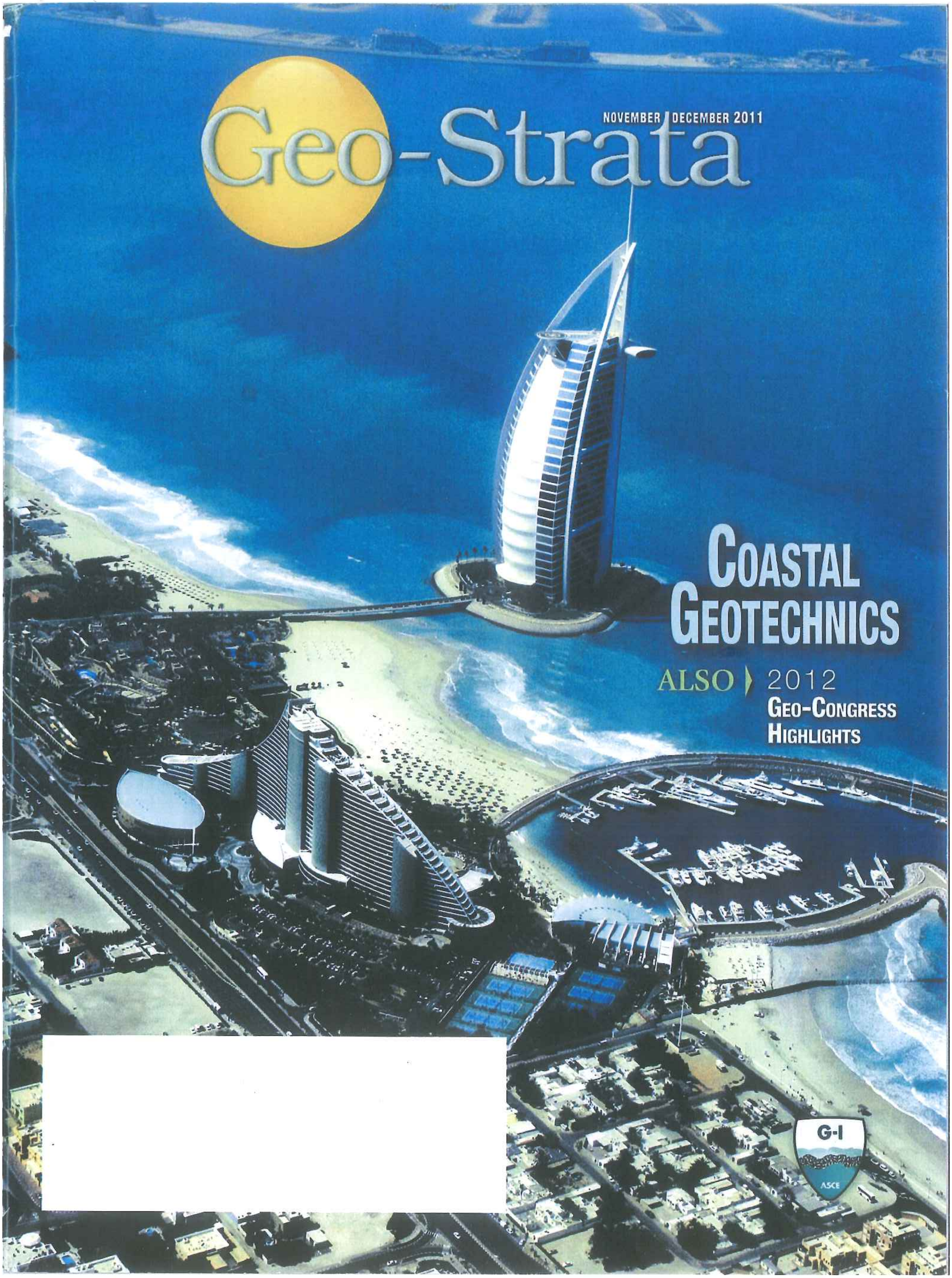
NOVEMBER / DECEMBER 2011

Geo-Strata



COASTAL GEOTECHNICS

ALSO ⟩ 2012 GEO-CONGRESS HIGHLIGHTS

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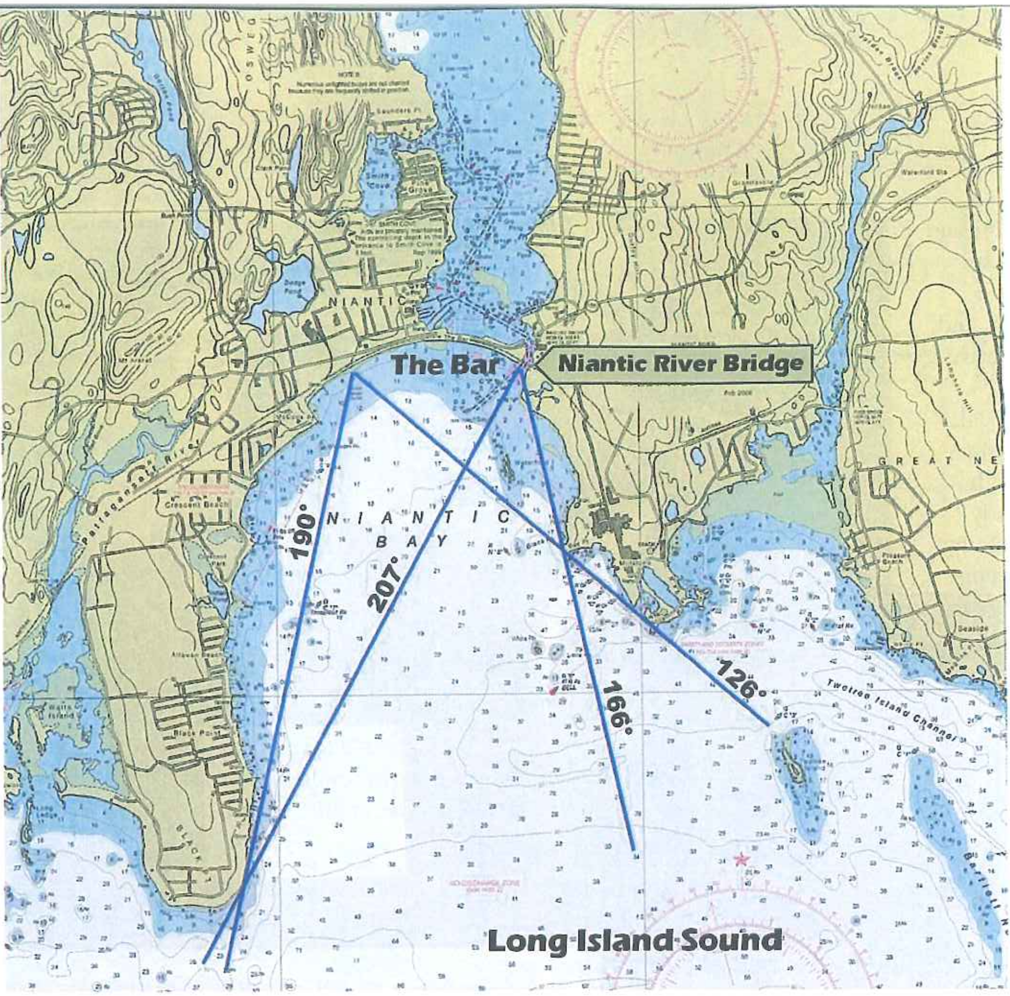

Figure 1. Location of Niantic Bay, East Lyme, CT, showing wave exposure windows for the easterly and westerly ends of the project area.

Beach Replenishment for Amtrak's Niantic River Bridge Replacement

By J. Richard Weggel, Ph.D., P.E., D.CE, F.ASCE, Craig M. Benedict, P.E., M.ASCE, and Ara G. Mouradian, P.E., M.ASCE

The National Railroad Passenger Corporation (Amtrak) is replacing the 1907-era bascule bridge over the Niantic River between East Lyme and Waterford, CT, along the heavily travelled Washington, D.C.-to-Boston Northeast Corridor. Niantic Bay is an arm of Long Island Sound and is occasionally subject to hurricanes, including "The Great New England Hurricane" of 1938, which wreaked destruction to the Connecticut coastline, including railroad infrastructure at Niantic Bay. The existing five-span bridge, with a Scherzer rolling-lift bascule central span, is being replaced with a three-span structure featuring a single-leaf Strauss-type bascule central span. The project will increase the width of the navigational channel at the bridge from 45 ft to 100 ft, and will increase underclearance from 11.5 ft to 16 ft with the bridge in the closed position.

Design challenges for the project included operational constraints to avoid rail service interruption, hurricane resistant structures and restoration of beaches due to the impacts of the new alignment on the existing beach. To support the new approach embankments to the replacement bridge, prestressed concrete sheet pile retaining walls are being installed along both the east and west approaches. Along the west approach, adjacent to the recreational beach, a 2,549-ft-long wall is being installed. This wall will be protected from storm action by a layered stone scour protection system. Near the bridge crossing, the beach needs to be moved approximately 27 ft seaward from its current location. In addition, a pedestrian walkway will be provided on the new elevated approach embankment to replace the boardwalk.

Site Description and Coastal Processes

The Amtrak tracks at Niantic run generally west to east along a 2,500-ft-long barrier spit known locally as "The Bar," with the Niantic River crossing at the easterly end of the spit. The spit ranges from 210 to 300 ft or more in width and has been augmented in various locations on its north side by various construction projects over the past century. "The Bar" is exposed to waves generally from the south, approaching through a relatively narrow window (Figure 1); however, the southwesterly fetch is somewhat limited by the easterly end of Long Island, NY.

The 100-year significant wave height off the easterly end of Long Island is 25.5 ft, while the 100-year storm surge level established by FEMA for Niantic Bay is 10.1 ft above NGVD29 datum. Thus, near-shore breaking wave heights are determined by the prevailing water level with maximum breaking wave heights occurring during periods of high water. The breaking wave height used for the design of the retaining walls and scour protection is approximately 78 percent of the prevailing water depth during the 100-year storm water level.

Railway Structure Scour Protection

The scour protection system at the base of the retaining wall for the new approach embankment limits the design water depth. The scour protection consists of a 25-ft-wide layer of 1,900-lb stone on top of a double layer of 190-lb stone, over a 1-ft-thick layer of 10-lb stone that is enclosed by a geotextile. Two layers of 3.4-ton armor stone will be placed on top of the scour blanket and against the retaining wall to reduce the likelihood of wave overtopping during the 100-year storm. Under normal conditions, the scour blanket and most of the armor stone will be buried beneath the restored beach.

The scour protection system at the base of the retaining wall for the new approach embankment limits the design water depth.

Beach Restoration

At Niantic, about 2,500 ft of beach will be restored, consisting of beach nourishment and beach stabilization features. Nourishment generally refers to engineered solutions that add sand to a beach, but do not generally alter the prevailing coastal process (i.e., areas that are subject to erosion generally continue to erode). In many cases, the annualized economic value of the nourished beach usually far exceeds the annualized cost of nourishing and periodically re-nourishing a beach. Beach stabilization structures such as groins and near shore breakwaters hold or redistribute sand on a beach so that accumulation in one area is a result in erosion from another. In support of nourishment, stabilization structures can slow erosion and prolong the life of the nourished beach.

Sea level rise may significantly impact coastal loading over the design life of a beach nourishment project.

Beach construction/erosion/deposition processes are complicated, with sand being carried on and off shore and to and away from various beaches by various wave conditions that depend on wind direction, tide, and storm surge level. Sea level rise may significantly impact coastal loading over the design life of a beach nourishment project. Longshore sand transport estimation and beach stabilization features to control sand transport are important aspects of beach nourishment design.

Longshore Sand Transport Process

Sand is carried along a shoreline when waves approach the beach at an angle. This "longshore transport" depends on the wave height, wave period and the angle the breaking wave crest makes with the shoreline. As the direction of wave approach changes, so does the direction of transport. At Niantic, sand is sometimes carried westward along the spit and at other times eastward. The sand transported westward by waves approaching from the southeast is lost from the project area to the beaches west of the project. This sand is stored on those beaches and recovered by the project when southwesterly waves reverse the transport direction.

Easterly transport carries sand into the Niantic River where it is also lost from the project beach; however, subsequent reversals in wave direction cannot carry it back to the project area. The eastward moving sand is carried into the harbor during flood tide or carried offshore and deposited in an ebb shoal during ebb tide. A large ebb-tidal shoal currently exists offshore of the Niantic River inlet (Figure 2).

Sea Level Rise and Beach Erosion

Based on an analysis of the rate of sea level rise at New London, CT (Figure 3) and sand transport processes, a beach erosion rate of about 1.5 ft/yr was calculated assuming a profile closure depth at elevation -22 ft (elevation of stable sea floor). However, an analysis of two recent surveys at the Niantic beach in 2004 and 2009 found an erosion rate of only 0.15 ft/yr. During this period, the 2,500-ft beach lost only about 200 or 300 cy/yr, suggesting a relatively stable pocket beach.

Restoration of the displaced recreational beach requires nourishment with sand having about the same size characteristics as the native beach sand. Coarser sands, which generally erode at a slower rate, produce steeper

Figure 2. Orthophoto shows Niantic Bay, "The Bar" and the Niantic River inlet. Flood flows carry and deposit sediment into the harbor, behind "The Bar."

beach slopes which are often undesirable. Finer sands erode more quickly, but result in flatter offshore slopes that require more sand to produce the same equilibrium beach width.

To prevent sand loss from the beach by transport into the river inlet, a rubble-mound terminal groin is planned for the westerly side of the inlet.

At Niantic, the median sand grain size determined from surficial samples is about 0.01 in., while that determined from project test borings is about 0.004 inches. In addition, rounded gravel-size stones, up to two or three inches in diameter, are present in the surface material. About 80,000 cy of fill will be brought in to restore the beach to pre-project conditions. About 1.1 cy of borrow sand must be placed per foot of shoreline to produce one square foot of beach.

Concerns about environmental permitting constraints on obtaining sand from an offshore source, and the relatively small volume of fill required for the replenishment, precluded dredging from an offshore source, so an upland source was selected. Immediately after construction, the beach will be about 88 ft wide, much wider than the 25-ft final target beach width; however, as time passes, waves will distribute the sand across the profile, ultimately resulting in the desired 25-ft equilibrium width. The beach will begin at the bayward limit of the 3.4-ton armor stones protecting the face of the new retaining wall. This profile equilibration is anticipated to take place during the first several storms following construction.

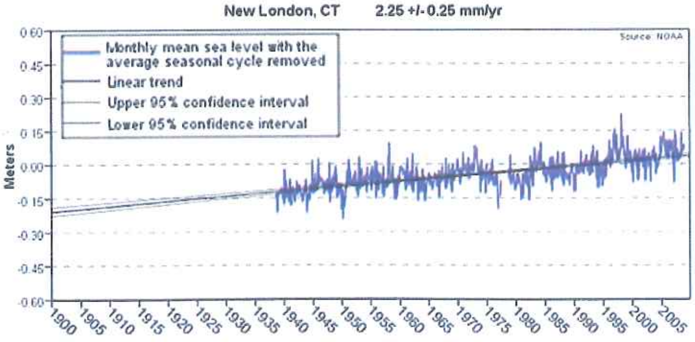

Figure 3. The historical rate of sea level rise at New London, CT is about 0.74 feet per century.

Beach Stabilization: Terminal Groin/Jetty

To prevent sand loss from the beach by transport into the river inlet, a rubble-mound terminal groin is planned

Figure 4. Looking eastward along "The Bar," the concrete sheet pile wall is visible at the left. Cranes are working near the bridge location.

for the westerly side of the inlet. The structure will also serve to keep sand out of the navigation channel, so it may be considered a jetty as well. The groin's alignment perpendicular to the local shoreline was established by the direction of incident wave approach at the easterly end of the project. The groin will extend about 180 ft seaward of the existing shoreline and be armored with a cover layer of 6.8-ton stone. A reinforced concrete sheet pile core will prevent sand from migrating through the structure into the inlet. The top surface of the groin will be chinked with small stone to provide a flat surface to accommodate fishermen and other recreational access. Figure 4 shows a photo from May 2011of the project construction.

What Will the Future Hold?

It will be interesting to observe the completed project to see how changes to the physical littoral environment change the prevailing coastal processes at the site. Will the ebb-tidal shoal remain in place or disappear since its source of sand will be interrupted? How long will the restored beach remain and how frequently will it require renourishment – which of the two estimated erosion rates will actually prevail? How long will it take the nourished beach profile to attain its equilibrium configuration? The answer to these and other questions will depend on the intensity and characteristics of future storms that impact the area.

AUTHORS

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