge (an extra elevation of the sea) driven by the wind and low barometer of 0.7 meters (or 2.5 ft) above that predicted. The difference from the predicted tide and the storm tide is the green line on the graph. It peaks between 10 and 11 a.m. on April 16, 2007 and remains elevated for 6 more high tides before the storm's influence abates. The surge seems to get slightly higher during flooding tides.

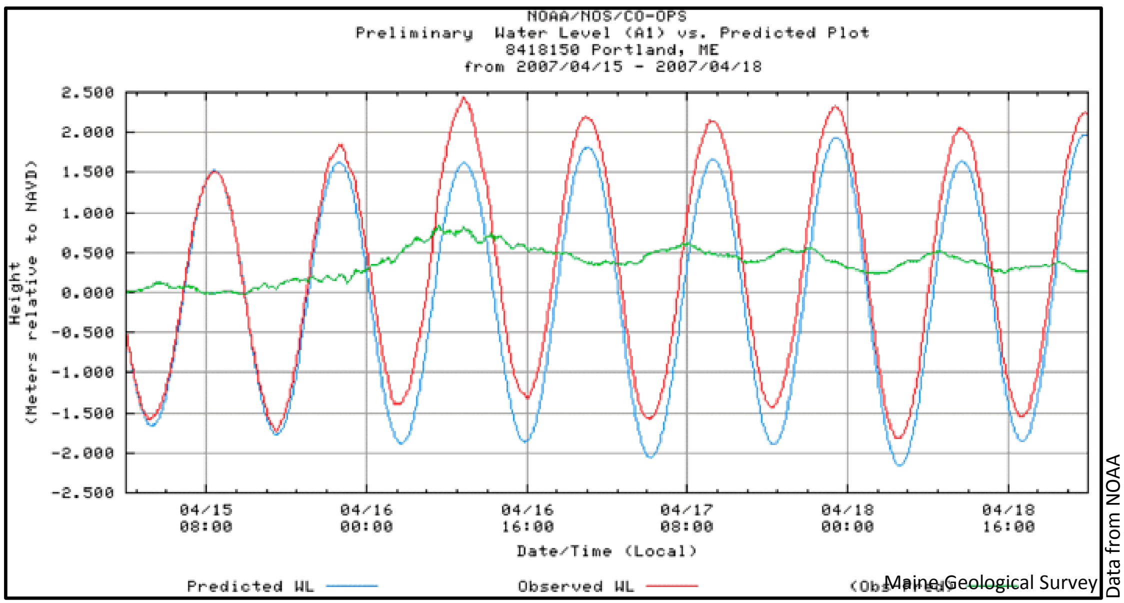


Figure 2. Tide gauge recordings of water levels in Portland Harbor from April 15-18th and shown in meters above the North American Vertical Datum (NAVD). Data recorded at the Portland Tide Gauge (No. 8418150).

Willard Beach

Many beaches along the southern and mid-coast, especially those that face east to northeast, underwent relatively substantial erosion from this storm. One such beach is Willard Beach, a small, crescent-shaped pocket beach located in suburban South Portland.

Willard Beach has been the site of a proactive community-based dune management program. Volunteers participate in monitoring the beach by conducting beach profiles on a monthly basis as part of the State of Maine Beach Profiling Project (SMBPP). A total of six beach profiles are recorded at Willard Beach each month (WI01-WI06). The Maine Geological Survey supplements this beach profile data with alongshore Real Time Kinematic Global Positioning System (RTK-GPS) terrestrial surveys of the edge of vegetation in order to accurately monitor horizontal changes in the dune and beach system.

A pre-storm survey of the vegetation line was completed by MGS on November 3, 2006. Subsequent beach profiles were collected along the beach on November 11, 2006 by the Southern Maine Community College, which participates in the SMBPP volunteer monitoring program.

Beach Profiles

Following the Patriots' Day storm, MGS resurveyed the edge of vegetation on April 19, 2007 in order to calculate the horizontal erosion that occurred along the edge of the dune. This was followed by beach profiling, completed on April 20, 2007, at the six set locations. The results of these observations are shown in Figure 3. Overall, the shoreline erosion or recession was quite even along the length of the frontal dune.

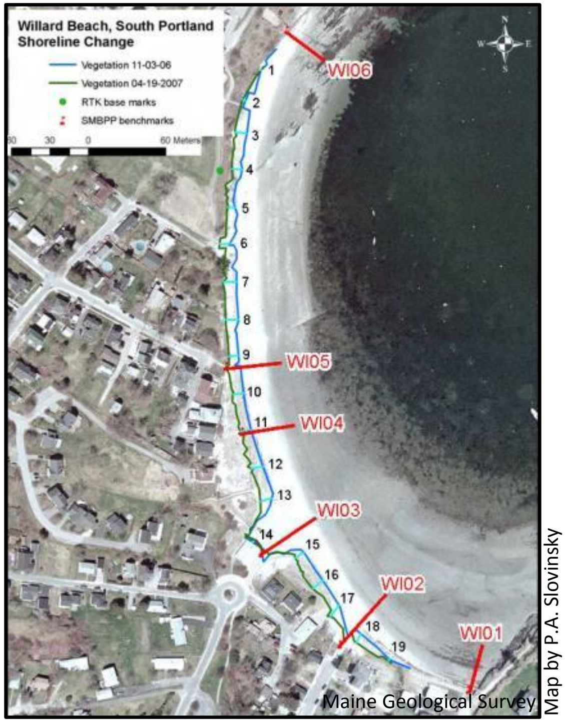
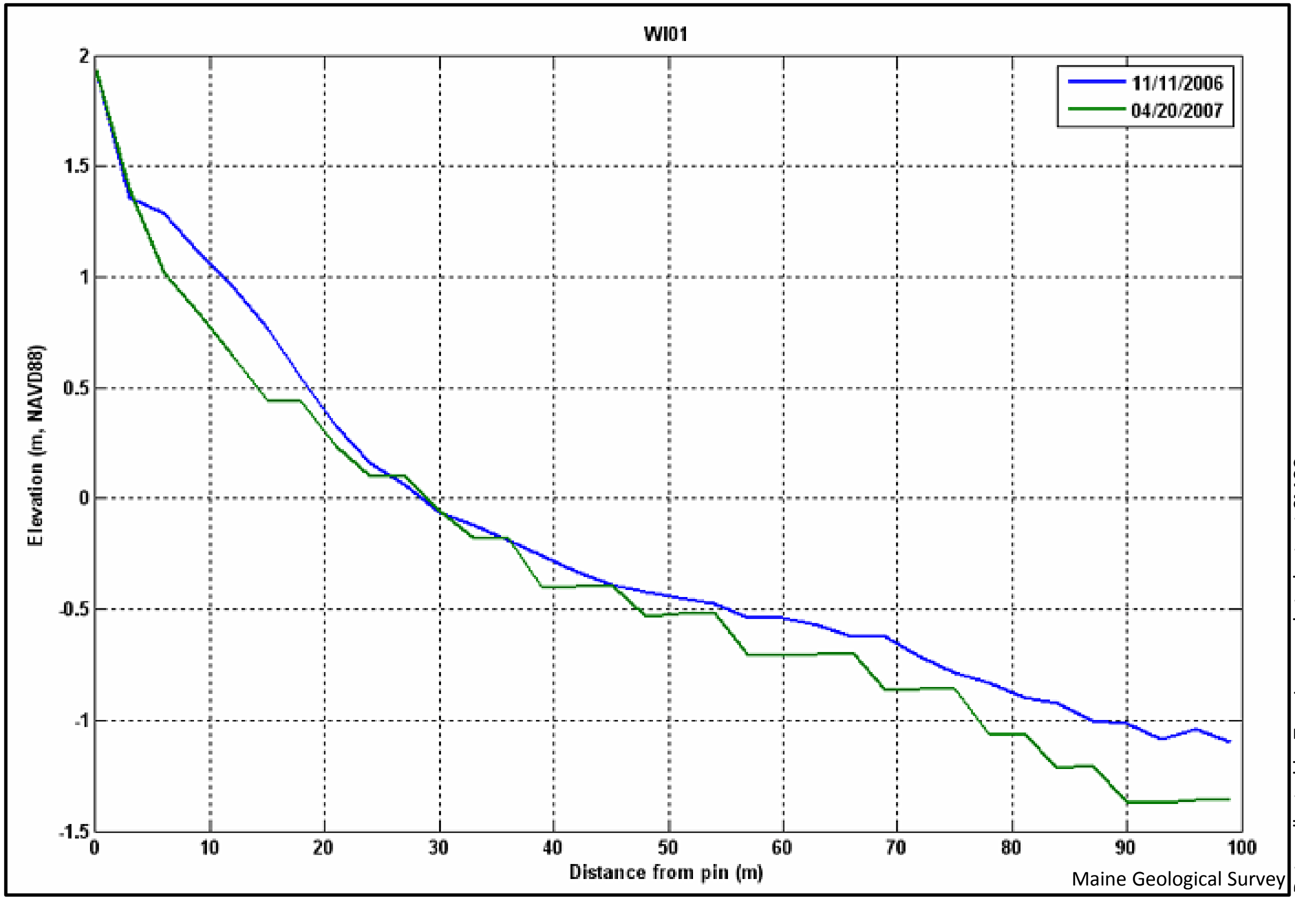


Figure 3. This map shows the shoreline change along the seaward edge of the dunes from November 3, 2006 (blue line) to just after the Patriots' Day Storm on April 19, 2007 (green line). The red lines across the beach show the locations of transects used to measure vertical beach changes each month by Tom Long and a team of students from SMCC.

Beach Profiles

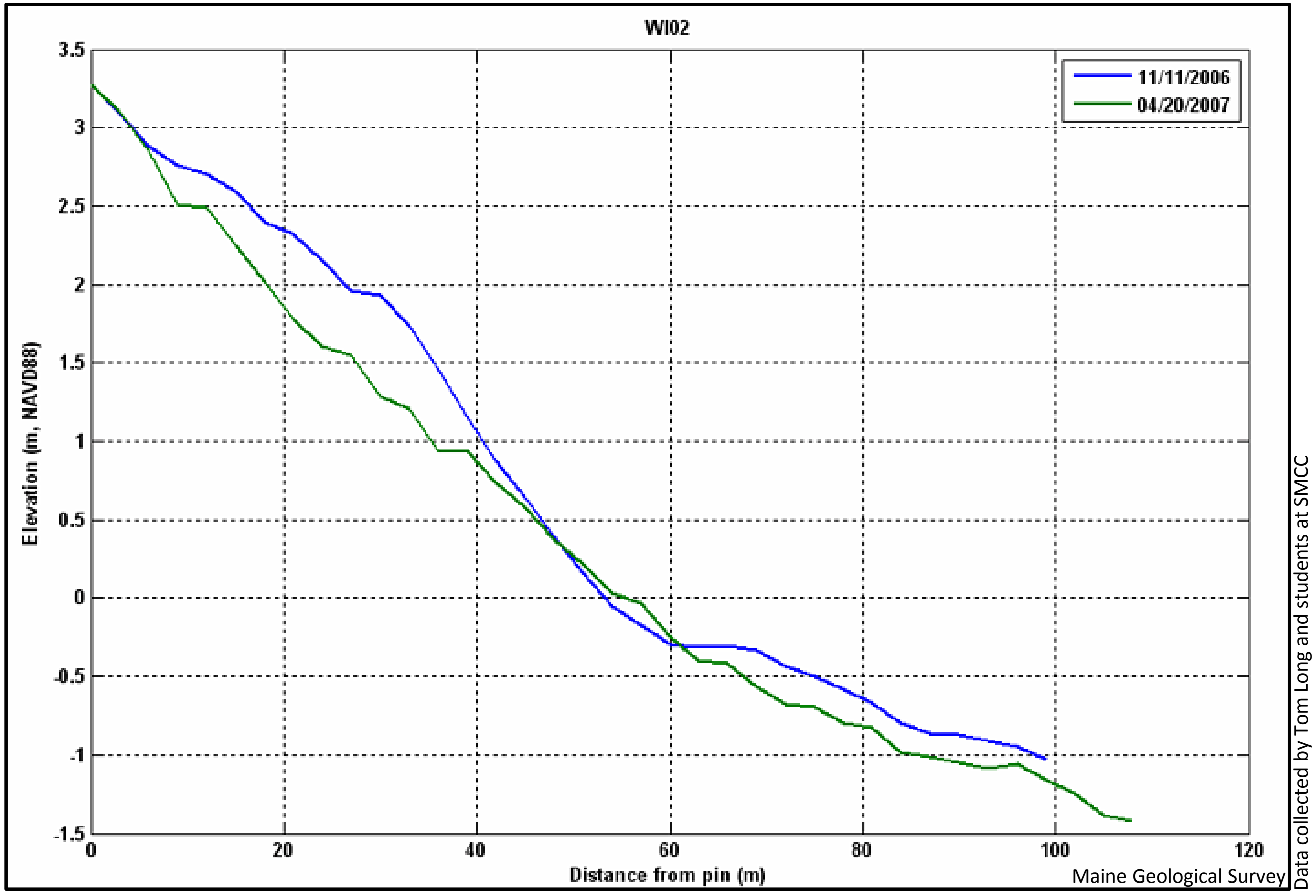
The profile lines indicated on Figure 3 are provided below.



Data collected by Tom Long and students at SMCC

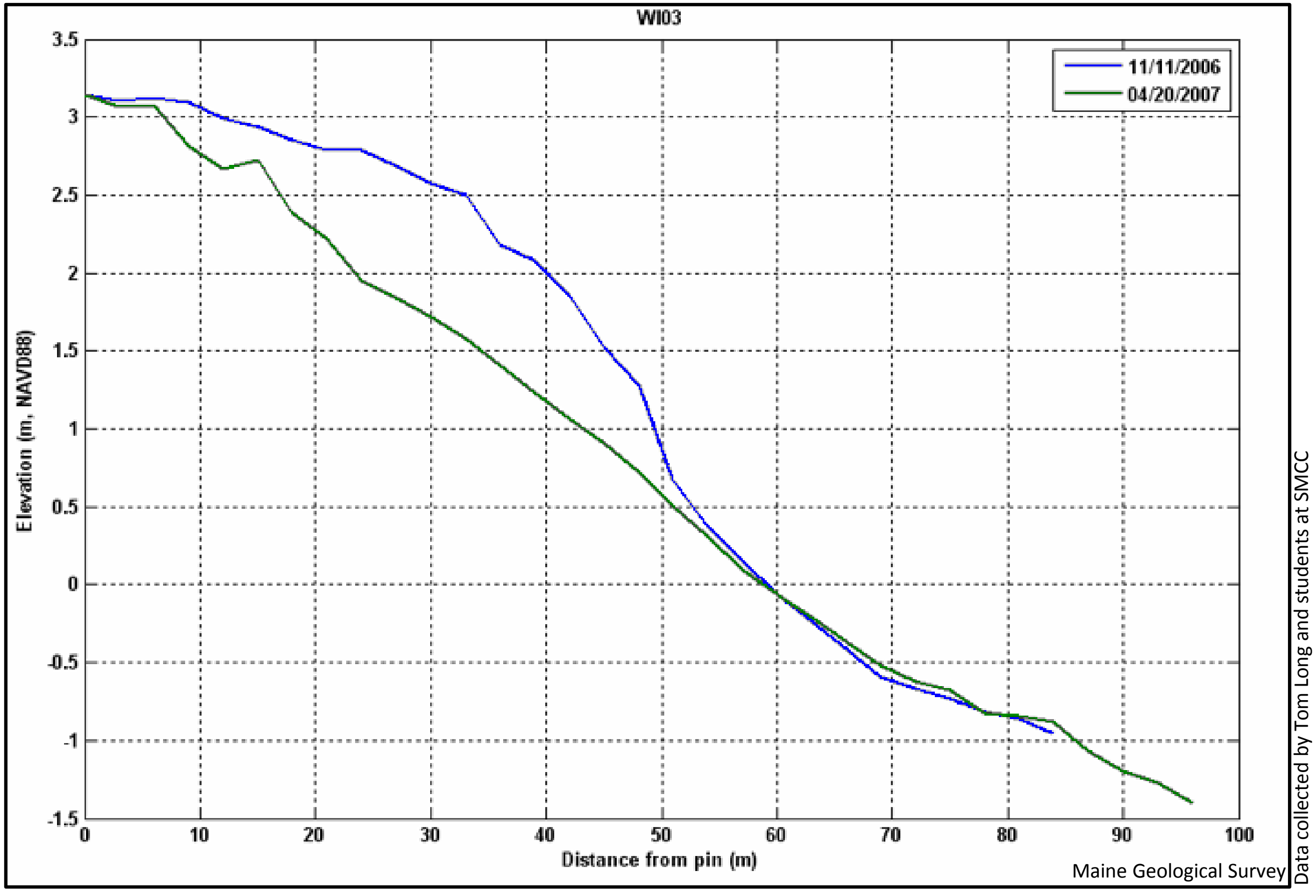
Profile WI01. Beach profiles show the beach lowering from November 11, 2006 (blue line) to April 20, 2007 (green line), just after the Patriots' Day Storm.

Beach Profiles



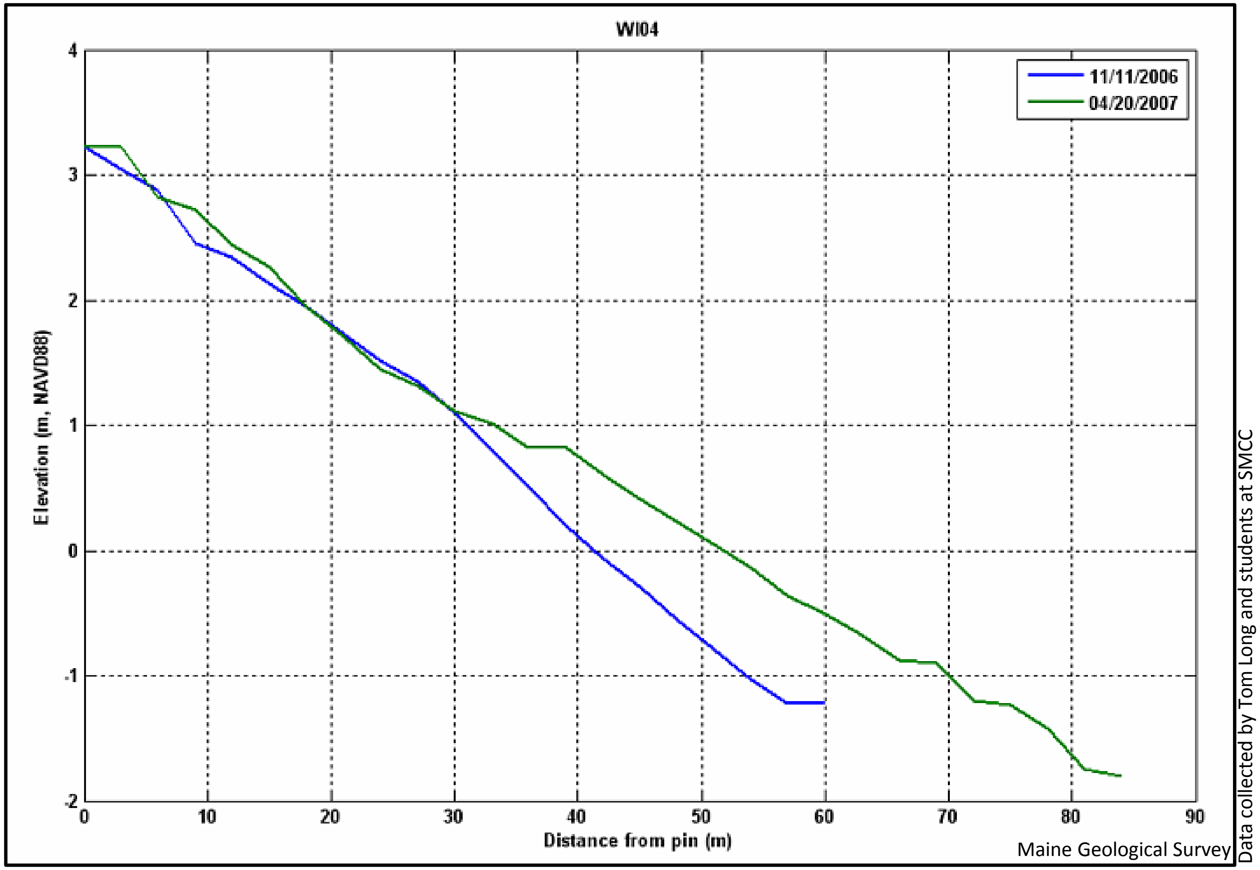
Profile WI02. Beach profiles show the beach lowering for the first 50 meters from the dune from November 11, 2006 (blue line) to April 20, 2007 (green line), just after the Patriots' Day Storm. The profile seaward of 60 meters shows accumulation or net gain in sand over this time period.

Beach Profiles



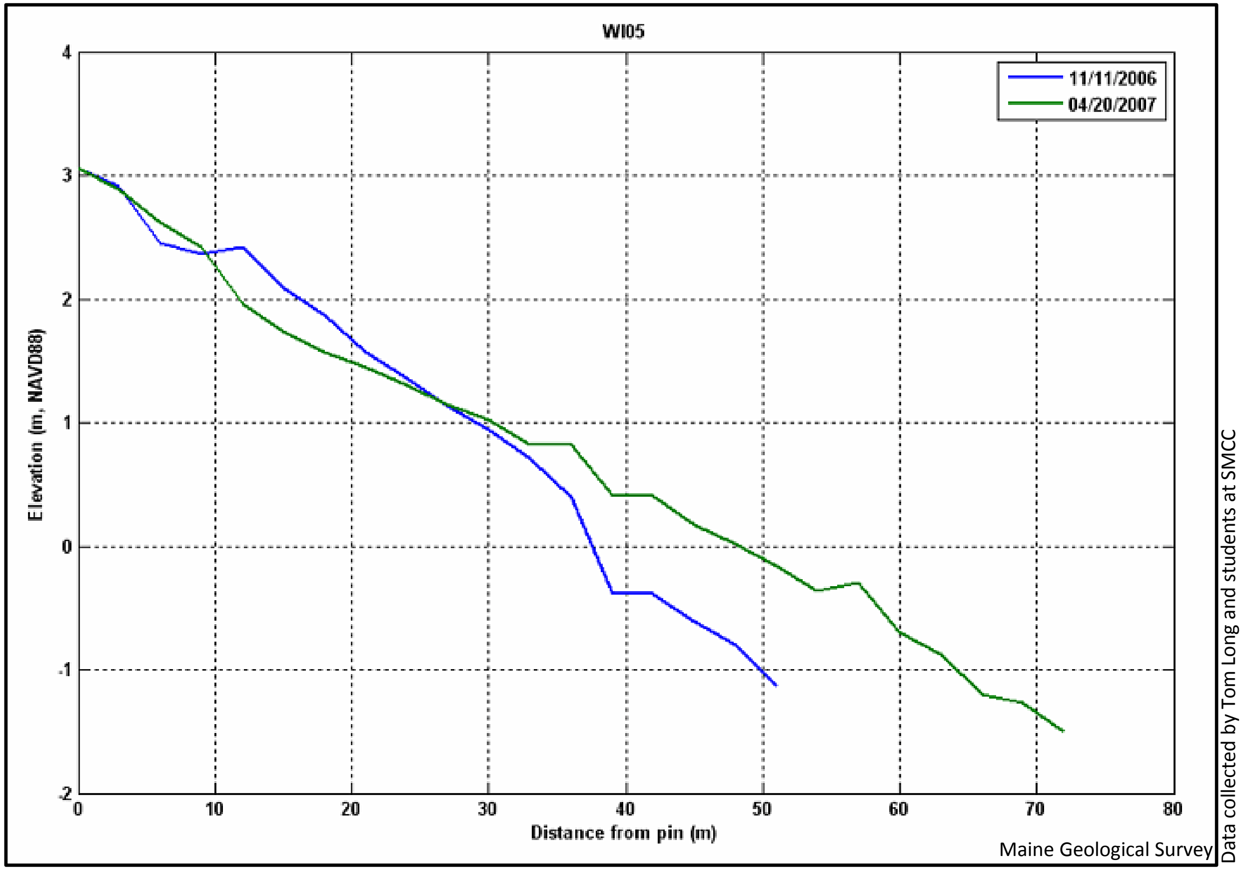
Profile WI03. Beach profiles show the beach lowering considerably over the first 60 meters from November 11, 2006 (blue line) to April 20, 2007 (green line), just after the Patriots' Day Storm. Seaward of 60 meters there is little change in the profile. Note how the storm profile is very linear compared to the concave profile in November.

Beach Profiles



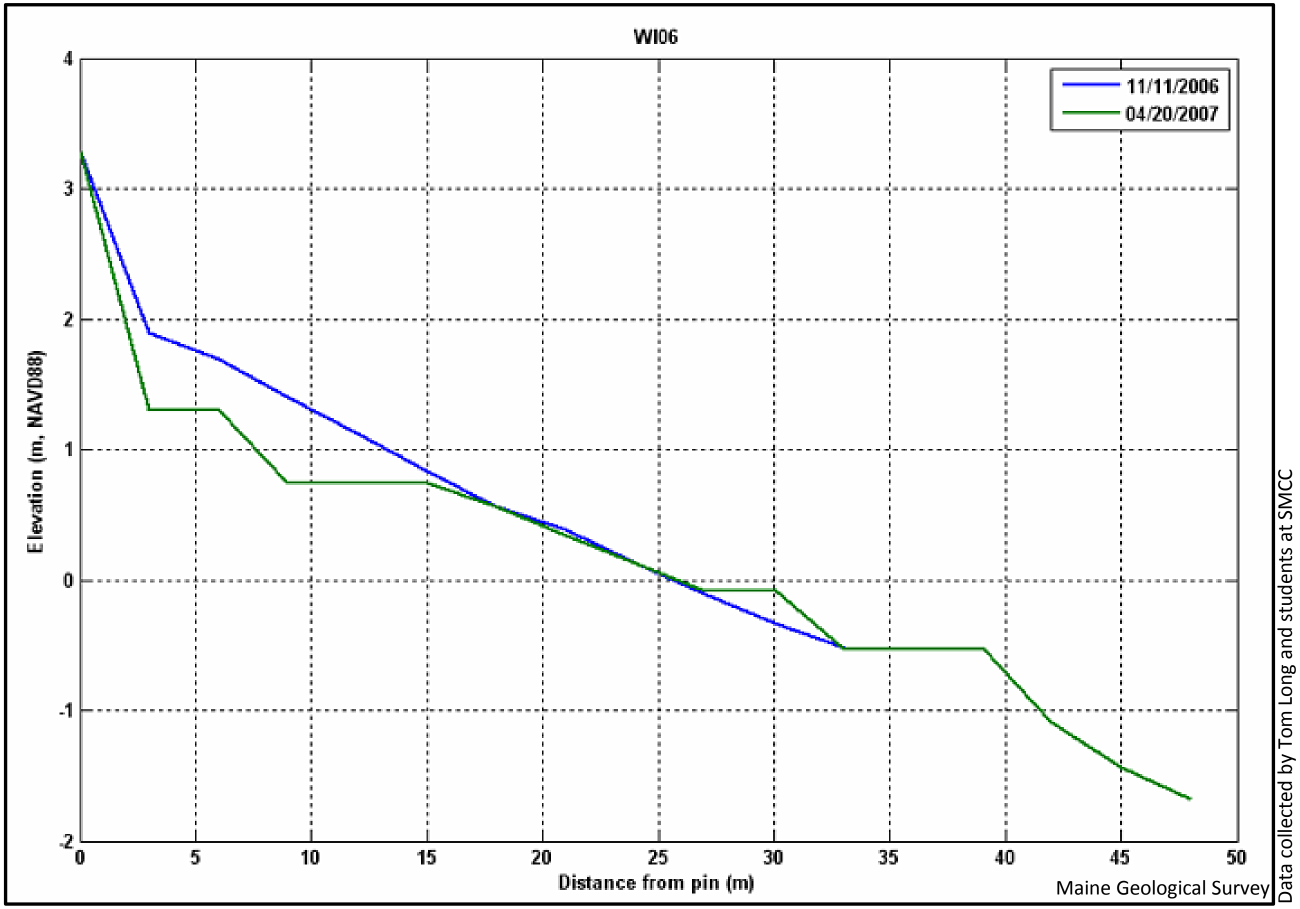
Profile WI04. Beach profiles show the beach not changing much for the first 40 meters on the line from November 11, 2006 (blue line) to April 20, 2007 (green line), just after the Patriots' Day Storm. On the deeper profile beyond 30 meters (or an elevation of 1 m, NAVD) there is a wedge of sand accumulated from the Patriots' Day Storm. In places there is nearly a meter of vertical profile buildup.

Beach Profiles



Profile WI05. Beach profiles show a well-developed berm (flat beach) at 10 m distance on November 11, 2006 (blue line) that is eroded by April 20, 2007 (green line), just after the Patriots' Day Storm. As in Transect 4 (WI04) there is sand build up on the lower profile of nearly a meter (at 50 m distance on the line). Note how linear the profile became after the storm.

Beach Profiles



Profile WI06. Beach profiles show the beach lowering by about a half a meter from November 11, 2006 (blue line) on the first 15 meters by April 20, 2007 (green line), just after the Patriots' Day Storm. The deeper profile position remained essentially the same between the two surveys.

Beach Profiles

Transects were cast at 30 meter (~100-foot) intervals along the beach, resulting in a total of 19 transects (see light blue lines, Figure 3). These transects were used to measure horizontal shoreline change along the beach. Results are shown in Table 1. Up to about 12 meters (~40 feet) of erosion occurred, with the areas of highest erosion between transects 7-13 and 15-17. The averaged erosion that occurred was 7.1 meters or about 23 feet.

Erosion of the Willard Beach frontal dune of 7 to 10 meters (23 to 33 feet) was common in the Patriots' Day Storm. This table shows the erosion distances (measured in meters) at 19 transects spaced about every 30 meters along the beach. The greatest erosion was 11.6 meters (38 feet).

Transect ID	Erosion (m)
1	-0.1
2	-2.5
3	-9.2
4	-8.0
5	-5.8
6	-7.7
7	-10.7
8	-9.9
9	-7.7
10	-8.5
11	-7.9
12	-9.5
13	-9.3
14	1.2
15	-8.5
16	-10.0
17	-11.6
18	-7.9
19	-1.7

Maine Geological Survey

Data collected by Tom Long and students at SMCC

Table 1. Transect data

Beach Profiles

Beach profile changes were determined from the SMBPP collected profiles. The differences between the November 2006 and April 2007 profiles can be interactively viewed by clicking on each beach profile location (WI01-WI06 in Figure 3). With these two data sets, both horizontal and vertical changes can be observed and estimated volumetric changes quantified.

Overall estimated volumetric changes at each beach profile location are shown in Table 2. This volumetric change estimate assumes that the beach profile is representative of a width of only one meter, which allows for the volumetric calculation of cubic meters. It is apparent that accretion actually occurred in the lower portions of the beach profiles at WI04-WI05. This is likely a result of erosion at the upper portion of the profile (the frontal dune), and accretion at the lower portion of the profile in the form of a protective sand bar. Alternatively, sediment eroded from adjacent areas of the beach could be stored within the lower portion of these profiles as it is moved offshore in response to the storm.

Profile	Δ Volume (m^3)
WI01	-4.9
WI02	-1.7
WI03	-9.0
WI04	-7.1
WI05	3.7
WI06	1.9

Maine Geological Survey

Data from SMCC

Table 2. Change in sand volume at each transect

Beach Cells

Based on this analysis and physical characteristics, we can break Willard Beach into three different cells due to littoral barriers (Figure 4). If we then assume that the volumetric changes observed at each beach profile apply to certain distances of beach, we can determine a rough estimate of the volumetric changes that occurred from time 1 (November 2006) to time 2 (April 2007).

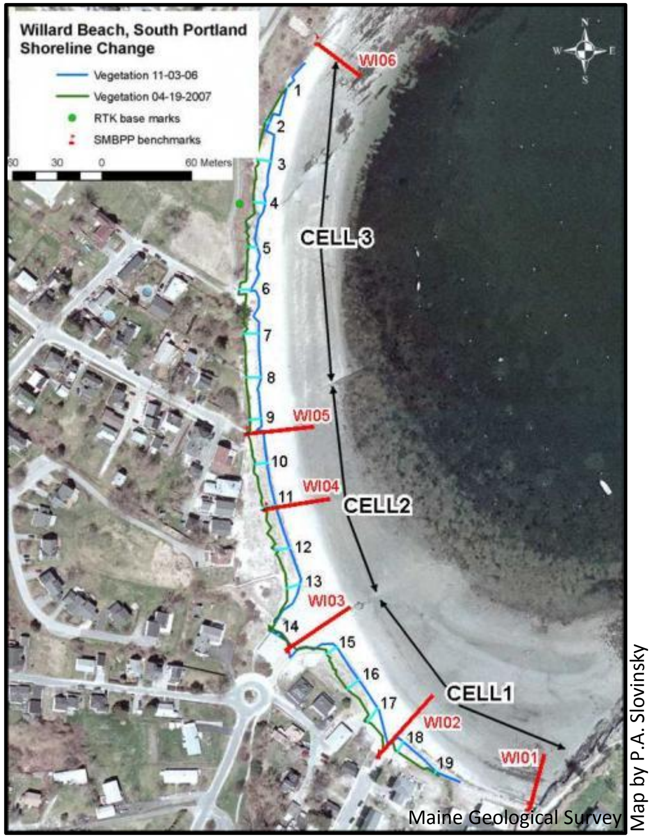


Figure 4. A map similar to that in Figure 3 with the three beach cells illustrated.

Beach Cells

The beach along the southeastern end of Willard Beach - from WI01 to WI03 - is confined by an outfall pipe adjacent to WI03 (Figure 4). Combining this stretch of beach (into Cell 1) provides for an alongshore distance of approximately 220 meters (Figure 4). The averaged volumetric change rate (per meter of beach) is -5.2 m^3. Assuming this change is representative of the 220 meters of beach contained in Cell 1, the overall volumetric change of this section of beach is -1143 m^3. Cell 1 lost a large amount of sediment from within its boundaries.

Profiles WI04-WI05 are located within a separate littoral cell, defined by a pipe that serves as a littoral barrier (Cell 2, Figure 4). This stretch of beach measures approximately 137 m. The averaged volumetric change (per meter of beach) was +5.4 m^3. This cell actually gained approximately +740 m^3 of sediment along the overall recorded profile shape.

Conversely, the final cell (Cell 3, Figure 4), from WI05 northwards to WI06 had an averaged negative volumetric change rate of -1.9 m^3 per meter of beach. The cell measures 250 m in length, and approximately -468 m^3 of material was removed from the beach profile within this cell.

Combining this data, we see a net change of -871 m^3 or -1139 cubic yards of material that was lost from the overall nearshore beach profile along Willard Beach. However, a gain in the beach profile volume occurred within Cell 2, even though the horizontal erosion along the dune appeared to be similar within this cell to the other cells.

Sand Migration

It appears that sediment within Cells 1 and 3 likely migrated towards the central cell - Cell 2 - during the storm event due to longshore currents created by wave attack, which focused on the headlands. This caused sediment to move towards the central cell before it was pulled offshore onto lower portions of the beach profile. Within Cells 1 and 3, sediment was lost from the entire beach profile, and likely migrated both offshore and into the adjacent Cell 2 (Figure 5).

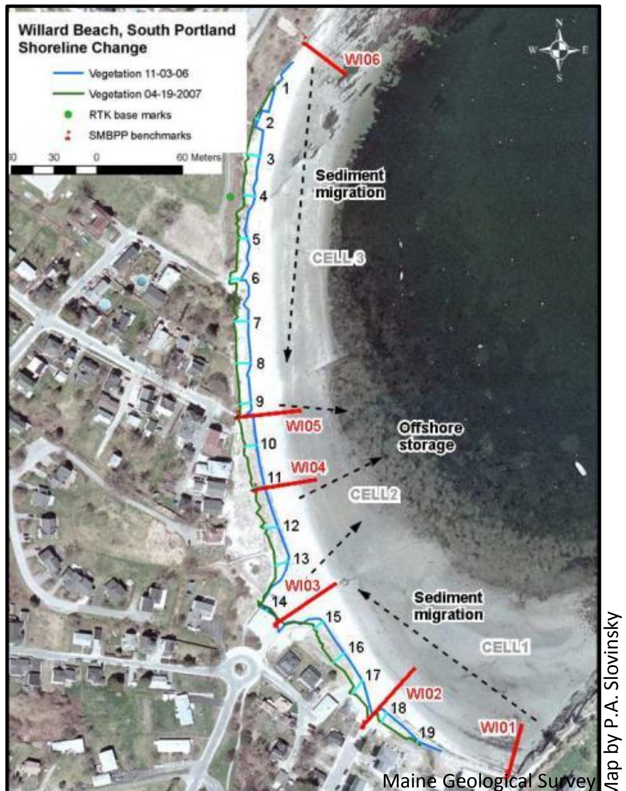


Figure 5. Map of Willard Beach showing the inferred direction of sand movement during the Patriots' Day Storm.

Sand Migration

It can be postulated that wave diffraction (wrapping) around the headland to the south (where the fishing shacks are) resulted in waves coming ashore at the southern end of the beach in Cell 1 and impacting ledge and seawalls with the result being increased scour of the upper profile and sand transport to the north. This accumulation of refracted waves may have resulted in an exiting flow or longshore drift to the north toward Cell 1. At the northern end of Willard Beach, Cell 3 is exposed to more direct wave attack from swells entering from the Portland Ship Channel and outer Casco Bay. The curvature of the shoreline and submerged beach here may have resulted in waves refracting (bending) and pushing a current to the south in the direction of Cell 2. The convergence of these two circulation cells in Cell 2 may have led to sand being swept down the central portion of Willard Beach during the Patriots' Day Storm.

Conclusion

Even though the dunes were eroded up to 30 feet in some areas, the active community dune management program at Willard Beach most likely helped protect many residential structures and public infrastructure from extensive flooding and damage from the Patriots' Day Storm. Sediment was not fully lost from the beach profiles, as evidenced by changes observed at WI04-WI05 within Cell 2.

The response of Willard Beach to the Patriots' Day storm, though it appears dramatic, is a natural seasonal shift of sediment that occurs at many beaches. The shift of sediment offshore during stormy months, followed by the onshore movement of sediment to build back the beach during calmer summer months, is a natural cycle. We expect the beach to begin recovery from this storm, and sand to return to the upper portion of the profiles, over the calmer summer months.

Related Sites

Willard Beach and Dunes - how the Willard dunes were restored over time.

Portland Tide Gauge - more about tides and surges with examples of other storms of record.