Managing sea level rise on shore and beaches

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This paper aims to help coastal policy makers understand global, here referred to as "eustatic," sea level change over the next century. Although sea level has been rising gradually for more than the past 1,000 years, the rate of sea level rise appears likely to increase over the next century. This paper puts sea level rise in context with other factors influencing coastal change and sets forth the American Shore and Beach Protection Association (ASBPA) position for managing shores and beaches. We conclude that beach nourishment remains the most effective and environmentally sound method for maintaining America's coasts in the face of rising sea levels over the next century.

There are wide differences of opinion among scientists regarding the rate of eustatic sea-level rise expected for the 21st century (Table 1). Sea-level rise projections should be placed in the context that: (1) the scientific community has only presented a range of scenarios and has not agreed on specific numbers, and (2) relative sea levels will certainly rise (or even fall) at different rates in different areas depending on other factors not related to eustatic rise and global warming.

Table 1. Sea Level Rise Projections During the 21st Century (i.e., by 2100)

Minimum	Maximum	Citation
0.18 m (0.59 ft)	0.59 m (1.94 ft)	IPCC, 2007[1]
0.18 m (0.59 ft)	0.82 m (2.69 ft)	Houston, in press[2]
0.28 m (0.92 ft)	0.34 m (1.12 ft)	Church and White, 2006[3]
0.45 m (1.49 ft)	1.42 m (4.67 ft)	USACE, 2011[4]
0.50 m (1.64 ft)	2.0 m (6.56 ft)	Nicholls et al., 2011[5]
0.50 m (1.64 ft)	1.4 m (4.59 ft)	Rahmstorf, 2007[6]
0.50 m (1.64 ft)	1.4 m (4.59 ft)	NRC, 2012[7]
0.56 m (1.84 ft)	2.0 m (6.56 ft)	NRC, 2010[8]
1.01 m (3.33 ft)	1.4 m (4.59 ft)	California Ocean Protection Council, 2011[9]

The values in Table 1 represent the total estimated rise by 2100. The annual predicted rate may be a more meaningful value to the average person. Using an estimate of 1 meter (m) of rise by 2100, the annual rate of sea level rise would be just a little more than the thickness of 3 stacked nickels a year.[10]

Finding 1. *The scientific community has presented a range of scenarios from which they have projected rates of eustatic sea level rise expected for the 21st century.*

The rate of SLR differs from place to place because of differences in land subsidence (or emergence) and other relatively minor factors. Coasts composed of recently-deposited muddy sediments, such as Louisiana, have subsidence rates many times higher than the global rate of

SLR. Parts of Alaska, Washington and northern California[11] [12] are emerging due to tectonic activity and glacial rebound and local sea level is actually falling. Therefore, relative sea level rise (RSLR) influences the position of the coast at a given location.

Finding 2. *The response of beaches to continued or accelerated SLR will not be uniform from place to place.*

The processes which mold and shape a particular segment of coast are site-specific. RSLR is the principal controlling factor of shoreline change along the few coasts that are inherently stable – neither gaining nor losing sand over time. As sea level rises, the beach is inundated and the shoreline moves inland. However, RSLR is not the principal controlling factor of shoreline change along most beaches, because few have a perfect balance of sand entering and leaving the system. Storm waves and currents can transport sand from one section of beach and deposit it along another segment. Inlets, harbors, and jetties may capture and hold sand, changing the quantity remaining on adjacent beaches from year to year. Typically, in project-influenced areas, the impact of site-specific processes dwarfs the impact of RSLR.

Finding 3. *Most beaches are not inherently stable and site-specific factors have more influence on their erosion rate than RSLR.*

A suite of tools exists to protect beaches and shores from coastal erosion. The management alternatives may include coastal structures, retreat, sand bypassing and beach nourishment using sand obtained from adjacent inlets, offshore or upland locations. For moderately eroding shorelines, the ASBPA and scores of local communities across America have found beach nourishment – the placement of sand onto the beach from a source outside the eroding area – to be an appropriate solution.

ASBPA advocates that in many areas, beach nourishment is the most cost effective and environmentally acceptable approach to providing a buffer against the sea while maintaining (or improving) the environmental value of the beach in an aesthetically-pleasing way. Every nourishment project is designed to include a significant amount of sacrificial sand. This sand is replaced at intervals of time as beaches are "renourished," or replenished with additional sand that may have eroded during the preceding interval. This "sacrificial" sand flows to and benefits adjacent beaches, while some sand remains in the nearshore zone. The renourishment interval can be 2, 5, 7, or in some cases 10 years or more depending upon the dynamics of a particular beach. Considering the simplified annual rate of eustatic sea-level rise of 3 stacked nickels[9], it is clear that, for many U.S. sites with low to moderate rates of RSLR, sea level change will not overwhelm any particular nourishment project before its next scheduled infusion of sand. As a result of an effective nourishment program, the Florida shoreline has not experienced net erosion despite the rise in sea level over more than the past 100 years[13].

Beaches respond to RSLR by increasing the elevation of the beach that lies above the high water mark (called the "berm"), which is constructed by tides and waves. With a slow rate of RSLR and a sufficient supply of beach sand, beaches can naturally "keep pace" with rising water levels and naturally increase the berm elevation. Often, there is a reservoir of sand at the back of the beach to make up for any beach consumed by the rising ocean. Therefore, if the sea level rises, so will the beach berm by the same amount. The position of the shoreline, however, will move landward unless it is renourished with additional sand[14]. In other words, for every unit rise in sea level, there is a corresponding increase in beach elevation and retreat in shoreline position. There is a volume of sand associated with this retreat that can be added to the beach proactively via beach nourishment[15], which is typically a small contribution (<10%) of the overall volumetric need. The concept assumes that the shoreline position can be maintained as the sea slowly rises.

Finding 4. *Beach nourishment is an effective method for maintaining shoreline position in areas with low to moderate erosion rates and keeping pace with accelerated SLR over the next century*.

The alternatives to nourishment in response to this gradual RSLR are building coastal structures to protect infrastructure or retreat – relocation to allow the beach to move inland. Coastal structures are usually more expensive, usually decrease aesthetics and, if not combined with nourishment, impinge on the sandy beach. Rather, the intersection between land and sea can become hardened with rock, steel or concrete rather than sand. Hardened beaches do not provide as many environmental and ecological benefits.

Along most developed coasts, beach nourishment is more feasible than retreat – relocating coastal structures, businesses, housing, infrastructure, environmental resources, and recreational amenities. While armoring or retreat may be the appropriate solution in certain circumstances, nourishment will likely remain the most physically effective, economically viable, and environmentally sound method for maintaining our nation's beaches for the next century.

Finding 5. Beach nourishment is generally the most effective method for maintaining developed beaches.

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