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Regional Sediment Management at East Rockaway Inlet, NY, Utilizing the USACE Coastal Modeling System

by US Army Engineer District, New York

PURPOSE. This Coastal and Hydraulics Engineering Technical Note (CHETN) describes a study to develop a cost-effective alternative deposition basin to trap material from upcoast and bypass across East Rockaway Inlet for placement on the adjacent downcoast Rockaway Beach, thus providing a reliable sediment borrow source while enhancing the hydrodynamic circulation of the inlet system. This study was supported by the US Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC), Regional Sediment Management (RSM) program; and the US Army Engineer District, New York, Rockaway Beach Reformulation Study. Numerical modeling support for this study was provided by Offshore & Coastal Technologies, Inc. This CHETN was extracted from US Army Engineer District, New York (in preparation).

INTRODUCTION. East Rockaway Inlet, NY, is located at the eastern limit of Rockaway Beach, a 10.8-mile-long barrier island stabilized since the 1880s with beach fill, groins, bulkheads, and a rock jetty at the western limit. The East Rockaway Inlet is a Federal navigation channel 250-ft wide and maintained to -14 ft mean low water (mlw) plus 2 ft allowable overdepth, creating a man-made sediment transport barrier.

Approximately 300,000 yd^3 of upcoast littoral material needs to pass the Inlet in a westerly direction annually, either by natural bypassing or channel maintenance dredging. Some material is lost permanently out of littoral system. Historical dredging records indicate the channel dredging rate increased from an average 30,000 yd^3/yr in the 1938-to-1978 time period to an average 115,000 yd^3/yr recently. The inlet channel is nominally maintained by a 2-year dredging cycle although more frequently in the last few years due to combined effect of storm activities and a saturated updrift sediment fillet. The shoreline of Rockaway Beach is currently eroding at a 2- to 5-ft annual rate decreasing from east to west, and requires periodic beach nourishment.

EXISTING CHANNEL. The currently maintained East Rockaway Inlet navigation channel and three existing deposition basins that are also dredged to the project depth are shown in Figure 1. These basins provide additional sand deposition capacity and reduce the frequency of maintenance dredging.

SEDIMENT BUDGET. A sediment budget of the Rockaway Beach shoreline and inlets was developed by combining inputs from historical shoreline comparisons, beachfill placement records, shore protection structures inventory, depth of closure determination, and inlet dredging records. The sediment budget analysis (Figure 2) considers the entire shoreline as one sediment cell bordered by Rockaway Inlet channel to the west, East Rockaway Inlet channel to the east, and the Atlantic Ocean to the south. Sediment transport rates are balanced in the cell with assumptions to determine the long term shoreline erosion rate.

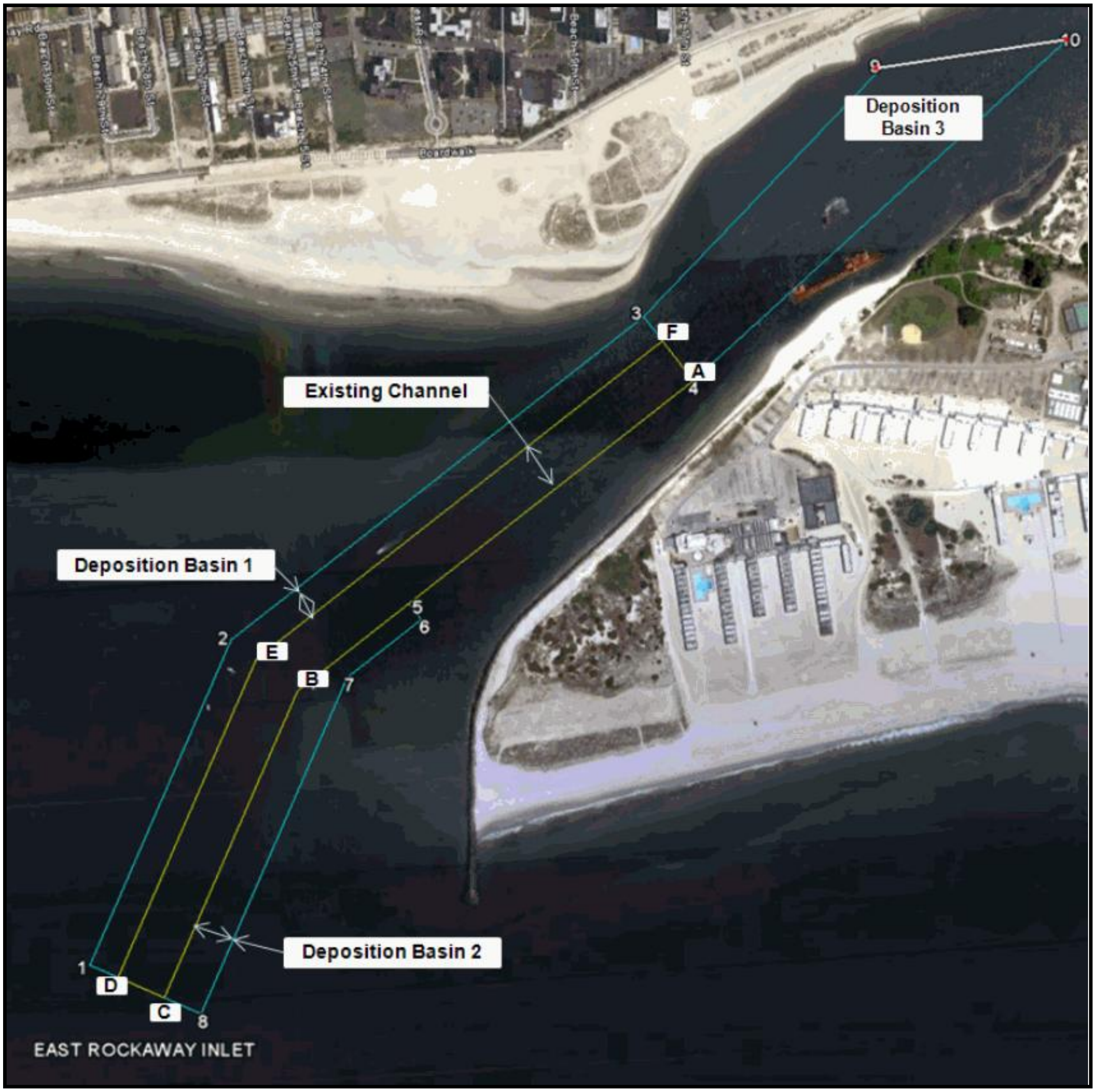

Figure 1. Existing channel and Deposition Basins 1, 2, and 3, East Rockaway Inlet, NY.

The sediment budget cell has balanced sediment sources (shown as "+") and sediment sinks (shown as "-"). The sediment transport into the cell (sources) is balanced with the sediment transport out of the cell (sinks). The sum of sediment sources equals the sum of sediment sinks in the designated sediment budget cell. All sediment transport rates are in thousands of yd^3/yr, and all rates are rounded to thousands, indicating the degree of accuracy of the estimated transport rates. The 1974-1997 shoreline change and beachfill records were used, which is considered to be most representative of recent conditions and least affected by construction of numerous shore stabilization structures that occurred prior to 1962. The following summarizes sediment sources and sinks used for the sediment budget. The updrift source was increased to 300,000 yd^3/yr for existing conditions.

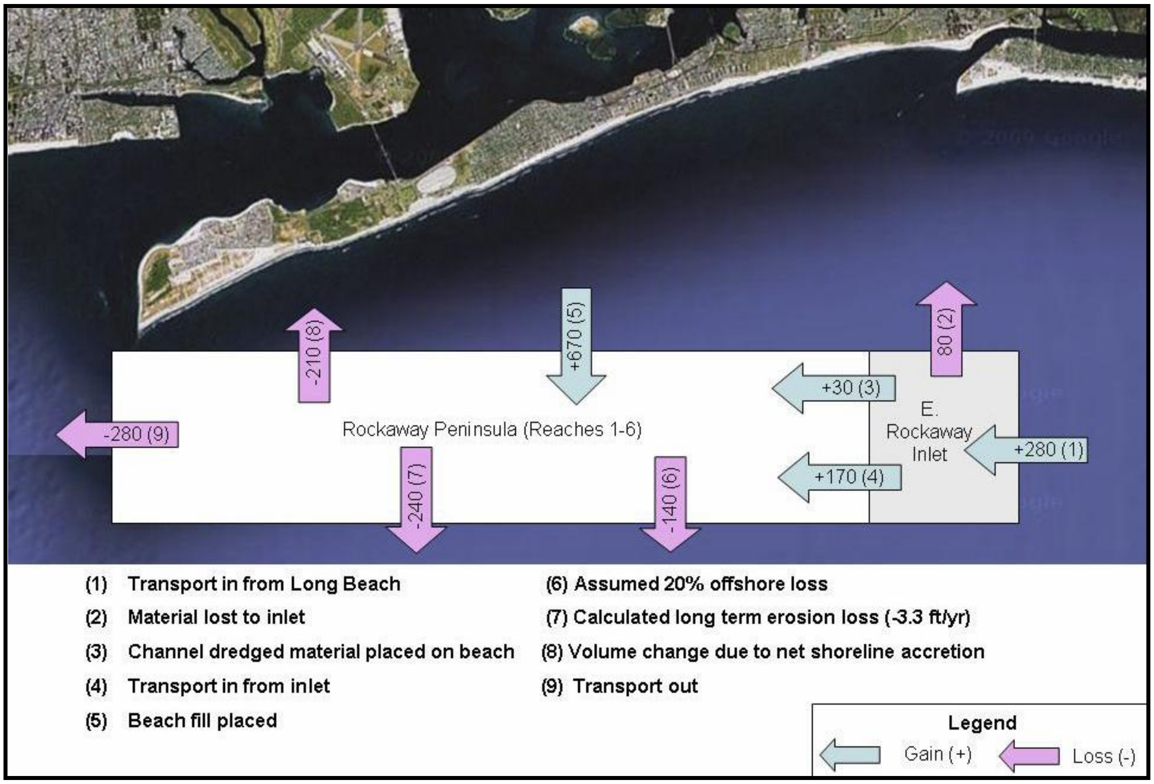

Figure 2. Rockaway Beach, NY, one-cell sediment budget diagram, 1974-1997 (1,000 yd^3/yr).

Sediment Sources.

- Beachfill: +670,000 yd^3/yr, compiled from 1974-1997 fill placement records
- Channel maintenance dredged material placed as beach fill: +30,000 yd^3/yr, based on 1974-1997 channel dredging records
- Naturally bypassed from updrift: +170,000 yd^3/yr, based on 280,000 yd^3/yr net littoral transport rate from updrift (source: Long Beach Feasibility Report) minus 110,000 yd^3/yr projected inlet shoaling rate (from East Rockaway Inlet dredging records)

Sediment Sinks.

- Net shoreline accretion: -210,000 yd^3/yr, calculated from net mean high water advance of comparative shorelines between 1974 and 1997, using an average +10 ft National Geodetic Vertical Datum (NGVD) berm and -25 ft NGVD depth of closure
- Littoral transport downdrift: -280,000 yd^3/yr (assumption)
- Offshore loss: -140,000 yd^3/yr (assumed at 20 percent of placed beach fill)
- Long term erosion: -240,000 yd^3/yr calculated, based on sediment budget balance; this long term erosion rate is equivalent to 3.3 ft/yr of shoreline retreat assuming an average +10 ft NGVD berm elevation and average -25 ft NGVD depth of closure

RSM ALTERNATIVES. The existing practice is continued bypassing of inlet shoaling material from the navigation channel and designated deposition basins. Based on channel dredging records, the channel maintenance dredging operation as dictated by navigation requirements has become more frequent and more material is being dredged. The existing channel dredging trend indicates that the shoaling rate is increasing, and more frequent maintenance will be necessary in the future. Without implementation of a regional sediment management program, channel maintenance will become more costly due to frequent mobilization of dredging equipment. Additionally, shoaling material not captured via dredging will be lost further into the bay and/or carried offshore by ebb currents.

Alternatives Screening. Based on the existing conditions sediment budget, there are up to 300,000 yd^3/yr updrift sediment being transported into the inlet system. Except for deposition in the channel and that which is naturally bypassed, there are increasing amount of material lost permanently from the littoral zone. Potential regional sediment management alternatives include:

- Excavation of a sediment fillet east of the jetty at Atlantic Beach, for downdrift beach nourishment
- Construction of a sediment bypassing plant, and bypass littoral material continuously
- Construction of a new sediment deposition basin at a strategic location, to trap updrift sediment and bypass periodically onto downdrift beach

Sediment fillet excavation and bypassing plant alternatives were not further considered due to environmental considerations, and high initial and maintenance costs of building a permanent bypassing plant. The proposed new deposition alternative basin is more cost effective. Three deposition alternative basin locations were proposed (Figure 3).

Proposed Deposition Alternative Basins.

- **Alternative Basin 1 (Alt 1).** Located on the north side of East Rockaway Inlet channel, a triangular shape approximately 2,500 ft along the main channel and 2,000 ft by 1,500 ft on each side. Basin would be dredged to -14 ft mlw (-12 ft mlw plus 2 ft over-dredging) with 1V:3H side slopes. Estimated sediment trapping capacity is up to 300,000 yd^3, with initial excavation volume of 400,000 yd^3.
- **Alternative Basin 2 (Alt 2).** Located west of the outer jetty, a rectangular shape approximately 1,200 ft by 500 ft dredged to the same depth as Basin 1. Approximate capacity of this basin is up to 150,000 yd^3, with initial excavation of 200,000 yd^3.
- **Alternative Basin 3 (Alt 3).** Would be combined with existing outer channel to create a new joint deposition basin with approximately 200,000 to 300,000 yd^3 capacity, depending on the allowable over-dredge depth.

SEDIMENT TRANSPORT MODELING. The cost-effectiveness, and environmental, hydrodynamic, and navigation considerations of the three proposed alternative basins were analyzed using the ERDC Coastal Modeling System (CMS) for hydrodynamic, wave, and sediment transport model simulations. CMS contains both CMS-Flow and CMS-Wave which can be coupled. The model results were used to analyze the sediment deposition rate at each proposed alternative basin. The best cost-efficient deposition basin with the least hydrodynamic impact would be recommended.

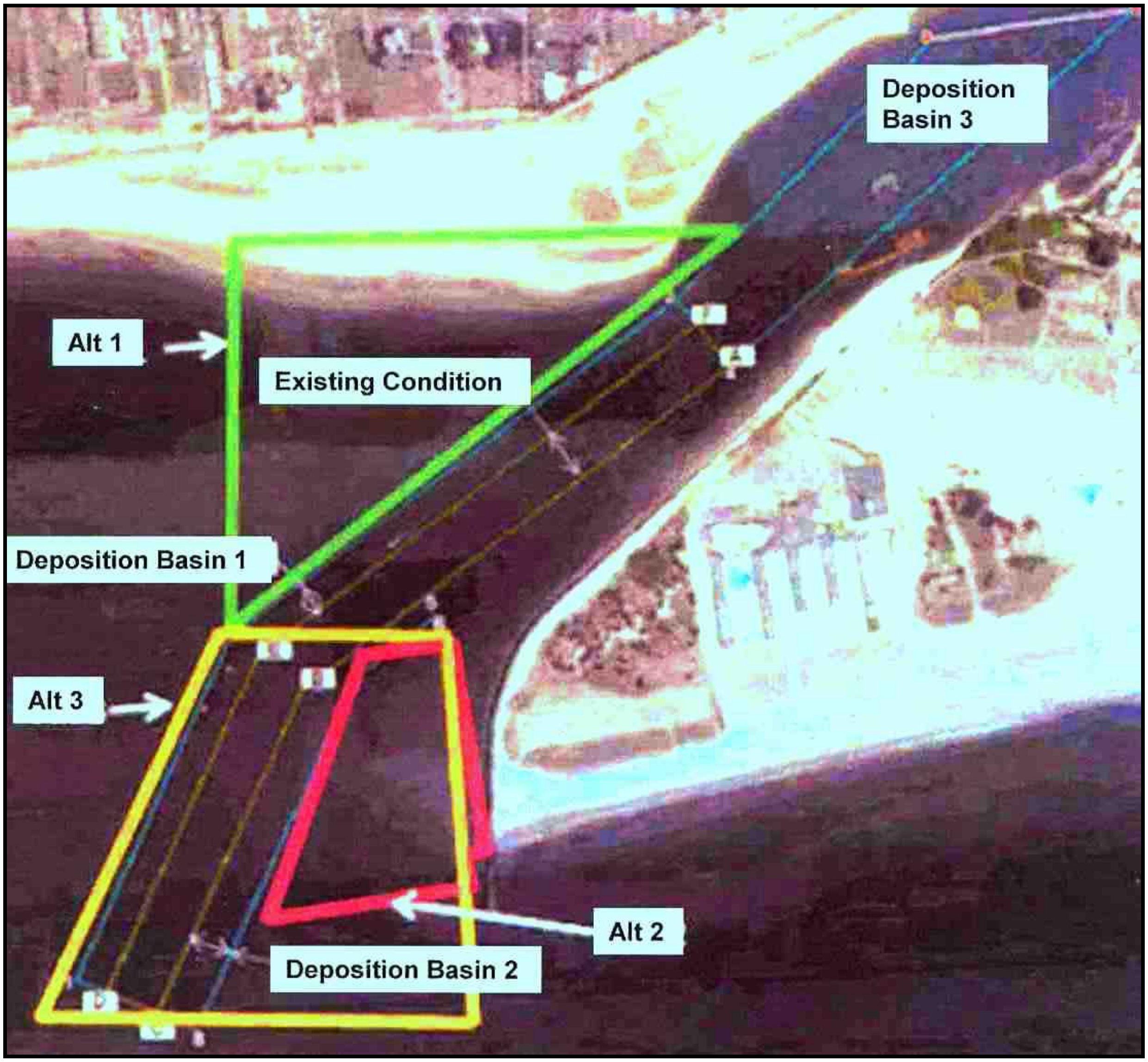

Figure 3. Proposed new alternative basins (Alt 1, Alt 2, and Alt 3) over existing channel, East Rockaway Inlet, NY.

All proposed alternative basins were specified to have a depth of -12 ft mlw plus 2 ft overdredging. Ambient depths within the design template that were shallower than 14 ft were increased to 14 ft. Cells having depths equal to or greater than 14 ft were not modified. Two-year simulations of circulation, waves, and sediment transport for the proposed alternative basins were conducted.

CMS Model. Coupling of the CMS-Flow and CMS-Wave models allowed for integrated calculation of tidal elevation, tidal currents, waves, wave-driven currents, wave-induced setup and setdown, sediment transport rates, and morphology change. CMS-Flow is a two-dimensional circulation and sediment transport model. CMS-Wave is a steady state spectral wave model. When the models are coupled, CMS-Flow and CMS-Wave exchange information such that CMS-Flow provides total water depth and current velocity fields to CMS-Wave so that the waves can vary owing to changing water depth and interaction with the current. CMS-Wave provides wave properties to CMS-Flow for calculation of wave-driven currents, wave mixing, wave-induced setup and setdown, and wave-driven sediment transport.

Sediment transport is calculated within CMS-Flow by applying one of three possible types of transport formulations; (a) total load, (b) advection-diffusion, or (c) non-equilibrium transport (NET). Spatially variable grain size can be specified over the domain and entered into the sediment transport calculations. Morphology change is computed based on the sediment transport values with bed evolution being updated at user-prescribed intervals.

CMS model grids were developed to include East Rockaway Inlet, Hempstead Bay, and an offshore area that extends approximately 4.8 km offshore from the east jetty to a depth of 60 ft. Bathymetry for the model was obtained from an inlet survey conducted in September 2005, and from an existing, highly-detailed ADvanced CIRCulation (ADCIRC) mesh developed for Federal Emergency Management Agency applications. The existing deposition basins in the Inlet were represented in the model.

Sediment transport calculations require specification of median grain size, d_{50}. Analysis from seven grab samples taken inside the Inlet in November 1991 provided information on the spatial distribution of d_{50}. In addition to tidal forcing by ADCIRC, waves were also included in the simulations using CMS-Flow v4 implicit. CMS-Wave is embedded within this version of CMS-Flow. CMS-Flow and CMS-Wave exchange information every 3 hrs. Six 4-month-long simulations were conducted, being 2 years prototype time. Time steps were 10 min prototype, with output being written at 0.5 hr prototype intervals. Sediment transport was calculated by application of the NET algorithm. NET was selected because of its improved formulation and superior results compared to the total load and advection-diffusion formulations. Once calibrated, calculations of morphology change computed by NET are more accurate and realistic than those by the other methods.

Calibration of the sediment transport model was based on comparison of modeled existing condition sedimentation results to analytically-based accretion rates in the inlet. The modeling was aimed to compute accretion in the inlet between 61,000 m^3/yr (from the sediment budget) to 88,000 m^3/yr (averaged from recent channel dredging records). There was strong agreement between the actual and calculated shoaling areas for the ebb shoal dredging region. The dredged area lying on the northern side of the channel exhibited less agreement, with the calculated shoaling area being only a small portion of the dredged area. Over this 2-year simulation, 141,893 m^3 of material were calculated to accrete both in the channel and deposition basins. Complete details of the calibration procedure are presented in Offshore & Coastal Technologies, Inc. (in preparation).

CMS Model Simulation Results. Evaluation of proposed alternative basin performance was conducted by calculation of volume change, and by examination of shoaling and erosion patterns. Volume change for the existing condition and for the three proposed alternative basins were computed for eight cells defined within the inlet and ebb shoal complex (Figure 4). Development of the cells was based on dredging areas, ebb shoal accretion patterns, proposed alternative basin templates, and inclusion of the remainder of the inlet to represent the inlet and shoal system. Infilling rates and net volume changes for the defined cells differed from

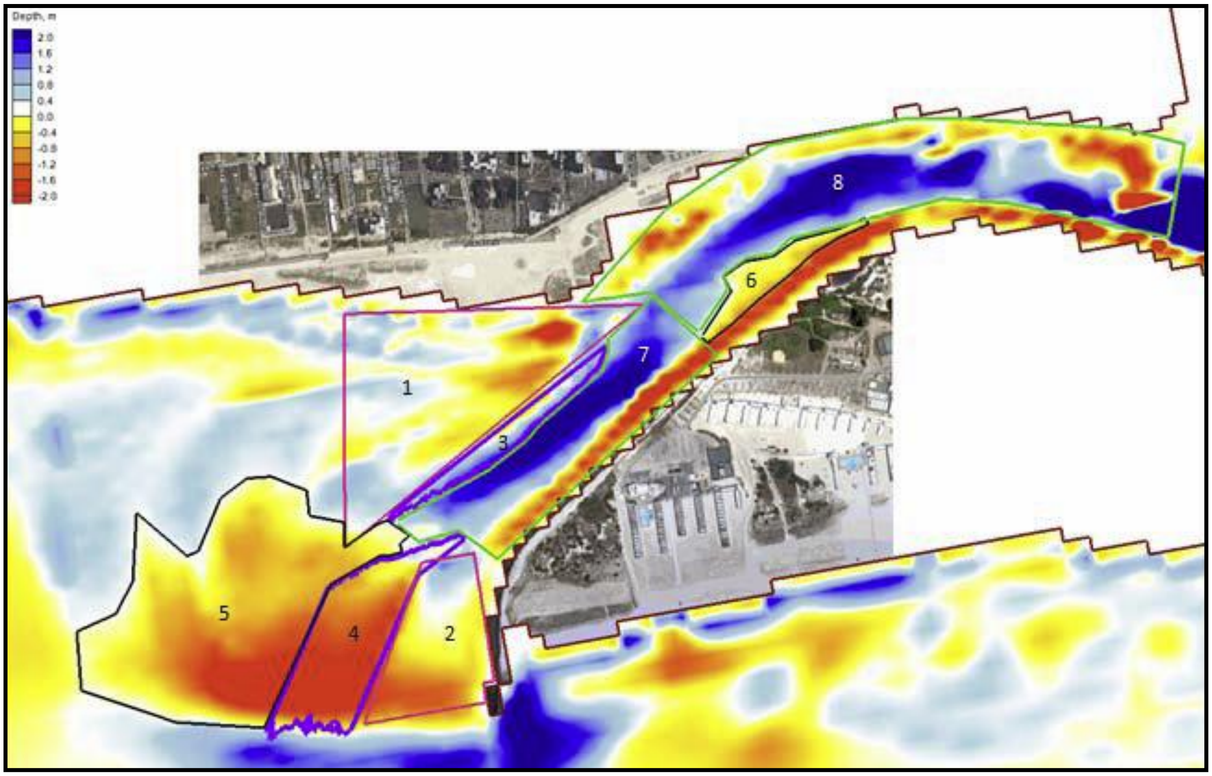

Figure 4. Cells defined for computing volume change, East Rockaway Inlet, NY.

Year 1 to Year 2, but the focus of this analysis was on the cumulative 2-year changes that correspond to the 2-year dredging cycle.

Estimates of annual infilling rates for the eight cells for quiescent and typical weather years are provided in Table 1 for the existing condition and proposed alternative basins. Values for quiescent years were calculated by averaging the January through August (non-storm conditions) infilling volumes for the two years of simulation, and then extrapolating those values out to one year. Values for the typical year were annualized directly from the 2-year volumes, which included the storm waves.

The values given in Table 1 are infilled volumes for all the analysis cells rather than only the volumes of sand deposited in the existing condition deposition basin (approximately Cells 3, 4, and 7). Under existing conditions, sand that deposits in Cell 2 would not likely be redistributed to other parts of the inlet system in subsequent years, but would be expected to remain in Cell 2 with a fraction transported offshore or toward the west along the outer ebb shoal. Sand that deposits in Cells 1, 6, and 8 will likely be mobilized either into other cells within the inlet system or bypassed to the west. The majority of sand that deposits in Cell 5 (the ebb shoal) is expected to continue being transported to the west under both existing and Alt 3 configurations.

Although Alt 1 is predicted to have reduced overall infilling as compared to the existing condition and to the minimum infilling during typical years for all of the alternatives, it will result in weaker currents through the inlet. These weakened currents are predicted to transition the sediment transport regime from self-scouring to depositional within a large area of the main inlet throat.

Table 1. Estimated Annual Infilling Volumes (m^3) for Quiescent and Typical Weather Years at all Analysis Cells, East Rockaway Inlet, NY.

	Existing Condition		Alternative 1 (Alt 1)		Alternative 2 (Alt 2)		Alternative 3 (Alt 3)	
Cell	Quiescent	Typical	Quiescent	Typical	Quiescent	Typical	Quiescent	Typical
1	27,662	25,742	67,109	36,271	15,386	14,149	15,950	14,065
2	5,309	24,757	5,912	13,221	28,112	39,950	30,318	35,563
3	3,412	947	5,783	2,352	6,700	3,542	5,821	3,030
4	35,480	65,870	10,010	17,963	21,371	34,198	21,273	43,414
5	87,821	104,724	37,975	39,451	51,869	96,198	48,068	80,382
6	6,140	5,844	6,542	3,010	8,633	9,318	8,606	9,299
7	26,678	26,076	54,984	33,203	9,880	8,902	9,116	8,271
8	59,304	41,277	25,804	13,110	26,210	25,586	26,272	25,620
Total	251,806	295,237	214,119	158,581	168,161	231,843	165,424	219,644

Alt 2 and Alt 3 were calculated to perform similarly. Both of these alternatives will increase sand bypassing over the present situation. About 25 percent less sediment enters the analysis cells each year. Additionally, both of these alternatives will increase the self-scouring potential of the inlet channel between the ebb shoal and back-bay area. The reduction in deposition in main channel Cells 7 and 8 is approximately 50 percent. Alt 3, however, appears to exert stronger scouring capability in the area where Cell 7 meets Cells 2, 4, and 5. Stronger scour capability in this area, as well as on the outer ebb shoal, may result in a greater tendency for the channel to naturally cut through the ebb shoal and maintain a navigable entrance.

Alt 3 appears to optimize natural bypassing while still providing between 70,000 (quiescent years) and 125,000 (typical years) m^3/yr of sand for bypassing in the new deposition basin (Cells 4 and 5). With its slight increase in self-scouring of the main channel (Cell 7), Alt 3 appears to satisfy the project objectives to the best degree. These findings should be confirmed using field monitoring surveys over the next several dredging cycles following construction, as also should the calculated potential migration of the navigation channel toward the east.

ALTERNATIVE SELECTION. In general, there was minimal adverse impact to the inlet hydrodynamics for all proposed alternative basins, while Alt 2 and Alt 3 would enhance the Back Bay flushing capacity due to increased ebb current strength at the inlet throat. All proposed alternative basins will have minimal impact to the inlet stability, while Alt 1 may introduce a wider flow area at the inlet throat initially and then adjust naturally. All proposed alternative basins would enhance the inlet sediment budget through increased natural sediment bypassing, and reduced net loss of littoral material within the inlet system due to net northward transport during storm. Alt 3, which includes an expanded deposition basin just to the west of the east jetty, showed the greatest potential for optimum utilization based upon its projected performance in the CMS modeling. Figures 5 and 6 illustrate net sediment transport patterns for quiescent conditions, and for storm conditions, respectively.

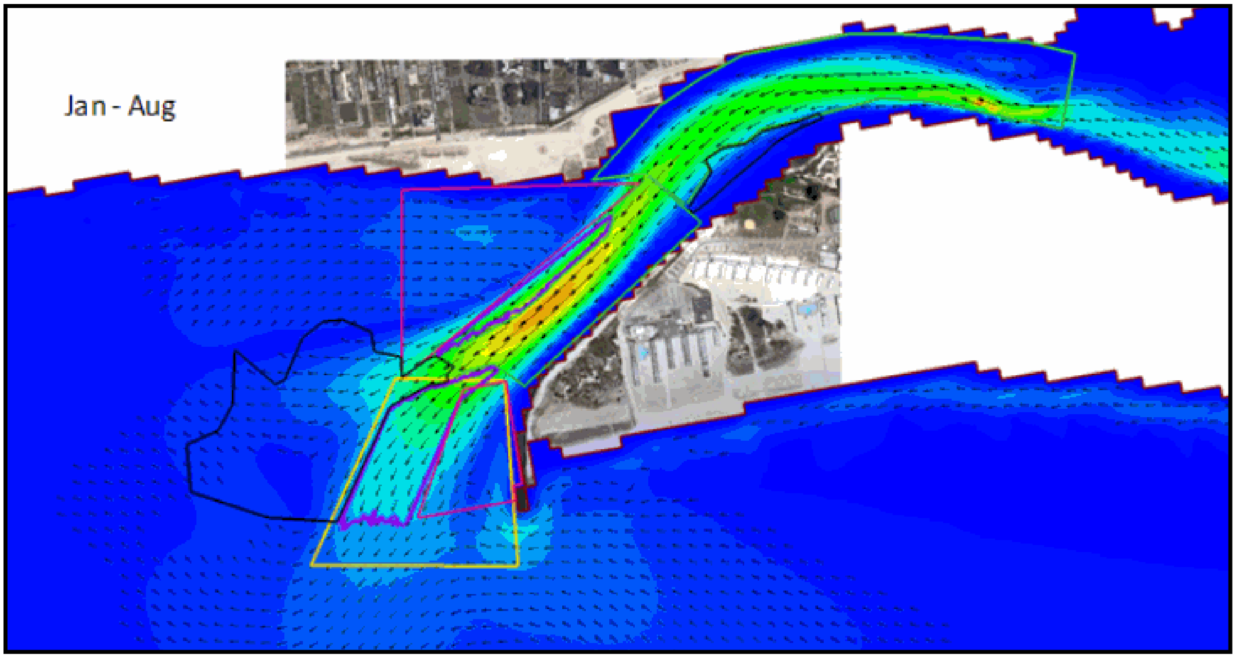

Figure 5. Alt 3 net sediment transport for non-storm conditions, East Rockaway Inlet, NY.

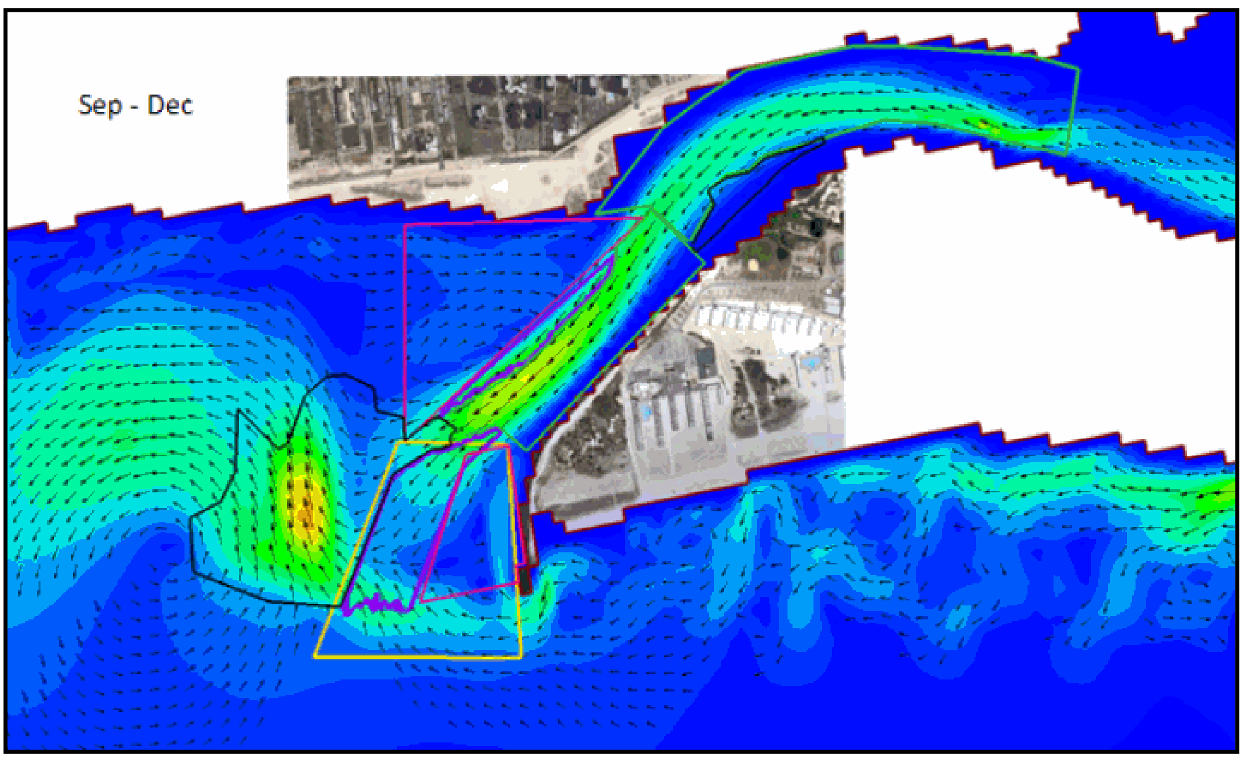

Figure 6. Alt 3 net sediment transport for storm conditions, East Rockaway Inlet, NY.

Sediment budget diagrams were prepared to illustrate sediment fluxes, and channel and deposition infilling rates for existing/future and for the three alternative basins (Figures 7 through 10). The sediment budget diagrams have closed boundaries at the eastern end of the inner channel, southern limit of the outer channel, and western limit of the ebb shoal. The estimated channel infilling rates are shown together with the estimated infilling rates of the proposed alternative basins. For each alternative basin, the available periodic bypassing rate and the required channel maintenance dredging rate are balanced with upstream influx, natural bypassing, and estimated sediment sinks (loss). As shown in the sediment budget diagrams, the existing condition sediment sinks are reduced while the natural bypassing rates are enhanced for all three alternatives. Maintenance dredging is greatly reduced for Alt 3 by including the outer channel as a part of the deposition basin. The comparison of alternative basins is summarized in Table 2.

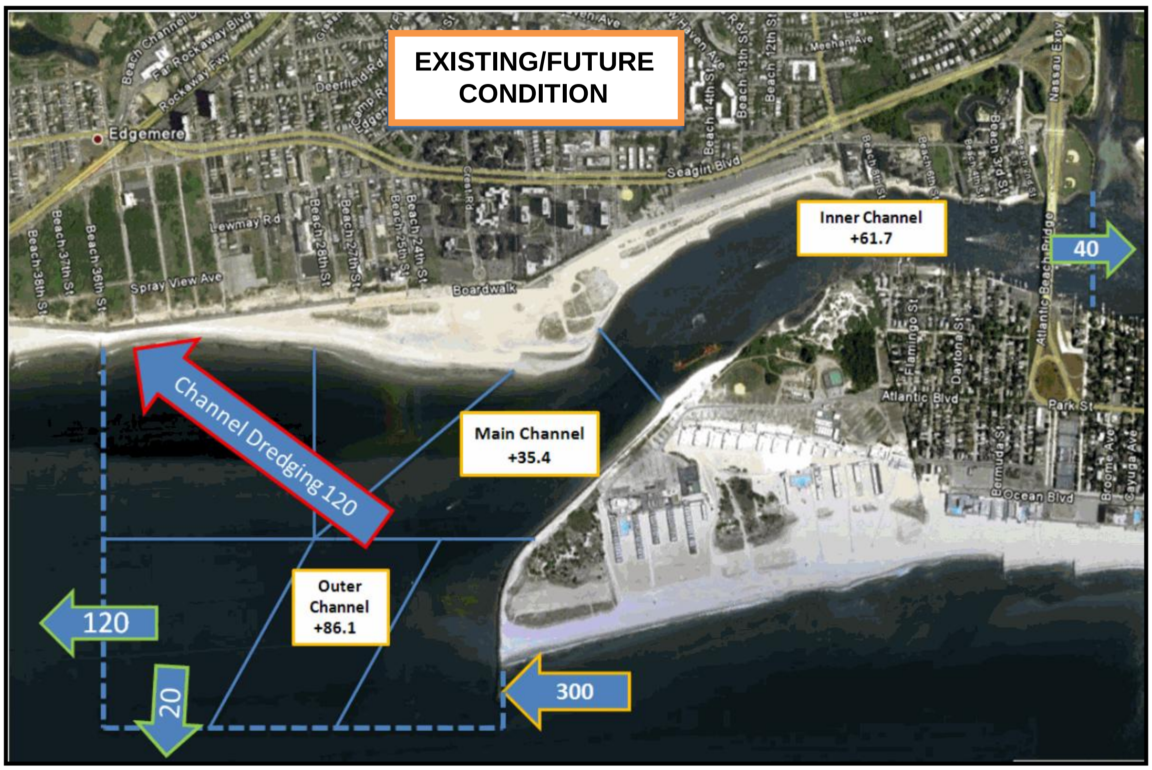

Figure 7. Existing/Future condition inlet sediment budget, East Rockaway Inlet, NY (rates in 1,000 yd^3/yr).

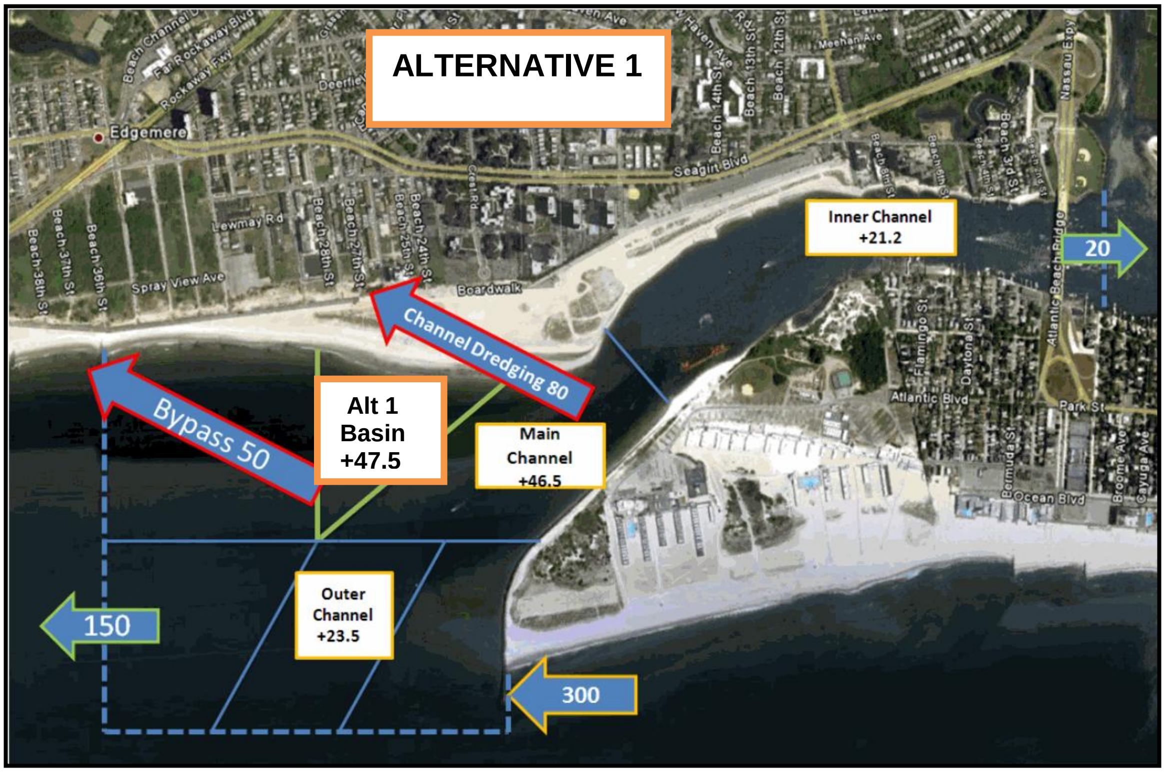

Figure 8. Deposition Alternative Basin 1 (Alt 1) inlet sediment budget, East Rockaway Inlet, NY (rates in 1,000 yd^3/yr).

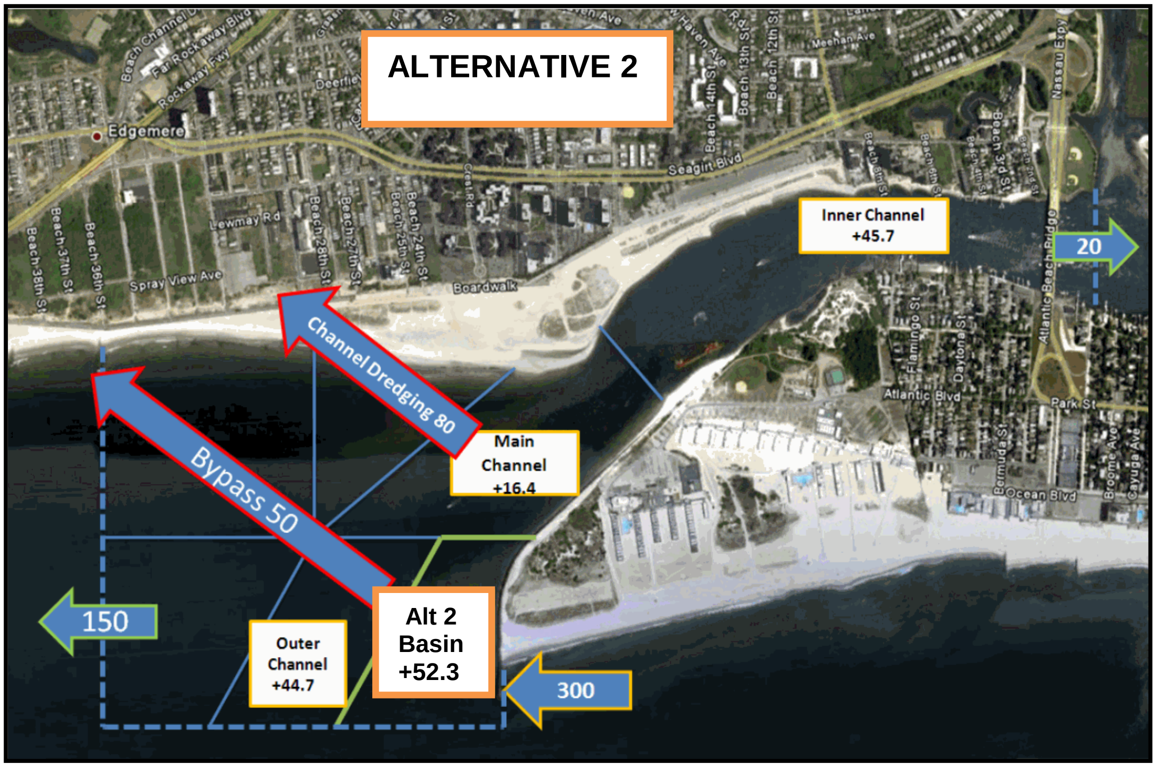

Figure 9. Deposition Alternative Basin 2 (Alt 2) inlet sediment budget, East Rockaway Inlet, NY (rates in 1,000 yd^3/yr).

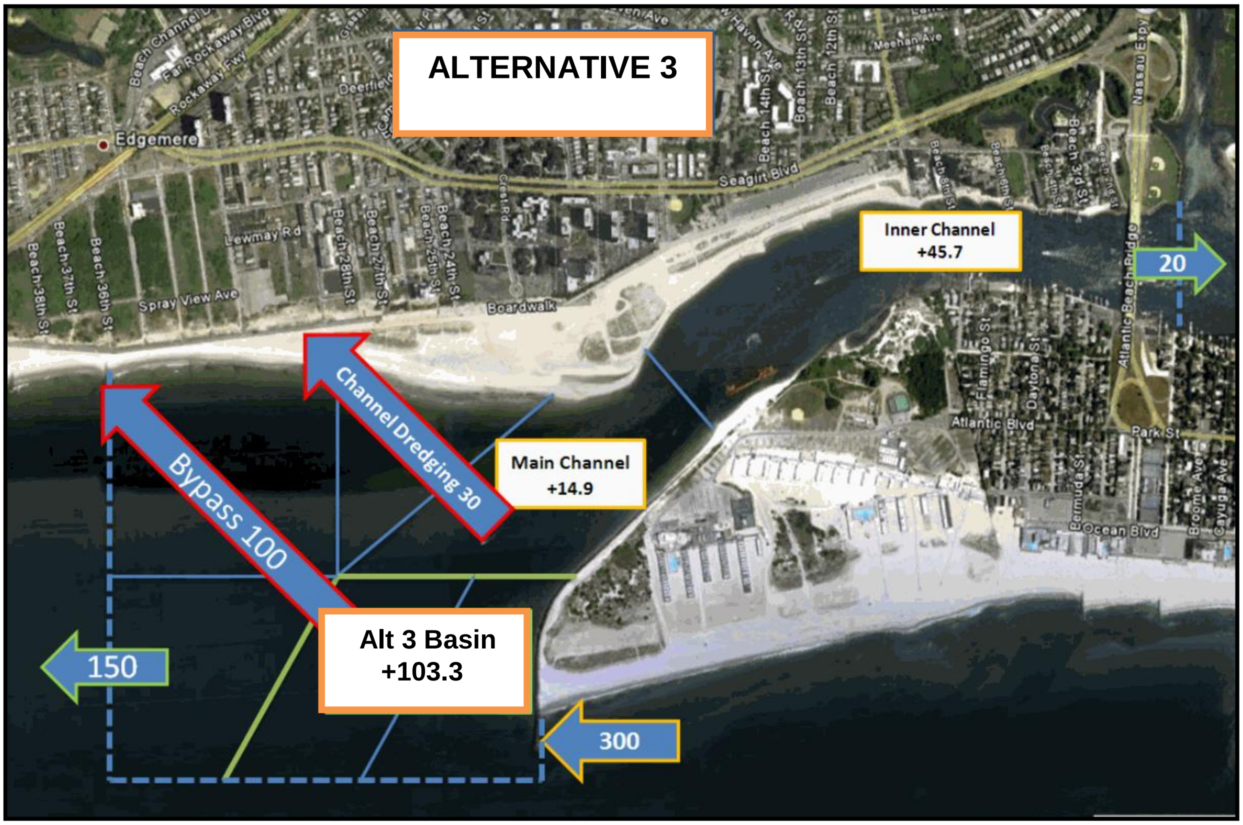

Figure 10. Deposition Alternative Basin 3 (Alt 3) inlet sediment budget, East Rockaway Inlet, NY (rates in 1,000 yd^3/yr).

Note in Table 2 that, for Future Condition, the estimated influx rate is increased to 300,000 yd^3/yr and the annual maintenance dredging rate is increased to 120,000 yd^3/yr (Offshore & Coastal Technologies, Inc., in preparation).

Table 2. Comparison of Existing/Future Conditions and Deposition Alternative Basins (volume and rates in 1,000 yd^3/yr).

	Existing/Future	Alternative 1 (Alt 1)	Alternative 2 (Alt 2)	**Alternative 3 (Alt 3)**
Available Borrow Volume	-	50	50	**100**
Maintenance Dredging Required	120	80	80	**30**
Natural Bypassing	120	150	150	**150**
Net Loss	60	20	20	**20**
Inlet Hydrodynamics	-	Reduced Ebb Current Speed	Increased Ebb Current Speed	**Increased Ebb Current Speed**
Tidal Flushing in Back Bay	-	No Change	Enhanced	**Enhanced**
Inlet Stability	-	Initial Change	No Change	**No Change**

CONCLUSIONS. It was determined that deposition Alternative Basin 3 (Alt 3) should be selected as a permanent deposition basin, and as part of the Regional Sediment Management implementation program of the Rockaway Erosion Control project. This recommended alternative offers the highest reliable borrow volume and the least frequent channel maintenance dredging. The proposed permanent deposition basin would provide approximately 100,000 yd^3 annually for periodic nourishment. The recommended deposition basin is expected to reduce the maintenance dredging requirement from the existing once every 1- to 2-year frequency to once every 4 years or longer. Additionally, this alternative would enhance tidal flushing without impact to the inlet stability. The recommended permanent Alt 3 will provide the best reliable borrow source for periodic nourishment, will enhance the natural bypassing of the Inlet, and will reduce net loss of the regional sediment.

ADDITIONAL INFORMATION. This Coastal and Hydraulics Engineering Technical Note (CHETN) was prepared by US Army Engineer District, New York (NAN), with numerical modeling support by Offshore & Coastal Technologies, Inc. (OCTI), East Coast, Chadds Ford, PA. (http://www.offshorecoastal.com). NAN point of contact (POC) for this study is David W. Yang. Additional information pertaining to the RSM can be found at the Regional Sediment Management website http://rsm.usace.army.mil.

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US Army Engineer District, New York. (in preparation). Regional sediment management, East Rockaway Inlet, New York, utilizing the USACE Coastal Modeling System. (Numerical modeling support provided by Offshore & Coastal Technologies, Inc., East Coasts, Chadds Ford, PA).