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Regional Wastewater Management Plan Sea-level Rise and Its Implications

DECEMBER 2012



Table of Contents

- SEA-LEVEL RISE & IMPLICATIONS FOR REGIONAL WASTEWATER MANAGEMENT1
 - SEA-LEVEL RISE IMPACTS TO COASTAL EROSION & FLOODING2
 - SEA-LEVEL RISE IMPACTS TO TIDAL RANGE & MIXING3
 - SEA-LEVEL RISE & HABITAT ALTERATION3
 - SEA-LEVEL RISE & WATER QUALITY4
 - SEA-LEVEL RISE IMPACTS TO WASTEWATER INFRASTRUCTURE5
 - OTHER CONSIDERATIONS6





Sea-level Rise and Implications for Regional Wastewater Management

Sea levels are rising globally due to the melting of glaciers and ice sheets and the thermal expansion of ocean water, both of which are driven by overall climate warming. In Massachusetts, these factors are further amplified by the local subsidence of land (Massachusetts Executive Office of Energy and Environmental Affairs, 2011). Relative sea-level rise in Massachusetts from 1921 to 2006 was 2.6 millimeters annually (0.10 inches/year), an increase of approximately 26 centimeters or 10.2 inches per century (see [National Oceanic and Atmospheric Administration’s Sea Levels Online](#); these figures vary locally). Projections of future global sea-level rise by 2100 range widely depending on a number of factors, including emission scenarios, temperature scenarios (influencing thermal expansion), and rates of glacial melting and discharge (see Table SLR-1).

The impacts of projected increases in the rate of sea-level rise on Cape Cod are multi-fold and will pose significant threats to coastal communities. Sea-level rise will increase the height of storm surges and associated coastal flooding frequencies, worsening shoreline erosion and causing permanent inundation of low-lying areas. The frequency of today’s 100-year flood events will significantly increase, putting the extensive development and infrastructure, both public and private, along much of the

Table SLR-1: Projected Sea-level Rise (centimeters/inches)*

SOURCE	PROJECTIONS BY 2050		PROJECTIONS BY 2100		
	LOW EMISSIONS	HIGH EMISSIONS	LOW EMISSIONS	MID EMISSIONS	HIGH EMISSIONS
Pfeffer et al. (2008)	—	—	78/31	83/33	201/79
Rahmstorf (2007)	20/8	40/16	50/20	80/32	140/55
IPCC (2007)	—	—	18/7	48/19	59/23
Current sea-level rate	16/6		29/11		

*All numbers have been rounded to the nearest whole number.

SOURCE: Data from Massachusetts Climate Change Adaptation Report, September 2011



Cape's shore at risk (Kirshen et al., 2008).

Increased sea level will also threaten barrier beaches and dunes, weakening the Cape's natural resilience during storm events. Salt marshes will be put at risk as they may be unable to keep pace with rising water levels and/or migrate inland along developed shorelines due to the presence of coastal structures. The range of tides in coastal ponds and estuaries may be altered with changes in inlet geometry, influencing salinities and the distribution and abundance of coastal marshes. Saltwater will also intrude on freshwater aquifers as sea levels rise, potentially affecting drinking water supplies and gradually converting freshwater wetlands to brackish and salt marshes. The myriad impacts of sea-level rise are discussed in greater detail in the following sections.

SEA-LEVEL RISE IMPACTS TO COASTAL EROSION AND FLOODING

Rising sea levels are an important driver of beach erosion, with long-term horizontal shoreline retreat rates averaging many times that of vertical sea-level rise. The long-term rate of shoreline change for all Cape Cod communities is -0.68 ft./yr., slightly higher than the statewide average, and varies significantly by coastal region (Cape Cod Commission Regional Hazard Risk Map). Back-barrier regions (i.e., coastal lagoons, salt ponds) around the world may respond to sea-level rise quite differently due to variations in sediment supply and saltmarsh accretion rates (see [Marine Biological Laboratory Library web site](#)). Changes in inlet geometry, flow dynamics, and net sand transport directions can be expected if sea-level rise alters the shoaling character of tidal wave propagation into the back-barrier basin. These alterations will produce changes in tidal range, tidal prism, ebb and flood durations, and strength of the tidal currents (see [Marine Biological Laboratory Library web site](#)). The loss of marshlands will increase tidal exchange between the ocean and back-barrier and ultimately change the direction and force of water flows in tidal inlets.

Case studies in the United States suggest that some areas flooded once or twice a century, today would be flooded every decade if sea level rises one meter. A higher water table (driven by sea-level rise) reduces the ability of the soil to absorb runoff, increasing the likelihood of flooding (see [New](#)



[York State Sea-level Rise Task Force Report to the Legislature](#), 2010).

SEA-LEVEL RISE IMPACTS TO TIDAL RANGE AND MIXING

Sea-level rise could change tidal range in tidal ponds and estuaries by removing the barriers to tidal currents and by changing the resonance frequencies of tidal basins (wave action as a result of basin geometry; see U.S. Environmental Protection Agency web site: [Climate Change Impacts and Adapting to Change](#)). Higher tidal ranges would further increase the salinity in estuaries due to increased tidal mixing. In addition, a greater tidal range would increase the inundation of dry land, while increasing or limiting the loss of intertidal wetlands. The potential for increased flushing of coastal embayments on Cape Cod with sea-level rise may improve water quality temporarily. The acceptable nitrogen load in each embayment is directly linked to flow of nutrients into an embayment and how often the seawater in the bay is exchanged. Sea-level rise may enlarge inlet openings to embayments, increasing the flushing and dilution of nutrients, potentially lessening the need for nitrogen removal to improve water quality. For example, if an embayment is 5 feet deep on average, and the sea level rises by even 1 foot, water volume may increase by as much as 20 percent, increasing the bay's ability to assimilate nitrogen and potentially reducing the need for wastewater treatment.

SEA-LEVEL RISE AND HABITAT ALTERATION

Coastal marshes are susceptible to accelerated sea-level rise since their vertical accretion rates are limited, potentially resulting in the eventual submergence and loss of marshes. On the other hand, new wetlands may be formed on inland sites from rising water tables. The intrusion of saltwater into groundwater systems will also impact coastal ecosystems such as marshes by changing the elevation of the freshwater-saltwater interface (see U.S. Geological Survey web site: [Sea-level Rise Hazards and Decision Support: Coastal Groundwater Systems](#)). Understanding how sea-level rise may impact groundwater hydrology in shallow, unconfined coastal aquifers such as those occurring on barrier islands is important when assessing potential impacts on the sustainability of coastal habitats like salt marshes. Sea-level rise is predicted to diminish the distribution of salt



marsh relative to bare mudflats, through marsh drowning. Tidal marshes at the lower and upper salinity ranges, and their attendant delivery of ecosystem services, will be most affected by accelerated sea-level rise, unless geomorphic conditions (i.e., gradual increase in elevation) enable tidal freshwater marshes to migrate inland or the vertical accretion of salt marshes increases to compensate for accelerated sea-level rise (see Ecological Society of America web site: [Frontiers in Ecology and the Environment](#)). Model simulations using the IPCC mean and maximum estimates of sea-level rise for the year 2100 suggest that salt marshes will decline in area by 20 percent and 45 percent, respectively (based on study along the Georgia coast; [ibid](#)). The area of tidal freshwater marshes will increase by two percent under the IPCC mean scenario, but will decline by 39 percent under the maximum scenario. Delivery of ecosystem services associated with productivity (plant biomass) and waste treatment (nitrogen accumulation in soil, potential denitrification) will also decline.

SEA-LEVEL RISE AND WATER QUALITY

Climate change in New England is expected to result in changes in the amount, frequency, and timing of precipitation. By the end of the century, under the high-emissions scenario, annual precipitation in the Northeast is expected to increase by 14 percent, with a slight decrease in the summer—a time when river flows are already low—and a 30 percent increase in the winter (Hyhoe et al., 2006). Scientists predict an eight percent increase in extreme precipitation events in the northeastern U.S. by midcentury, and up to a 13 percent rise by 2100 (Massachusetts Executive Office of Energy and Environmental Affairs, 2011). Water quality problems are likely to worsen in estuarine waters if more extreme precipitation events create increased polluted runoff (see U.S. Environmental Protection Agency web site: [Introduction to Common Estuarine Environmental Problems](#)). Published studies comparing denitrification in temperate vegetated sediments (including salt marsh) and mudflats show higher rates in vegetated sediments (see Elkhorn Slough National Estuarine Research Reserve web site: [Research Program](#)). Vegetated sediments—a mix of submerged and emergent vegetation—removed 10 to 100 percent of nitrate, while mudflats removed 0 to 40 percent of nitrate.



SEA-LEVEL RISE IMPACTS TO WASTEWATER INFRASTRUCTURE

Increases in sea level will raise the freshwater table in many coastal regions. As sea level rises over time, the water table may rise along with it so that the height of the water table relative to sea level will not change. Under these conditions, the depth to the freshwater/saltwater interface below the water table also will not change. However, in areas of streams, the rate of groundwater discharge may increase and the depth to the interface may decrease. If the aquifer system is stressed by pumping for drinking water, the water table near the well may remain constant or decline even as sea level rises. In this case, the height of the water table above sea level would decrease, as would the depth to the freshwater/saltwater interface (see U.S. Geological Survey web site: [Potential Changes in Ground-water Flow and their Effects on the Ecology and Water Resources of the Cape Cod National Seashore, Massachusetts](#)).

Sea-level rise may increase the potential for basement or septic system failure due to elevation of the water table (see U.S. Geological Survey web site: [Sea-level Rise Hazards and Decision Support: Coastal Groundwater Systems](#)), and increase the need for even higher mounded Title 5 systems near coasts. Groundwater contamination will occur as septic tanks and their leach fields become submerged (see U.S. Environmental Protection Agency web site: [Climate Change Impacts and Adapting to Change](#)), potentially creating public health problems and harming ecosystems. Sea-level rise can also contaminate groundwater supplies due to landward and upward movement of seawater in coastal aquifers, and cause the failure of other drainage systems, such as storm drains, which need to be located at a certain elevation above the water table.

Higher groundwater levels may submerge wastewater infrastructure elements, interfering with their function and preventing access. Wastewater treatment plants in the coastal zone are at risk from flooding and the associated corrosion caused by salt water infiltration. In addition to the treatment facilities themselves, the substrate for sewer pipes could be damaged by erosion and a rising water table (see [New York State Sea-level Rise Task Force Report to the Legislature](#), 2010). Combined sewer outfall systems, already experiencing untreated discharges during high rainfall events, will be further compromised by backflow and/or gravity discharge problems as sea level and/or water tables rise. Treatment plants located at low elevation to maximize gravity flow may be jeopardized, and additional pumping may be necessary to maintain service in low-lying areas ([ibid](#)).



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OTHER CONSIDERATIONS

The science of climate change is continually evolving and will likely result in changing estimates of the rate of sea-level rise and storm frequency. Most Cape towns are using a 20- to 30-year planning horizon to plan for wastewater improvements. The decisions made today on wastewater infrastructure need to be responsive to climate change impacts we will experience over the next 50 years (see opinion column by Mark Nelson published in the *Cape Cod Times* newspaper on September 7, 2011: [Warming Must Inform Sewer Plans](#)). In addition, existing and future homes and wastewater infrastructure may not survive if extreme storm events strike Cape Cod more often. The infrastructure built today should be constructed to withstand, adapt, and/or avoid changing conditions.

