Popham Beach, Maine: An example of engineering activity that saved beach property without harming the beach

Joseph T. Kelley

University of Maine, Department of Earth Sciences, Orono, ME 04469-5790, United States

ABSTRACT

Beach and property erosion on coasts is a widespread and chronic problem. Historical approaches to this issue, including seawalls and sand replenishment, are often inappropriate or too expensive. In Maine, seawalls were banned in 1983 and replenishment is too costly to employ. Replacement of storm-damaged buildings is also not allowed, and a precedent case on Popham Beach, Maine required that the owner remove an unpermitted building from a site where an earlier structure was damaged. When the most popular park in Maine, Popham Beach State Park, experienced inlet associated erosion that threatened park infrastructure (a bathhouse), temporary measures were all that the law allowed. Because it was clear that the inlet channel causing the erosion would eventually change course, the state opted to erect a temporary seawall with fallen trees at the site. This may or may not have slowed the erosion temporarily, but reassured the public that "something was being done". Once a storm cut a new tidal inlet channel and closed off the old one, tidal water still entered the former channel and continued to threaten the bathhouse. To ultimately save the property, beach scraping was employed. Sand was scraped from the lower beach to construct a sand berm that deflected the tidal current away from the endangered property. This action created enough time for natural processes to drive the remains of the former spit onto the beach and widen it significantly. Whereas many examples of engineering practices exist that endanger instead of saving beaches, this example is one of an appropriate engineering effort to rescue unwise located beach-front property.

1. Introduction

In recent decades, American society has moved away from arming eroding shorelines with seawalls towards other approaches that impact the shoreline less and, to a degree, mimic natural processes. Although sand replenishment is the most important and widespread alternative to seawalls, it is very costly and temporary (Leonard et al., 1990; Lentz and Hapke, 2011). On a more local scale, efforts to protect beachfront property include beach scraping and temporary protective structures. Beach scraping involves bulldozing sand from the lower to the upper beach (Wells and McNinch, 1991; Kratzmann and Hapke, 2012), but not actually adding new material to the system. Temporary structures vary from Christmas tree mounds, hay bales (O'Connor et al., 2010) to various forms of sand-filled geotubes. The latter are often described as "temporary" and "harmless" protective structures by their advocates, but they act like seawalls in the face of wave attack, and are only temporary because they are ultimately destroyed by storms (McQuarrie and Pilkey, 1998).

Popham Beach, Maine is part of the largest adjoining set of beaches in northern New England (Fig. 1). Sourced by the largest river in Maine, the Kennebec (Fenster et al., 2001), Popham Beach hosts an extremely popular state park alongside a community of 19th century summer vacation cottages. The storms and legal battles that impacted this beach in the 1970s and 1980s led Maine to introduce a sand dune law, the first ordinance in the United States banning seawalls and requiring property owners to remove buildings damaged by more than 50% by storms (Massey, 1984; Kelley et al., 1989; NRPA, 2012). This law withstood a legal challenge all the way to the Maine Supreme Court in the 1980s, which upheld the right of the State to protect its beaches without paying compensation for taking of property.

Recently, apparently natural changes in the location of a small tidal inlet on the southern boundary of the Popham Beach State Park have threatened park infrastructure and challenged the state to abide by its own rules even when they risk significant use of one of its most popular parks. Clearly a large public good exists in maintaining access to a popular state beach, but the example of using banned engineering practices to do so creates a situation that is difficult to reconcile with its past policies.

The history of storms and shoreline changes at Popham Beach, and the subsequent reaction of society to those changes, illuminates the challenges people face in trying to live with natural geomorphic changes and still enjoy coastal lifestyles, which most users expect and some demand. Herein, the geological setting of Popham Beach is described and what is understood of the coastal processes that formed and maintain this popular coastal location. Then the historical context...
for the creation of a “Sand Dune Law” in Maine is presented. This is an unusual law in that it promotes living with rising sea level and natural changes in a state with relatively few beaches and a small population of beach recreationalists. Finally, the recent dilemma that confronted the state is described, as is the novel solution devised to respond to this situation.

2. Geological background and setting

2.1. Location

The coast of Maine is 3478 miles long and is framed by Paleozoic igneous and metamorphic rocks (Osberg et al., 1985). The resulting geologic structure forms four coastal compartments of varying orientation and possessing distinctly different coastal environments (Fig. 1) (Kelley et al., 1995; Kelley, 2004). Cliffs of bedrock dominate much of the coast with sand beaches comprising only 2% of the coast, or about 100 km, the smallest percentage of sandy coastline of any state in the United States (Ringold and Clark, 1980). Many beaches in the state are gravel, with sand beaches only common in the southern region and at the mouth of the largest river in the State, the Kennebec (Fig. 1).

Despite its passive continental margin setting, Maine does not possess Coastal Plain sediments (Cretaceous and younger), a distinctly different setting from most of the US East Coast. Glaciation removed these materials, and left behind numerous outcrops of till. During deglaciation, isostatic depression of the land allowed sea level to drown the coastal region to a depth of about 75 m (Kelley et al., 2010). Glacial-marine, muddy sediment blanketed this area and commonly overlies till and bedrock outcrops in most coastal embayments. Sea level fell to about 60 m below present by 12,500 B.P. and subsequently rose to the present level at an irregular rate (Barnhardt et al., 1997; Kelley et al., 2010). Contemporary sea level has risen about 2 mm/yr since early in the 20th (NOAA, 2012).

Popham Beach is located in the indented shoreline coastal compartment (Figs. 1 and 2), and at the end of a 20 km-long peninsula. The adjacent Kennebec River is the largest in Maine with a mean annual discharge of 280 m$^3$/s (Fenster et al., 2001). Tides in the study area are semidiurnal and have a 2.6 m mean range. Winds are dominantly from the north-northwest in fall and winter, but summer swells and wind are from the southeast–southwest. Because of the sheltering effects of nearby shoals and islands, typical waves reaching the beach are less than 0.6 m (FitzGerald et al., 2000). Extratropical storms occur several times each winter, with the largest storm waves from the northeast and east (Hill et al., 2004) and capable of developing 3 m waves at the beach (FitzGerald et al., 2000).

2.2. Regional sand budget

At its mouth, the narrow, bedrock confined channel of the Kennebec River may occupy a new post-glacial location as a result of glacial drainage pattern derangement. During spring freshets, the river drives its salt wedge onto the inner continental shelf and actively exports sand and mud (Fenster et al., 2001). When sand exits the river mouth, some travels directly seaward onto the inner shelf, whereas some sand and water diverges and follows a path between Pond and Wood Islands (Figs. 2 and 3) (FitzGerald et al., 2000). This sand encounters incoming waves, leading to deposition of a large bar (outer bar) seaward of Hunnewell Beach between Wood Island and Fox Island (Fig. 2).

Whereas sand is exported by the Kennebec River, the volume of this sand contribution is not known (Fenster et al., 2001). In addition, a sand and gravel deposit exists seaward of the river mouth, and extends to the lowstand position of sea level, about 10 km from the
modern coast (Barnhardt et al., 1997; Kelley et al., 2003). This "paleodelta" deposit includes $>330 \times 10^9$ m$^3$ of sand (Kelley et al., 2003), some of which is presumed to reach the coast and beaches to the north and south of Popham (Reid Beach and Seawall Beach, respectively), although no sand budget has ever detailed the relative contributions. Whereas the sand on Popham Beach is likely sourced from the modern Kennebec River and its offshore lowstand paleodelta, sand may spend time in several other local reservoirs either before or after deposition on the beach. Pond Island Shoal contains a very large amount of sand, probably mostly derived from the Kennebec River. Between Pond and Fox Islands, an "outer bar" deposit occurs where ocean waves regularly break (Fig. 2) (FitzGerald et al., 2000). Sand from this bar feeds into smaller bar complexes that ultimately weld to Hunnewell and Popham Beaches. Significant amounts of sand also occur on the extension of Hunnewell Beach alongside the Kennebec River and extend seaward as an intertidal tombolo to Wood Island (Fig. 2). Another prominent tombolo connects to Fox Island. To the west of Fox Island, the shifting ebb tidal delta of the Morse River comprises another sand reservoir for the system. Finally, still farther to the west, Seawall Beach represents a distinct sand system, but one that is connected to Popham Beach despite the intervening rock islands and shoals (Fig. 2). Though the past few decades of research have slowly

Fig. 2. Detailed map of Popham Beach with place names mentioned in the text (modified from Fenster and FitzGerald, 1996).

Fig. 3. Shoreline changes and inferred nearshore circulation (arrows) at the mouth of the Kennebec River (modified from FitzGerald et al., 2000). The site of the Hall property is indicated by a circle.
documented these connections (FitzGerald et al., 2000; Fenster et al., 2001; Buynevich and FitzGerald, 2003), no sand budget has been developed to quantitatively link these reservoirs through temporally and spatially variable nearshore processes.

3. Results

3.1. Shoreline changes at Popham Beach

Owing to the complexity of its sand sources and reservoirs, the shorelines of the Popham Beach region have changed dramatically over time (Fig. 3) (Nelson, 1979). In one of the earliest well surveyed maps available (1856), the shoreline at Hunnewell Beach is shown in an extreme landward position, whereas the shoreline at what is now the State Park is much farther to the sea. By 1942, Hunnewell Beach had accreted significantly, although there was a small recession at the State Park location. In 1953, the State Park beach had eroded dramatically, including loss of part of the maritime forest, along with less erosion at Hunnewell Beach. For many years after 1953, the erosion of the maritime forest at the State Park and subsequent growth of sand dunes were important landmarks in the history of shoreline change in the park (Fig. 4) (Nelson, 1979). By the late 1970s, Hunnewell Beach had gone into another significant recessionary phase, despite beach growth at the State Park. Both areas experienced sand accretion into the 1990s (Figs. 3 and 4).

Smaller changes also occurred on Seawall Beach and along the beach flanking the Kennebec River, but were generally not as dramatic. Some of the shoreline changes along stretches of Popham Beach appear directly related to changes in adjacent areas. Most striking are the inverse accretion/erosion phases at Hunnewell and State Park Beaches (Goldschmidt et al., 1991). All the beaches in the area change on a multi-decadal time frame, but not perfectly synchronously in terms of erosion/accretion (FitzGerald et al., 2000). One amplifier of shoreline change in the system is the Morse River ebb tidal delta. This undeveloped inlet is controlled by the shifting location of its main ebb channel over time. When the channel debouches into the sea in a more westerly position (towards Seawall Beach), sand accretes at the State Park. When the channel migrates to the east, it erodes into the State Park maritime forest, although accompanying changes in Seawall or Hunnewell Beaches do not always occur. Hunnewell Beach is most impacted by the welding of sand bars, with up to 200,000 m$^3$ of sand derived from the outer bar (Fig. 3) (FitzGerald et al., 2000).

3.2. Societal response to Popham Beach shoreline changes

By the time of the erosional phase of Hunnewell Beach in the 1970s, many private cottages were built (Fig. 5A). Some were protected by a seawall, but that structure engendered local opposition because it projected out onto the beach at high tide and prevented passage by strollers on the beach. In the middle 1970s, storms threatened and destroyed 15 properties (4 others were moved) at Hunnewell Beach (Fig. 5A), and led to a public discussion on shoreline armoring (Austin, 1976; Barringer and Ten Broeck, 1978). The State of Maine took a strong position to oppose seawalls at Hunnewell Beach because they were viewed as a possible threat to the State Park beach. As a result, many of the properties at Hunnewell were destroyed or moved (Massey, 1984).

In the winter of 1978, Maine experienced several large storms, including the “storm of record” on February 8, and recorded $47 million in property damage along its shoreline. A visiting panel of experts pointed out that seawalls did not save many of the properties “protected” by these structures, although the walls did interfere with public recreation (Barringer and Ten Broeck, 1978). The walls were overtopped, knocked down or undercut at the time they were most needed. They ridiculed the value of seawalls to protect property, and in 1979, the Maine Legislature passed a law precluding construction that “unreasonably interfered with the storage or movement of sand” on beaches (Public Law, 1979). They also precluded building structures that were “unreasonable flood hazards” to themselves or their neighbors. Though this law seemed strong, “unreasonable” was not defined, and houses and seawalls continued to be built on the coast.

In 1983, the State developed a set of standards to define what was unreasonable. Among other practices, those rules precluded the building of seawalls, because they interfered with the storage and movement of sand. The rules also precluded rebuilding houses destroyed by 50% or more by a coastal storm as flood hazards to themselves. One of the first cases that involved the new “sand dune rules” to go to court was from Popham Beach (Massey, 1984).

The Hall family, whose house on Hunnewell Beach was destroyed in the 1970s, sought an after-the-fact permit in 1983 for a cottage they had just constructed without a permit (Fig. 5B). They had lived

![Aerial view of Popham Beach State Park in September, 1995. The striking boundary between the sand dunes and maritime forest is stippled. This was the location of the 1953 shoreline.](image-url)
seasonally in a trailer on the site since the destruction of their house, and built the new structure on the ruins of the old (Fig. 5C), less than 10 m from the high water line. In hearings before the Maine Board of Environmental Protection (BEP) (the environmental jury of the State for such disputes), the Hall’s geological consultant argued that the beach had periodically eroded and accreted, and that it was presently entering an accretional phase that would last another century. The State argued that past changes were episodic, not periodic, and unpredictable. The proximity of the new cottage to the high tide line indicated that another single storm could destroy the building (Fig. 5B). The Halls were initially denied a permit by the BEP, and instructed to demolish the house. They sued to the Maine Supreme Court, claiming their property was “taken” without fair compensation, but were denied again, and compelled to tear down the house (Massey, 1984; Kelley et al., 1989).

Following this precedent, hundreds of other permits to build in frontal dune areas were also denied. It became the policy of the State to retreat from hazards posed by coastal storms and rising sea level (Kelley et al., 1989). Because this policy originated in the Maine Geological Survey and Bureau of Parks and Recreation, each of which was located in the Maine Department of Conservation, it became strongly associated with that department of state government.

3.3. Twenty-first century erosion of the State Park

Since 1953, the Morse River ebb channel stayed west of the State Park maritime forest (Fig. 4). In the late 1990s the channel, which is constricted by bedrock at its throat, made a right angle turn toward the northeast, but then veered to the southeast, avoiding the park (Fig. 6A). The second turn appears to have been influenced by the

Fig. 5. Hunnewell Beach and the site of the Hall cottage: A) a 1976 photo from the Maine Geological Survey shows many houses on Hunnewell Beach as they neared destruction. The Hall cottage is just beyond the seawall to the left; B) the new Hall cottage in May, 1983 rests on an eroded dune scarp less than 10 m from the high water mark. The low-tide terrace is visible in the foreground; C) the new Hall cottage in May, 1984 is seen next to the ruins of the former house.

Fig. 6. GoogleEarth images of Popham Beach: A) 1997, note that arrow points to view from Fig. 7B; C) 2003, note arrow points to new channel; C).
presence of a 50 cm thick peat deposit that resisted erosion on the east bank of the channel (Fig. 7A). Significant sand bars blocked a shorter, more southerly path of the channel to the sea.

In 2003, a new branch of the Morse River ebb channel bypassed or cut through the peat deposit and began cutting into the State Park dune field (Fig. 6B, arrow). This was a new path that offered little resistance to the stream. By 2007 (Fig. 6C), this new channel had completely eroded the western dune field of the State Park (>150 m wide) and was removing the edge of the maritime forest. This erosion was apparently without precedent and certainly exceeded the 1953 erosion limit. This new pathway was abetted by reorganization of the sand bars of the ebb tidal delta into a new 0.4 km-long subaerial spit attached to a 0.4 km-long submerged component growing eastward from Seawall Beach. This spit blocked the tidal creek from a shorter path to the sea and directed it towards the State Park beach and Fox Island tombolo.

In the spring of 2009, the Maine Parks and Recreation Department began to build a bathhouse on the southwest corner of the parking lot at Popham Beach (Fig. 8A, circle) (Dickson, 2010). Convenience clearly dictated this unfortunate decision, though the on-going erosion was without historical precedent. Earlier views from the 1953 shoreline scarp created undeserved confidence that the wide dune field would protect the structure (Fig. 7B). As the dune erosion approached the new bathhouse (Fig. 7C), an effort was made to get permission from the owner/manager of the Seawall Beach spit to bring equipment over to breach the spit. This was of no avail, as Seawall Beach was privately managed on the principle of no artificial interference in the undeveloped beach. In a desperate effort to save the bathhouse in December, 2009, the Parks Department roped many of the fallen Pitch Pine (Pinus rigida) trees together and secured them to standing trees on the top of the dune as a “treewall” (Fig. 9A) (Dickson, 2010). This is legal under the current sand dune regulations in Maine as a temporary structure. In this configuration, the bundle of trees dissipated wave and current energy in an attempt to reduce the rate of dune erosion.

In March 2010, a late winter northeast storm finally broke through the Seawall Beach spit and created a channel more than 100 m wide (Fig. 8A) (Dickson, 2011). This new channel provided a more efficient route to the sea than the channel eroding the park bathhouse area. Although the old channel past the eroding State Park beach still existed, it was reasonable to assume that it would close as the new barrier island migrated into its location (Dickson, 2011). A smaller spit was similarly breached in 1986, and the resulting sand bar migrated onshore and contributed up to 100,000 m³ to the State Park beach (Goldschmidt et al., 1991).

Fig. 7. Photographs of the erosion site: A) Morse River channel looking northwest. Arrows point to the peat outcrop that resisted erosion by the channel; B) View from near the present bathhouse, October, 1995, showing the extent of dunes. The near island is Fox Island, the distant one is Sequin Island. Arrow in Fig. 6A shows the direction of view; C) Photograph from same approximate position as Fig. 7B. Taken in December, 2010, it shows the extent of erosion of the dunes.

Fig. 8. GoogleEarth images of Popham Beach: A) 2010; B) 2011. Circled area near parking lot marks the location of the bathhouse. 1 locates the areas or fill used to block off the old channel; 2 marks the site where a new opening to the channel was carved and the location from which Fig. 9B was taken.
During 2011, the new Morse River channel sealed off the former channel past the park, and significant amounts of sand began to fill the channel (Fig. 8B). The eastern mouth of the old channel remained open, however, and continued to experience tidal exchange. Unfortunately for the State Park infrastructure, the old channel made a sharp bend in front of the bathhouse and the cut bank of the tidal channel continued to erode in the direction of the bathhouse. By the fall of 2011, the bathhouse was less than 10 m from the tidal channel, and it was clear that erosion would claim it in the coming winter (Dickson, 2012).

To rescue the building, the Parks and Recreation Department obtained a permit to scrape the beach in front of the bathhouse to protect the structure. Although beach scraping is very uncommon in Maine, it is allowed because it does not involve removing sand from the beach system. In December 2011, construction equipment scraped sand from the spit to cut a new opening for the lagoon that formed in the old channel and to create an artificial sand barrier that deflected the tidal channel that threatened the bathhouse (Figs. 9A, B and 10) and (Fig. 9B). In all, about 10,000 m³ of sand were moved, including sand banked up against the bathhouse (Dickson, 2012). With the former channel of the Morse River contained, it now appears that the large sand bar will continue to migrate onto the beach.

4. Discussion

Historically, one of the first actions of property owners experiencing beach erosion was to erect a seawall (Nordstrom, 2000). Developed beaches in Maine were lined with seawalls. With time, the public became aware of the access and other issues created by seawalls, and the 1978 storm demonstrated that seawalls were generally ineffective when most needed. At Hunnewell Beach, the removal of buildings, either damaged by a storm or at risk for damage, was a rallying call for the banning of seawalls in the state (Austin, 1976).

The state construction of a bathhouse at Popham Beach State Park was permitted because it was in a back dune setting and, possibly when planned, a great distance from the sea (Figs. 4 and 7B). The rapidity of shoreline change in the park was surprising, despite the rapid shoreline changes observed in the past. The Hall cottage, which was removed because of a perceived threat of erosion in the 1980s (Fig. 5B), later experienced extreme accretion (Fig. 9C), although the State did not relax its standards on reconstruction. That site is once again eroding and the Hall cottage would be at risk once again had it been allowed to remain. Thus, when State property was in danger because of shoreline changes at Popham Beach, precedents from past decisions, as well as the existing ban on seawalls, required an examination of how to cope with beach erosion in a benign manner.

The original response, to breach the Seawall Beach spit as it was still forming, proved impossible not because of the law, but for lack of...
of permission from the owner. Once a storm provided a new channel for the Morse River, it appeared that the threat to the bathing house was over. The continuing tidal action in the former channel and its geomorphology, which focused currents on the area of the bathhouse, however, posed a new surprise that required immediate action. When the State developed its sand dune law, homeowners won permission to perform actions on beaches that were temporary, hence “reasonable”. In southern Maine at Camp Ellis Beach, the erection of geotubes and Jersey Barriers (movable concrete walls) on an eroding beach is allowed because the Army Corps of Engineers is developing a long-term plan to inhibit the erosion there (Kean and Svetlichny, 1982). If beach scraping has ever previously occurred in Maine, it was a rare event. By steepening the local beach face, beach scraping can lead to rapid removal of the moved sand (Wells and McNinch, 1991) through wave or eolian processes. Beach scraping does offer temporary relief in the face of a pending erosional event (typically a storm). It is not considered a solution to an erosion problem, simply an interim measure that provides more time for natural processes or people to act. In this regard, scraping sand to erect a barrier to divert the tidal creek from away from the bathhouse was acknowledged as temporary, but it allowed enough time for the sand on the remainder of the tidal delta to weld to the beach and alleviate the problem. In this regard, it provided a unique solution to an unusual problem.

At Popham Beach, the use of wood derived from erosion of the maritime forest to construct a wall was clearly a temporary action. Qualitative observations suggest that the retreat of the dunes behind the trees was similar to that at either end of the wall (Fig. 9A), but it was psychologically reassuring for the State to do something. This is similar to the placement of hay bales in front of eroding dunes on Five Finger Strand, Republic of Ireland. They had little physical influence, but appear to have calmed the public and helped preclude a more rash effort to construct a stone wall (O’Connor et al., 2010). In the end, the beach scraping that diverted the channel away from the bathhouse saved the day. Although a temporary solution, it may be decades before erosion again threatens the bathhouse and allowed the state to set a good example of complying with its own rules.

Few beach-erosion problems are temporary, but some are. In this example from Maine, use of the temporary solutions of beach scraping and biological barriers proved useful to save public property without resorting to permanent armor or costly replenishment. In a sense this was an example of “working with natural processes” (Cooper and McKenna, 2008), because local sand was used to divert a tidal creek away from a structure of interest to the State.

5. Conclusions

Beach scraping can be an effective and appropriate tool to combat temporary beach erosion, but only when it addresses the primary reason for the erosion. The total volume of sand on the beach is not affected, and natural processes are free to act on the material after the action is taken. Use of eroded trees was less effective as a temporary method to reduce the rate of erosion than as a mechanism to retain calmness in a difficult situation. The use of naturally produced material to provide protection for a threatened area also provides landowners the satisfaction of taking action to address a problem.

References


