New Jersey Geological Survey

Information Circular

Sea Level Rise in New Jersey

Introduction

Along coastal regions, where the ocean meets the land, the forces of nature have always challenged human activities. This is especially true along the heavily populated New Jersey shoreline, where increased erosion, flooding, loss of wetlands, and salinity of surface and ground waters are environmental factors which have major impacts on heavily developed communities. These environmental problems are in part the result of rising global sea level. Sea-level has been rising due to melting of major ice sheets after the last major glaciation 20,000 years ago and thermal expansion of the oceans. The rate of sea-level rise, however, may be exacerbated by human-induced climate change from the production of greenhouse gases. This information circular surveys current scientific understanding about recent sea level changes as well as variations that occurred in the distant geologic past.

There have been many significant changes in sea level over the course of Earth's history. During the geologic past there is evidence of repeated variations of more than 100 m (330 ft) from present sea level. These have occurred both during times of intense glaciation and when the Earth was completely ice-free. Sea-level variations are well documented for the past few hundred thousand years, but are less well-known before then. In the most recent glacial event approximately 20,000 years ago, global sea level was more than 100 m lower than at present (fig. 1).

During the past 42 million years, the Earth has operated as an "icehouse" world where global changes in sea level resulted from the successive formation and melting of continental ice sheets. When ice sheets melt, water is returned to the ocean and sea level rises. When ice sheets expand, water is withdrawn from the ocean and sea level falls.

During earlier times in Earth's history, warmer climates inhibited the formation of large ice sheets, resulting in a period when the Earth operated as a "greenhouse" world. Between 50 and 65 million years ago, the world was intermittently ice free. During the Mesozoic Era (the age of dinosaurs, 65 to 250 million years ago), continental ice was seemingly absent. Consequently, sea level was higher during the Mesozoic, and was at its highest (over 200 m above the present level) 100 million years ago.

Glacial History

Water is found in the oceans, locked in ice sheets and mountain glaciers, underground, on the surface as lakes and rivers, and in the atmosphere. By far the greatest volume of water, approximately 97 percent, is stored in the world's oceans. Ice sheets and glaciers account for approximately 2 percent, leaving less than 1 percent in ground and surface waters, and the atmosphere.

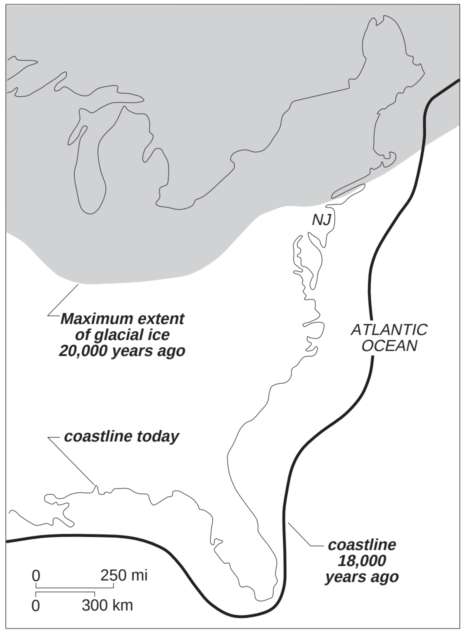

Figure 1. Maximum extent of northern ice sheet during most recent glaciation 20,000 years before present. Global sea level was more than 100 m (approximately 330 feet) lower, resulting in a shoreline extending to the edge of the continental shelf.

During the last several million years vast amounts of liquid water have changed to ice and back again, having a profound effect on sea level. Indeed, sea-level change within the next few thousand years will probably be dominated by water stored in glaciers and by ice sheet dynamics. Therefore, it is important to have an understanding of glacial history and the Ice Age to appreciate the relationship between climate change, the buildup of glaciers, and sea level variations.

The Ice Age began two to three million years ago. There were multiple periods of glacial advance during the Ice Age, with warmer intervals (interglacial periods) between them. During advances, glaciers were far more extensive than they are today.

The best evidence of glacial control on eustatic (worldwide) sea level comes from marine records from seafloor sediments. Glacial/interglacial cycles occurred approximately every 100,000 years during the Ice Age, resulting in about 20 cycles of cooling (glacials) and warming (interglacials). These climatic cycles and corresponding sea-level events are best determined from changes in the ratio between two isotopes of oxygen (O): O^{16} which is the more common and lighter form, and the heavier O^{18}. By measuring O^{18}/O^{16} ratios in the calcium carbonate shells of small marine organisms (foraminifera) retrieved from the sea floor, scientists can determine climatic conditions that existed in the past. When ocean water evaporates, O^{16} is concentrated in water vapor and eventually falls as snow on the surface of an ice sheet. The remaining sea water is thus enriched in O^{18}. When deglaciation occurs, glacial meltwater enriched in O^{16} returns to the ocean, and a corresponding O^{16} spike is recorded in foraminifera from ocean sediments. In looking at the past trend of O^{18}/O^{16} glacial/interglacial (cold/warm) cycles, each cycle lasted about 40,000 years from 2.75 million years to 900,000 years ago; since then, these cycles have lasted about 100,000 years each.

Most Recent Glacial Period

During the Ice Age, New Jersey underwent at least three glaciations. The last glaciation is known as the late Wisconsinan Glaciation. During this period, huge continental ice sheets covered most of Canada, parts of the northern United States, Greenland, northwestern Europe and Antarctica. In New Jersey, the furthest advance of the Wisconsinan ice sheet is marked by a poorly sorted mixture of sand, clay and boulders called the Terminal Moraine.

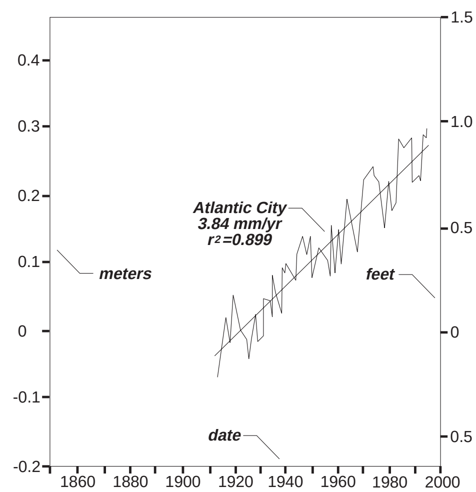

Figure 2. Tide gauge records for Atlantic City and Sandy Hook, New Jersey (modified from Psuty and Collins, 1996).

During the late Wisconsinan glaciation, global sea level was more than 100 m lower than it is today, and both the Hudson and Delaware Rivers cut canyons deep into the continental shelf. As sea level rose, these canyons were drowned, creating the present Hudson and Delaware estuaries. The ice began to melt back from its maximum position around 20,000 years ago (fig. 1).

The ice sheets in North America and Europe began to melt more rapidly about 15,000 years ago. The meltwater returned to the ocean basins and sea level rose. The rapid melting of the northern continental ice sheets between 15,000 - 7,000 years ago probably accounted for most of the rise of the sea to its present level. During most of this time, the average rise in sea level was 12.5 mm/yr (0.5 in/yr). In New Jersey, from 7,500 to 2,500 years ago, there was a steady rate of sea level rise of approximately 2.0 mm per year (0.1 in/year). Sea-level rise slowed to a rate of approximately 0.8 mm (0.03 in/year) between 2,500 to 1,000 years ago. During the last 1,000 years it has accelerated again to a rate of 4 mm/yr (0.16 in/yr).

Historical Shoreline Change in Response to Sea Level Rise (recent to past 100 years)

Worldwide relative sea level has risen by an estimated 1 - 2 mm/yr (0.04 - 0.08 in/yr) over the past 80 years. This was determined by using data from key tide-gauge stations and a grouping of records from different regions. In New Jersey, sea-level rise has been measured at approximately 3.8 mm/yr (0.15 in/yr at Atlantic City) using tide gauges (fig. 2), or about twice the world rate. This may be the result of land subsidence along the coast due to sediment compaction. Global sea level has risen up to 15 cm (6 inches) in the past 100 years (fig. 3); much of this rise may be related to the increase of global mean temperature (fig. 3). Indeed, sea-level change during the next few thousand years will probably be controlled by water within the global ice budget and by ice sheet dynamics. If the polar ice sheets were to completely melt, sea level would rise by 70 m (over 200 ft). The Statue of Liberty would just be visible in New York Bay (fig. 4).

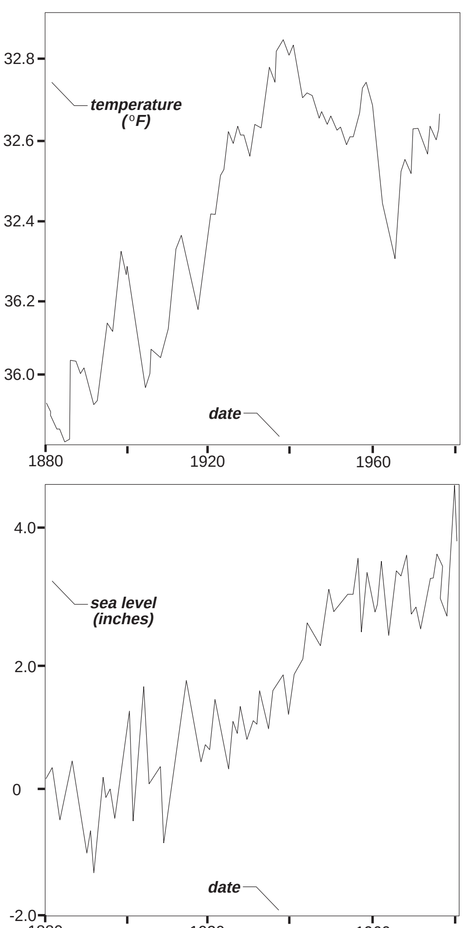

Figure 3. Correlation between global temperature and sea-level rise during the last century (from Intergovernmental Panel on Climate Change, 1990).

Figure 4. View of the Statue of Liberty if the Antarctic and Greenland ice sheets were to completely melt (from K. Miller, Rutgers University).

Causes of Sea Level Rise; Natural and Anthropogenic

Global warming of the atmosphere and ocean resulting from increasing concentrations of carbon dioxide and greenhouse gases (greenhouse gas warming) will control the rise of global sea level during the next 100 years by:

1) thermal expansion of ocean waters as they become warmer (termed steric volume change); and **2**) changes in the mass of land ice in both continental ice sheets and mountain glaciers from increased snow and ice melting.

There is a close correlation between sea-level rise and global mean temperature for the past 100 years (fig. 3). One future projection of sea-level rise due to global warming, based only on the steric volume component, is shown on Figure 5. This projection does not include the effect of melting continental ice sheets, which may cause the amount of sea-level rise to be significantly higher.

A difficult question which cannot be answered is how much of the global warming observed during the last decade is attributable to the natural fluctuations of climate, and how much to emissions of heat-trapping greenhouse gases produced by the burning of coal, oil, and natural gases. The prevailing scientific view is that continued and increased emissions of greenhouse gases will disrupt the Earth's climate in the foreseeable future.

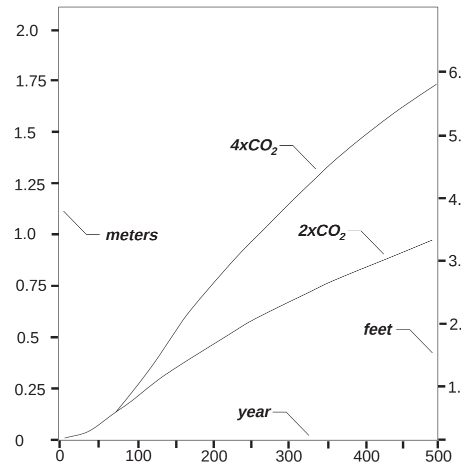

Figure 5. Sea-level rise projections based on a model of projected CO_2 increases of 2x and 4x present levels (Manabe and Stouffer, 1994). These projections only include thermal expansion of ocean waters and do not take into consideration melting continental ice sheets.

The forces of nature can be severe along coastlines. As sea level rises, coastal storms penetrate farther inland, increasing the vulnerability of these areas through the loss of wetlands, increased flooding, and the increase of salt-water intrusion into major aquifers and estuaries. This reality must be accepted and planned for to ensure a secure future for New Jersey.

Sources of Information

Intergovernmental Panel on Climate Change (IPCC), 1990, Scientific Assessment of Climate Change, Working Group I., WMO-UNEP, Geneva, Switzerland.

Manabe, S. and Stouffer, R., 1994. Multiple century response of a coupled ocean-atmosphere model to an increase of atmospheric carbon dioxide. Journal of Climate, v. 7, p. 5-23.

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October, 1998

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