

Coastal Modeling Is All Around Us

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Figure 1: Rockaway Rail Line crossing Jamaica Bay

Coastal engineers apply numerical modeling to a wide variety of projects, such as coastal ecosystem restoration, shoreline protection, flood protection, harbor design, beach nourishment, navigation channel improvements, and bridge design. Most of these projects involve analyses of complex coastal phenomena including waves, currents, tides, storm surge, and sediment transport. With the rapid advancements in coastal numerical modeling over the past 20 years, the application of numerical models to support these analyses has become standard practice.

Many of the hydraulic processes relevant to coastal engineering are commonly observed in nature and easily recognizable to the general public. For instance, even someone who has never been to the beach could recognize a wave traveling toward the shore, or visualize rising floodwaters (i.e., storm surge) and inundation during a hurricane. The ability to observe or imagine what's being modeled - without having a detailed understanding of the underlying physics - helps broaden interest in coastal modeling,

and allows members of the general public to more easily recognize the phenomena being analyzed.

Adding to the "reliability" of coastal modeling are the high-resolution images and animations generated to visualize model output. Ongoing advancements in modeling software and computing hardware make possible a realistic display of modeling results that significantly simplify interpretation. Although coastal engineering is often thought of as a niche discipline, a broad range of HDR's civil engineering projects requires analyses of coastal processes. Several of these are described in more detail below.

Flood Protection

The need for reliable flood protection in coastal regions has been highlighted over the past decade by the impacts from Hurricane Katrina in New Orleans, Hurricane Ike in Galveston, Texas, and Hurricane Sandy in New York and New Jersey. The



Debris on Rockaway Rail Line after Hurricane Sandy

storm surges from these hurricanes caused devastating flooding that impacted large areas extending as far as 50 miles inland from the open coast. These natural disasters have demonstrated the vulnerability of many heavily developed coastal communities and industrial regions. Holistic engineering solutions – through collaboration among water engineering, transportation, industry, and Federal entities (to name a few) – improve asset resiliency in the face of flooding and erosion.

Coastal modeling has obvious applications for flood protection design, particularly for analysis of storm surge and waves. Recently, we performed analysis and design for flood protection along the Rockaway Rail Line, a rapid transit line connecting Queens to the Rockaways in New York (Figure 1). A section of the line crossing Jamaica Bay was severely damaged during Hurricane Sandy, requiring emergency repairs. Through an existing on-call contract with the New York City Transit Authority (NYCTA), we were engaged immediately to perform damage assessments and associated engineering design.

Observed damage and analysis of tide data recorded during the storm made it clear that most of the rail embankment was completely inundated by Sandy's storm surge – which exceeded the level for a 100-year (1 percent annual chance) event.

Combined with wave impacts, the severe flooding covered the tracks with debris, and resulted in two large breaches along the embankment.

To prevent similar damage in the future, HDR recommended construction of a quarrystone revetment and sheet pile wall for wave protection, as well as a water transfer structure for more controlled discharge of storm surge runoff. Hydrodynamic numerical models were developed to establish the needed design criteria associated with wave run-up, wave impact loads, and the water transfer structure. The models

were also applied for an adjacent impact study to help ensure that wave reflection and diverted floodwaters caused by the improvements would not adversely affect surrounding neighborhoods and sensitive environmental areas (Figure 2). Based on these recommendations, NYCTA proceeded with construction of a steel sheet pile “wave wall” along the most exposed side of the rail embankment. The wall will provide improved protection and allow the railway to resume operation much sooner after the next major storm.

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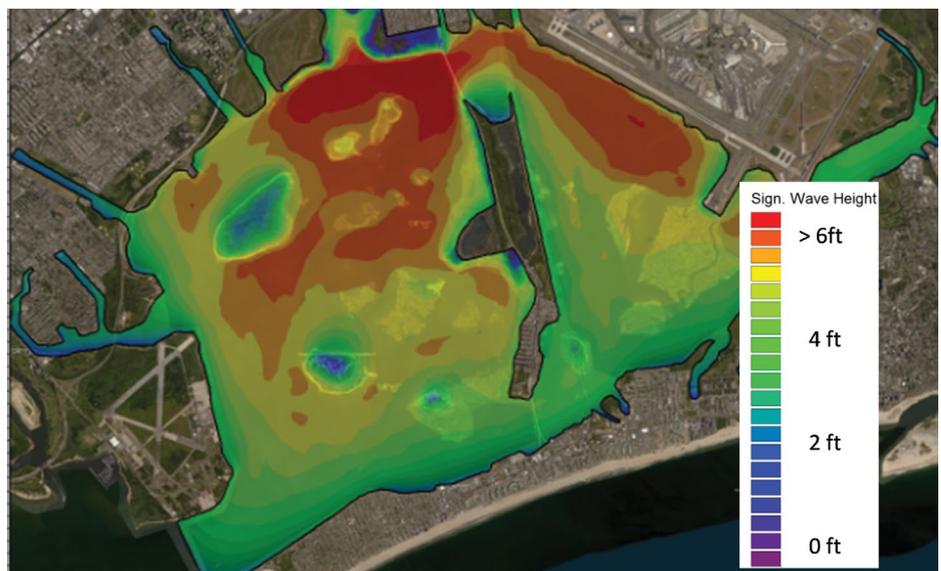


Figure 2: Modeled storm surge and currents propagating from Gulf of Mexico

Bridge Hydraulic Studies

From large multilane highways to rural farm roads, bridge projects require careful consideration of hydraulic conditions. Many bridges are located in coastal regions, spanning tidal inlets or large embayments, exposing them to direct impacts from waves, storm surge, and tidal currents. Coastal engineers provide hydraulic design criteria for these projects, addressing storm surge, waves, and currents, which control scour and bridge loadings and are necessary to determine required bridge elevations; member sizing; and abutment and shoreline protection design. Development of these criteria often involves coastal numerical modeling.

For example, HDR recently performed hurricane storm surge modeling for a bridge design project for the Texas Department of Transportation (TxDOT), a replacement for a bridge over the Gulf Intracoastal Waterway at Sargent Beach, Texas (Figure 3). Input from HDR's coastal engineers was requested to analyze potential scour at the bridge piers, as well as to quantify vertical and lateral loads on the bridge from storm surge and waves.

The Sargent Beach model was developed to simulate storm surge propagating from the Gulf of Mexico, and flooding of the low-lying land around the bridge foundation and approach ramps. Calculations based on the model results indicated that up to 16 feet of scour was possible at the base of the bridge piers, and that the embankments at the bridge approaches could be subjected to significant erosion if left unprotected. Figures 4 and 5 provide examples of the model output.

TxDOT's final design will include sufficient pile embedment to resist scour, and incorporation of riprap (among other measures) to help prevent erosion of the bridge approach and channel bank. The improved bridge will allow more continuous transit of recreational and commercial traffic and will make the bridge less vulnerable to damage during the next major hurricane.



Figure 3: Currents under proposed bridge

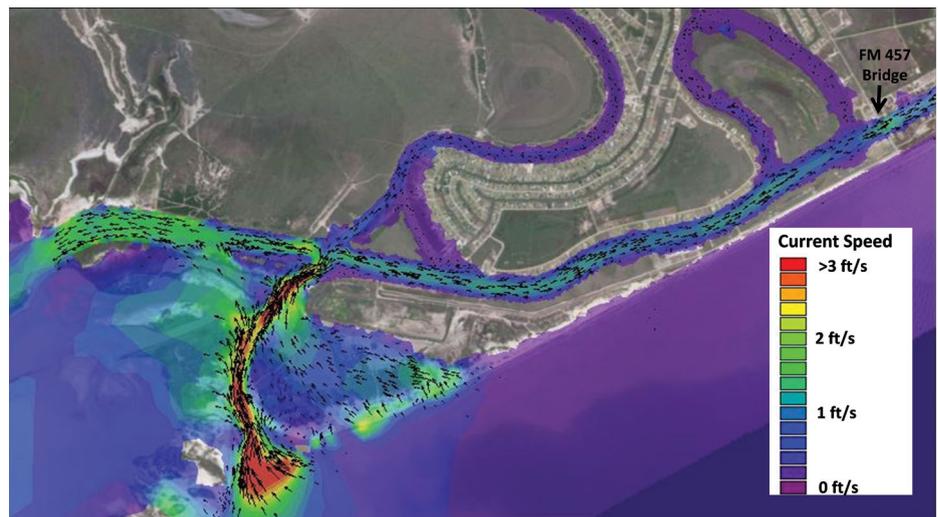


Figure 4: Modeled storm surge and currents propagating from Gulf of Mexico

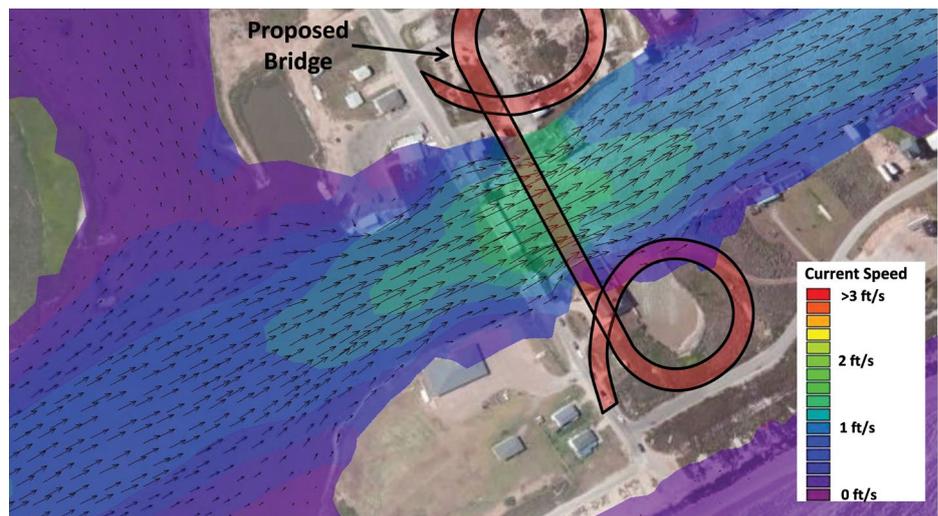


Figure 5: Currents under proposed bridge



Figure 6: Location of St. George Island

Harbor Design

Another common application for coastal modeling is harbor design, where relatively tranquil waves and currents are essential for safe maneuvering and mooring of boats. Since 2013, HDR has been working for the Alaska Department of Transportation & Public Facilities (DOT&PF) to improve a remote fishing harbor at St. George Island. Located in the middle of the Bering Sea (Figure 6), the island is exposed to large open-ocean swell that frequently results in wave heights of over 30 feet just outside of the harbor. Because of the relatively small size of the harbor (Figure 7), maneuvering space for local crabbing vessels and supply barges is extremely limited. In addition to creating dangerous conditions for the vessels entering and exiting the harbor, these large waves create strong currents in the harbor that have damaged boats and injured crews during loading/unloading operations.

A fundamental challenge for harbor designers is developing a configuration that not only allows boats to safely access the harbor, but also prevents large waves from propagating into the harbor from the open ocean. For St. George Harbor, HDR's coastal engineers applied wave numerical modeling to analyze wave



Figure 7: St. George Harbor

interaction with the breakwaters at the harbor entrance. This allowed a detailed comparison of multiple harbor improvement configurations. The high level of detail in the modeling results assisted HDR in recommending construction of two jetties extending from the existing breakwaters, creating a safer entry to the harbor that will improve subsistence and commercial fishing for the local community.

Ready to Help

In addition to being highly desired living and recreational areas, coastal regions attract significant industry and host a range of valuable natural habitat. Without proper planning, however, hazards like erosion and flooding pose threats of lost life and property, economic damage, and environmental destruction. As coastal engineers continue to make advancements, numerical modeling will play an integral role in risk allocation for planning resilient communities, contributing to the ultimate goals of long-term sustainability and balance with nature.

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