NEW JERSEY ATLANTIC BACK BAYS REGIONAL SEDIMENT FRAMEWORK

Sediment Quantity & Dynamics

Authored by:

Kimberly McKenna, MS, PG & Danielle Dyson, BS I Stockton University, Coastal Research Center

Thomas Herrington, PhD I Monmouth University, Urban Coast Institute I October 2023

Introduction

Sediment movement within the New Jersey Atlantic back bays impacts navigation via shoaling, reduces habitats via eroding marshes, or muddles bayside community infrastructure via clogged outfalls. Sediment transport patterns can be punctuated by large storms or flood events. With rising sea level and the potential for increased large storms, existing sedimentation patterns may be altered in a way that increases the risks of habitat loss or to public safety.

Goal of White Paper

i. identify what is known about New Jersey Atlantic back bays sediment systems (sources and sinks, transport mechanisms, budgets)

ii. identify sediment system data/knowledge gaps

The New Jersey Atlantic Back Bays

Geomorphologic Features & Terms Used

The New Jersey Coastal Plain physiographic province hosts a variety of geomorphologic features including freshwater tributaries, estuaries, lagoons and bays (back bays), bay islands, tidal inlets, and headland, barrier spit, and barrier island beaches. Table 1 provides the major geomorphological features that occur within each of the New Jersey Atlantic coastal counties. These features are potential sediment sources or sinks. Figures 1-5 show the state and federal channels within the Atlantic back bays.

Table 1. Major Features of the New Jersey Atlantic Coast

County	Features
Monmouth	Navesink River, Shrewsbury River, estuarine lakes (Shark River, Lake Takanasseel), headland beaches
Ocean	Manasquan Inlet, upper Barnegat Bay, Metedecunk River, Toms River, Barnegat Inlet, barrier spit, Barnegat Bay/Manahawkin Bay/Little Egg Harbor complex, Little Egg Inlet, Long Beach Island
Atlantic	Great Bay, Mullica River, Reeds Bay, Absecon Bay, Lakes Bay, Abescon Creek, Absecon Inlet, Great Egg Habor Inlet, Little Beach Island, Brigantine Island, Absecon Island
Caper May	Great Egg Harbor Bay, Peck Bay, Strathmere Bay, Corson Sound, Ludlam Bay, Townsend Sound, Stites Sound, Great Sound, Jenkins Sound, Grassy Sound, Richardson Sound, Susnet Lake, Jarvis Sound, Cape May Harbor, Great Egg Harbor River, Cape May Canal, Corson Inlet, Towndsends Inlet, Hereford Inlet, Cape May Inlet, Ocean City (Peck's Beach), Ludlam Island, Seven Mile Island, Five Mile Island, Cape Island

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Figure 1. Monmouth County features.

Figure 2. Northern Ocean County features.

Figure 3. Southern Ocean County features.

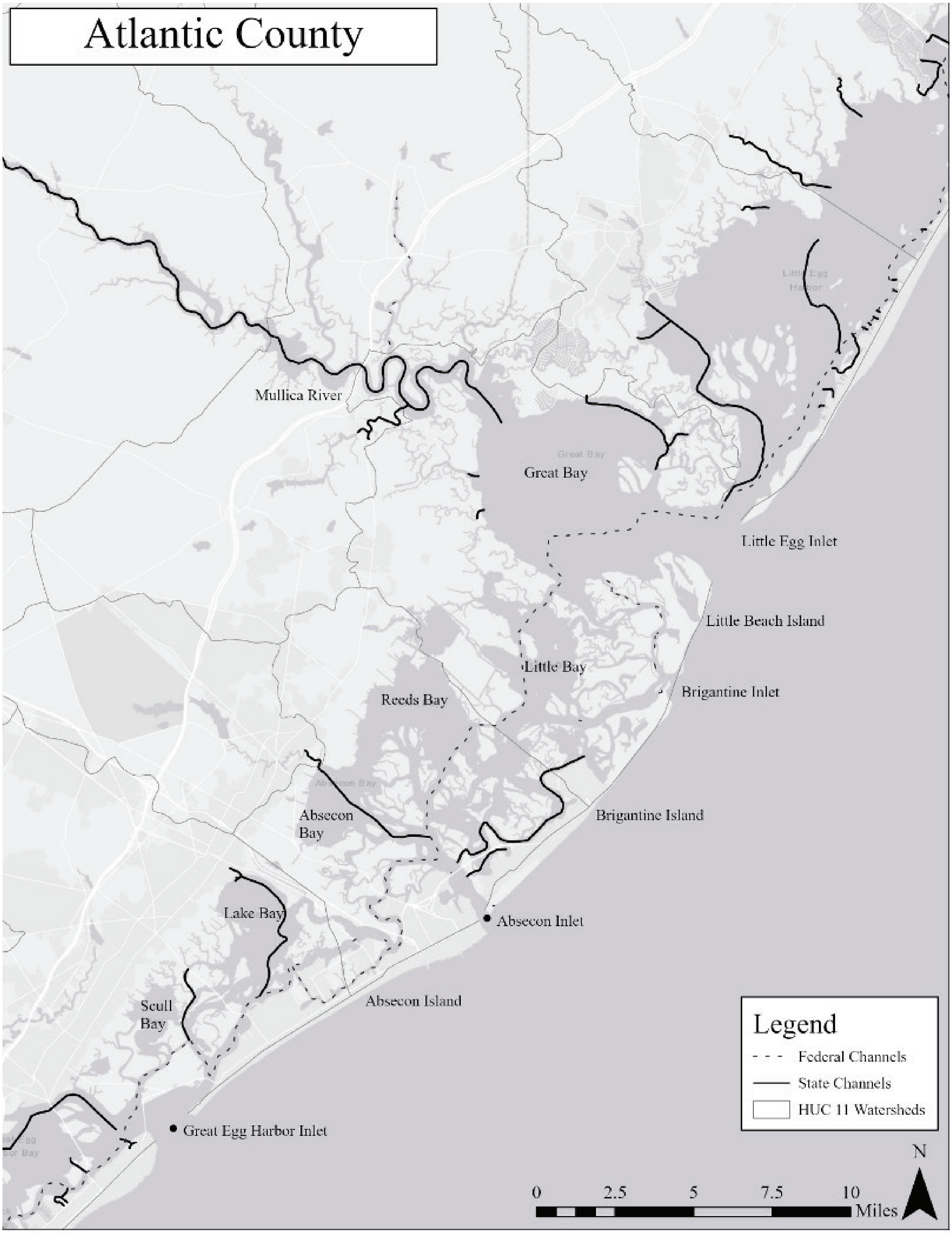

Figure 4. Atlantic County features.

Figure 5. Cape May County features.

Sediment Sources

The general distribution of sediments along the New Jersey Atlantic back bays is determined by the geomorphologic landforms and coastal processes found within the coastal watersheds. Sediments are brought to the back bays via terrestrial freshwater tributaries and streams, eroding marshes (biogenic sediments) located within the estuaries/lagoons, erosion and resuspension of older estuarine sediments, the Atlantic Ocean via inlets or overwash, natural and dredged channels, ocean beach-nearshore exchange (including wind-blown sediments), and littoral currents or by other anthropogenic activities such as road building, beach nourishment, channel dredging, and utilities maintenance (Figures 6 and 7).

Figure 6. General sediment pathways along the New Jersey coast.

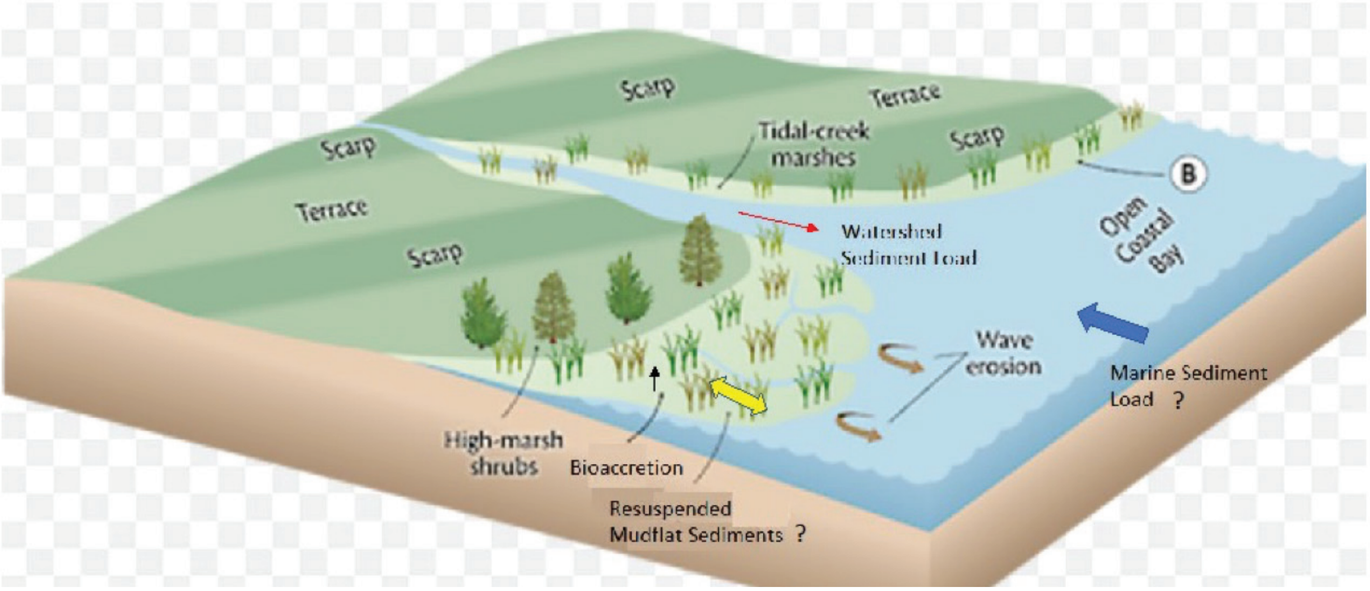

Figure 7. General sediment pathways at tidal marshes.(Modified from Integration and Application Network (ian.umces.edu/media-library), Jane Thompson illustrator)

Studies of long-term sediment deposition rates in Atlantic coastal New Jersey are sparse but one found a mean range from 4.4 to 7.4 mm/yr in open-water bays and sounds to 4.5 mm/yr on the marsh surface (Kirby and Widjeskog, 2013).

Terrestrial freshwater sources have been reported to contribute 0.2 inches (5 mm) of sediment per year (Kana et al., 1988). In Monmouth County, several small freshwater tributaries feed into the Navesink and Shrewsbury rivers with both estuaries having a direct connection to Sandy Hook Bay/Raritan Bay. Studies of sediments in the New Jersey back bays predominantly focus on the Barnegat Bay estuarine system (Olsen et al., 1980; Rogers et al, 1990; Kennish, 2001). In Barnegat Bay, sediment grain size increases from the mainland marshes to the barrier beaches. Fine grained sediments (silts and clays) originating from river flow and marshland runoff are found along the mainland shore of Barnegat Bay. This transitions to sands in the inlet flood- and ebb-tidal deltas (Olsen et al., 1980; Kennish, 2001). Rates of sedimentation were found to be highest at the river mouths, along the New Jersey Intracoastal Waterway (NJIWW), and at the inlets (Rogers et al, 1990).

In a study sponsored by the New Jersey Department of Environmental Protection, the USGS determined sediment loadings into Barnegat Bay between 2012 and 2015 (Wilson, unpublished). During the period of study, sediment loads from Toms River, Metedeconk River, Cedar Creek, and several smaller tributaries contributed 2,839,000 kg (3,713 cubic yards) per year with 36% supplied by Toms River, 26% supplied by Metedeconk River, and the remaining from Cedar Creek and the smaller tributaries (Wilson, unpublished). Also studied were the effects of Barnegat Inlet, Little Egg Inlet, and the Point Pleasant Canal on water levels within the bay. Calculated water balances indicated that the volume of seawater entering and remaining in the bay after each tide cycle significantly exceeded the volume of freshwater entering the bay with periodic expulsions of excess water through the inlets (Wilson, unpublished). However, inlet sediment loads were not determined in the study.

Another USGS study quantified suspended-sediment fluxes in two tidal creeks in the Barnegat Bay estuary, New Jersey, from August 11, 2014, to July 10, 2015, and found suspended sediment concentrations ranged from 0.0047 to 0.0448 g/l (Suttles et al, 2016 USGS data report).

This likely influences back bay turbidity levels while it is uncertain how much of the suspended sediments are transported to the back bay tidal marshes and channels. The small river sediment loads measured by the USGS studies is typical of most watersheds along the mid-Atlantic coastal plain.

Regional differences in river-transported sediments into coastal bays are a function of the distributions of watershed size, which is highly skewed toward very small watersheds (Ensign et al, 2023). Within the New Jersey Atlantic Coastal Bays, watershed areas range from a high of 2,000 km^2 to a low of 1 km2 (Sediment Pancakes). This pales in comparison to the Delaware Bay Estuary that drains a watershed area of over 35,000 km^2 with an annual sediment load on the order of 1.5 billion kg/yr. (Sediment Pancakes). The low slope watersheds and associated sediment loads are too small to contribute a sediment volume that can meaningfully affect sediment deposition along the bay bottom, navigation channels and the tidal marshes on an annual basis (Ensign et al, 2023). Typical river sediment accretion rates within the coastal bays is estimated to be on the order of 0.1 mm/yr. (Sediment Pancakes).

Weis et al (2021) conducted a literature review of marsh evolution in NJ to determine the status and future of tidal marshes in New Jersey faced with sea level rise. Based on Surface Elevation Tables (SETs) data collected by Barnegat Bay Partnership, tidal marsh elevation change in the Barnegat Bay over a period of 5 to 7 years ranged from -2 to +5.8 mm/yr. with an average value of 2.85 mm/yr. (Weis et al, 2021). The imbalance between river supplied sediment and vertical accretion of the tidal marshes in Barnegat Bay can be attributed to above and below ground organic matter production (estimated to be up to 3 mm/yr. by Morris et al, 2016), mudflat sediments resuspended by tidal currents and marine sediments derived from erosion of coastal landforms (Figure 7).

Large storms influence sedimentation in the New Jersey back bays. Following Hurricane (Superstorm) Sandy, USGS researchers found that surge created by the epic storm added a net 218,722 cubic yards (200,000 cubic meters) of sediment in the Barnegat Bay/Manahawkin Bay/Little Egg Harbor estuarine complex (Miselis et al, 2015). This amounted to 10% of the total estuarine depositional volume. Most sediments were carried through the barrier breaches that spontaneously ensued near Mantoloking in northern Ocean County. But some sediments were transported through Barnegat Inlet and Little Egg Inlet. Sediment deposition was not spread uniformly throughout the complex but were found in discrete deposits in the deeper areas closer to the back barriers (Miselis et al, 2015). Model runs using data collected from the storm showed that local sediment resuspension levels were larger when the storm's winds were stronger and water levels were shallower. The resuspended sediments were redistributed from areas below sea level to those above sea level, indicating the storm's transfer of sediments from the estuary to marsh surfaces (Defne et al., 2019). This was a consistent finding for hurricane-induced sediment transport.

Similar deposition patterns were found in Assateague Island and adjacent areas following Sandy (Smith et al, 2015). Marine overwash fans on the bay side of the barrier island complex were formed due to elevated water levels along oceanfront generally transporting sediment from offshore shoals and bars, foredunes, or both in areas where the barrier island has remained topographically low. In contrast, surface sediment on landside marshes was found to be much finer-grained than the overwash deposits. Smith et al (2015) postulate that given a decrease in organic matter and increase in bulk density, the fine-grain texture, and the lack of sand deposition on the marshes that the sediment originated as estuarine overwash (that is, sediment re-suspended and advected from the estuary, tidal flats, or marsh edge and onto the marsh during storm conditions). Smith et al (2013) found similar characteristics in marshes on the periphery of Mobile Bay, Alabama. This process of storm-generated estuarine deposition is abundant in the literature (e.g., Delaune et al, 1986; Nyman et al, 1995; Turner et al, 2006; Törnqvist et al, 2007).

Sediment contributions from eroding marshes and mosquito ditching to adjacent marshes and lagoons/bays was investigated by Kirby and Widjeskog (2013). Table 2 shows much less sediment deposition at ditched marshes than at non-ditched marshes.

Sediment accumulation rates on tidal marshes in Barnegat Bay were found to be 0.18 to 0.30 cm/yr and were found to be comparable to other Mid-Atlantic barrier-lagoon marshes but fall below rates of relative sea level rise (Velinsky et al, 2011).

Table 2. Sediment deposition rates from Kirby and Widjeskog, 2013.

Location	Rate mm/yr (± SE if available)	Method	Source
Jenkins and Great sounds[a]	5-10	Sediment core	Kelley, 1975
Great Sound (deeper sections)	1.8-5.4	Radiometric ^{210}Pb	Thorbjarnarson *et al*., 1988
Great Sound	8.9	Deposition model	Young, Weisman, and Lennon, 1988
Great Sound	1.7-5.2	Corrected Thorbjarnarson *et al*. (1985) for compaction	Faas and Carson, 1988
Absecon marsh surface[b]	3.9 ± 0.0	Radiometric ^{210}Pb	Erwin *et al*. 2006a
	3.7 ± 0.0	Radiometric ^{210}Pb	
E.B. Forsythe National Wildlife Refuge marsh[c]	3.4 ± 0.1	Radiometric ^{210}Pb	Erwin *et al*. 2006a
	4.1 ± 0.0	Radiometric ^{210}Pb	
Little Beach[c]			
Surface (n = 3)	3.8 ± 1.0	Surface elevation table	Erwin *et al*. 2006b
Pond (n = 3)	7.9 ± 1.1	Surface elevation table	
Seaville Study Area			
All open water	0.082-0.16	Historical records and contemporary measures of ditches	Kirby and Widjeskog, 2013
All marsh surface	0.036	Historical records and contemporary measures of ditches	

[a] About 10 km SW of the Seaville Study Area
[b] About 16 km NE of the Seaville Study Area
[c] About 39 km NE of the Seaville Study Area

Sediment Budgets/Sediment Transport Processes

Defne and Ganju (2014) applied hydrodynamic and particle tracking models to identify the mechanisms controlling flushing residence time, and spatial variability of particle retention in Barnegat Bay and Little Egg Harbor. The models demonstrated a pronounced northward subtidal flow from Little Egg Inlet in the south to Pt. Pleasant Canal in the north and attributed this to the frictional effects in the inlets, but the tides were relatively inefficient in flushing the northern end of the Bay. As a result, the models show better flushing in the southern half of the estuary and better particle retention in the northern portion of the Barnegat estuary. Also identified was that offshore forcing were stronger drivers of exchange than riverine inflow.

The inference that estuarine and marine sediments sources must help offset river sediment loads requires more detailed assessments of the hydrodynamic factors affecting sediment transport (Ensign et al, 2023) within the New Jersey back bays. Logs of sediment volume dredged for navigation channels indicate significant sediment transport occurring within the coastal bay system. A determination of sediment transport pathways and sediment budgets for the back bays is required to effectively manage sediment and the beneficial use of sediment for community and ecosystem resilience. Presently, there is a dearth of data regarding sediment transport into and out of the back bay systems over sufficient spatiotemporal scales to allow for even simple conceptual sediment transport models to be developed (Ganju, 2019).

Sediment Distribution & Classification

Figure 8 shows an example of sediment distribution in the back bays of Atlantic County (from *The Nature Conservancy Coastal Resilience New Jersey Marsh Explorer* tool). The maps were created from soil cores and geographic information system interpolation (Stockton University Coastal Research Center, 2018). In general, sandier areas are closer to the inlets while the embayments and tributary mouths have less sand content. The New Jersey Bay Islands Restoration Planner includes the USDA-NRCS subaqueous soils map for Barnegat Bay/Little Egg Harbor. These data can be extracted from the NRCS Web Soil Survey.

The US Army Corps of Engineers (USACE) completed sediment sampling of the back bays from Great Bay to Cape May in 2002 to evaluate potential impacts from the dredging of the New Jersey Intracoastal Waterway (NJIWW). Sediments found within the NJIWW consisted of predominantly silt and sand that varied by location. The channels landward of Brigantine and Absecon Island consisted of mixtures of fine sand and silt. From Ocean City to Seven Mile Island sediments ranged from fine sand to silt, and from Hereford Inlet to Cape May the sediments were composed of predominantly fine sands (Table 3) (US Army Corps of Engineers, 2009). Table 4 describes the dominant soil types in the New Jersey Back Bays (USACE, 2021, Table 11).

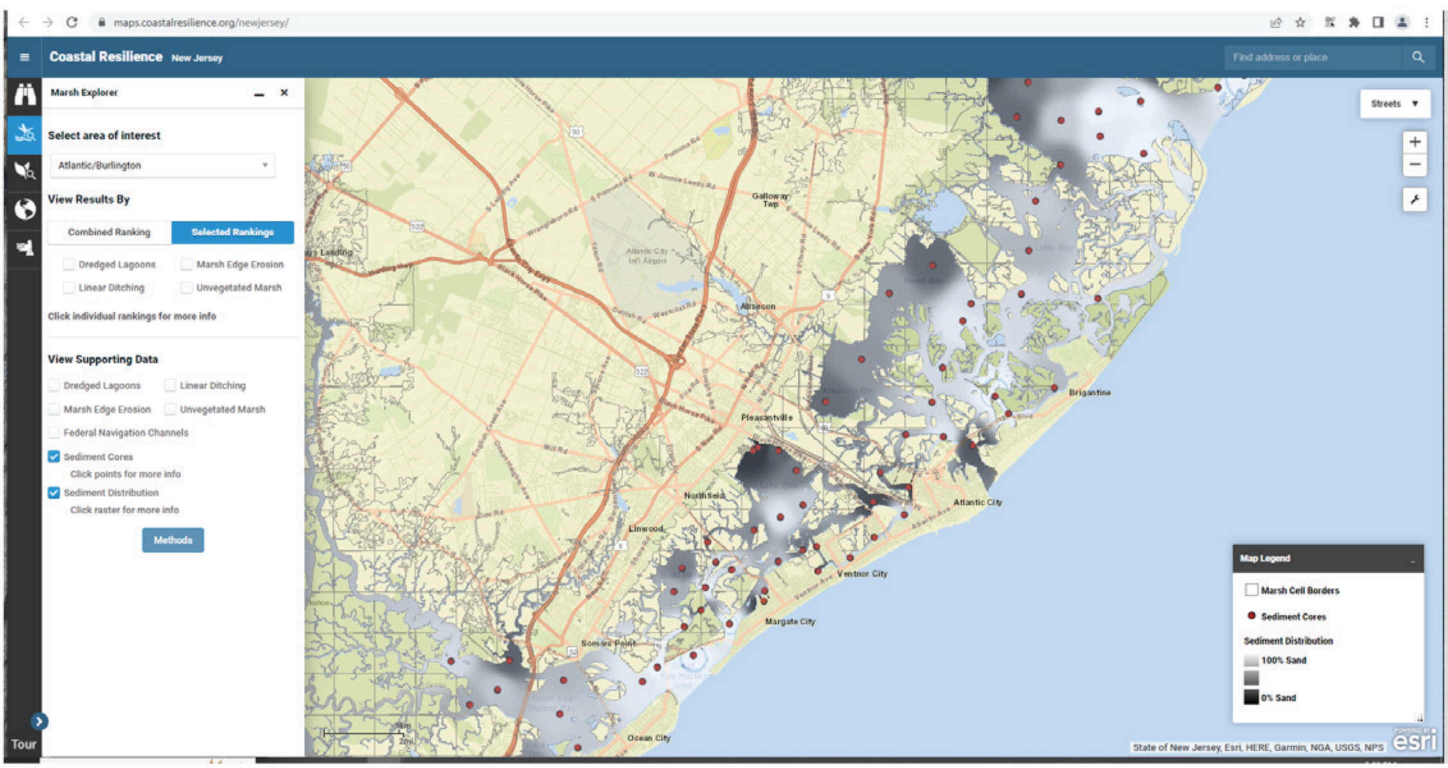

Figure 8. Map showing sediment distribution in the New Jersey Back Bays in Atlantic County (The Nature Conservancy, 2017).

Table 3. Descriptions of sediment samples obtained by the US Army Corps of Engineers for the channels from Great Bay to Cape May (US Army Corps of Engineers, 2009)

TABLE 2-14SEDIMENT COMPOSITION BY REACH			
Maintenance Dredge Study Area Designation (Corps)	Njdep Reach Designation	Reach Distance (Miles)	Sediment Composition
A1	21	3	AID #144-#136 is Silt; AID #136 to #127 is Sand
A1	20	3	80% Fine Sand 20% Silt
A2	19	6	Sand
A2	18	1.6	40% Sand 60% Silt
B1	17	1.5	50% Sand 50% Silt
B2	16	1	?
B3	15	4.8	Sand
C1	14	0.75	?
C2	13	6	Silt
C2	12	1.1	70% Silt 30% Sand
C2	11	3.1	Sand
C3	10	2.3	AID #352 to #345 is Silt; AID #345 to #339 is Sand
D1	9	3	Sand
D2	8	1.65	Sand
D2	7	2.2	Sand
E1	6	3.5	Sand bay ward of Ferry; Silt at Ferry; sand east of Ferry
E1	5	2.4	Fine Sand to Sand
E2	4	1.6	AID #10 to #6A is silt; AID #6A to #6C is sand
E2	3	1.2	Silt
E2	2	1.5	Silt
E3	1	2.1	Sand bay ward of Ferry; silt at Ferry; sand east of Ferry

Table 4. Descriptions of sediment samples obtained by the US Army Corps of Engineers for the channels from Great Bay to Cape May (US Army Corps of Engineers, 2009)

Soil Association	County	Properties
Downer-Sassafras-Fort Mott	Cape May	Well-drained sandy loams or loamy sands in high landscape positions.
Downer-Hammonton-Sassafras	Atlantic	Nearly level or gently sloping, well drained to somewhat poorly drained soils that have a loamy subsoil in high or intermediate landscape postilions.
Downer-Evesboro	Ocean	Nearly level or gently sloping, well drained and excessively drained, loamy, and sandy soils on uplands on broad, high, intermediate landscape postilions.
Manahawkin-Atsion-Berryland	Ocean	Nearly level, very poor drained and poorly drained, organic, and sandy soils on lowlands.
Hammonton-Woodstown-Klej	Cape May	Nearly level, moderately well-drained and somewhat poorly drained soils that have dominantly loamy subsoil and a sandy substratum in intermediate landscape positions.
Sassafras-Aura-Woodstown	Atlantic	Nearly level or gently sloping, well drained and moderately well drained soils that have a loamy subsoil in high to intermediate landscape positions.
Sassafras-Downer-Woodstown	Monmouth, Burlington	Nearly level to steep, deep, well drained, and moderately well drained, loamy soils; on uplands.
Klej-Lakehurst-Evesboro	Atlantic	Nearly level to gently sloping, excessively drained to somewhat poorly drained soils that have a sandy sub-soil in high to intermediate landscaper positions.
Pocomoke-Muck	Cape May	Nearly level, very poorly drained soils that have a loamy subsoil and a sandy substratum and soils that are organic throughout in low landscape positions.
Atison-Muck-Pocomoke	Atlanta, Burlington	Nearly level, poorly drained soils that have a sandy or loamy subsoil, and organic soils underlain mainly by sand that are organic throughout in low landscape positions.
Tidal Marsh	Cape May, Atlantic, Burlington	Nearly level, very poorly drained silty or mucky tidal flats that are subject to daily flooding.
Sulfaquents-Sulfihemists and Hooksan	Ocean, Monmouth	Nearly level, poorly drained, mineral, and organic soils on tidal flats and sand dunes and beaches (Hooksan).
Coastal beach-Urban Land	Cape May, Atlantic	Nearly level to strongly sloping barrier beaches and areas developed for residential and commercial uses.
Urban land-Fripp	Ocean	Urban land on nearly level and gently sloping excessively drained sandy soils; beaches on the barrier islands.

Turbidity, Sediment Resuspension, Sedimentation

Dredging and dredged material placement is necessary to maintain navigable waterways. However, these activities can alter water quality, at least, temporarily. The following terms are defined in context with the New Jersey back bays.

Turbidity – *"Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, very tiny inorganic and organic matter, algae, dissolved colored organic compounds, and plankton and other microscopic organisms."* (USGS, accessed 2023).

Sediment Resuspension – *"the suspension and redistribution of previously deposited sediment particles in the water column due to hydrodynamic forcing. Sediment suspension is the mobilization and entrainment of sediment particles from the bed due to hydrodynamic forcing."* (Hsu, 2016).

Sedimentation – *"the action or process of forming or depositing sediment"* (Merriam-Webster)

Turbidity is commonly measured in NTU (nephelometric turbidity units) using hand-held or mounted sensors that are placed in the water column for either spot- or longer-term intervals. New Jersey Coastal Zone Management (CZM) rules (N. J. A. C. 7:9B Surface Water Quality Standards) regulates NTU in coastal waterbodies. Many permits issued by the state require measurements of turbidity during sediment placement, and there may be further requirements if NTU levels are exceeded. A more detailed discussion on the state regulations is included in the *Sediment Quality* white paper.

Sediment resuspension is commonly measured in TSS (total suspended solids) or Suspended Sediment Concentration (SSC) in mg/l. Both impact water clarity and visibility and are indicators of local water quality conditions. To estimate TSS or SSC, water samples are collected and typically sent to a lab for analysis. The New Jersey CZM water quality rules do not have a condition for TSS or SSC and sometimes permit conditions require that both NTU and TSS measurements are collected. Problems can arise when comparing the two metrics if different instruments are used or if laboratory procedures are altered (McKenna et al, 2023). Measuring NTU does not provide the appropriate information to quantify resuspension in the water column.

Resuspension of sediments during dredging or dredged material placement could affect surrounding habitats, though the impacts may be temporary. Data from USACE indicate that placed sediment does not travel far, and high wind events (> 5 m/s or >11 mph) can contribute to higher turbidity variability (Fall et al, 2021). This reinforces that temporary increases in turbidity in the natural back bay environment are common and species have learned to adapt to sudden changes. Ganju (2019) noted that sediment transport into landside tidal marshes is associated with persistent or episodic high suspended sediment loads that create a turbidity maximum (e.g., Smith et al, 2015). A back barrier marsh in a suspended sediment poor environment will likely rely on storm-induced overwash from the oceanside to periodically move the sand-marsh line landward (Walters and Kirwan, 2016).

Questions that need to be addressed include:

- What causes more habitat impacts – sediment resuspension or turbidity?
- Does boat traffic have a greater impact on sediment resuspension or turbidity than sediment placement?
- Is the sediment staying where it is placed? How do currents and winds affect resuspension?
- Are there viable techniques and models to track or measure sediment movement?

Ongoing Research

Ongoing research in sediment movement along the New Jersey Atlantic coastal zone is concentrated predominantly in areas with multiple collaborators. In 2019, the USACE Philadelphia District and Engineer Research and Development Center (ERDC) partnered with the NJDEP-Division of Fish and Wildlife and The Wetlands Institute (TWI) to create the Seven Mile Island Innovation Laboratory, a field research facility to test innovative practices for dredged material management and nature-based solutions for restoring degraded tidal marshes (USACE, 2019). ERDC researchers monitored turbidity and hydrodynamics during sediment placement on Sturgeon Island. Study observations found that turbidity levels quickly returned to background conditions when placement operations ceased (Fall et al, 2021). ERDC researchers also partner with academia for landscape designs and monitoring assistance (e.g., University of Pennsylvania, Boston College).

Summary

Very little is known about sediment transport in the New Jersey back bays beyond dredging volumes from channel maintenance. Most information comes from studies of the Barnegat Estuary. Some key findings include:

- Sediment cores indicate grain size distribution varies from medium/fine sand on the east side of the Bays to fine sand and silt along the west side.
- Marsh features along the barrier island complex and eastern side of the bay are built on overwash fans and relic tidal inlet flood shoals.
- Marsh plant growth generates vertical marsh growth as the root mat grow upward and fine sediments and decaying biomass accrete on top of the sand.
  - This creates a find grain silty sand layer on top of the relic sand feature comprised of inorganic and organic soils that is easily mobilized by wave action.
- In Barnegat Bay USGS measured net transport into the Bay from Little Egg Inlet and outflow at Barnegat Inlet and a balanced transport through Pt. Pleasant Canal.
  - Sediment transport most likely follows a similar pattern with supply from the oceanfront beaches into the bay at the south.
- Turbidity measurements were collected by USGS at 13 gauged and 9 un-gaged freshwater tributaries of Barnegat Bay at the three largest rivers: Toms River, Metedeconk River, and Cedar Creek. All three rivers in general have low turbidity and show short lived pulses of turbidity during storms. It is estimated that the tributaries deliver 2 million kg of sediment per year.
- The watersheds along the back bays are too small to contribute large volumes of riverine sediments. The Sediment Pancakes Web Application developed by the University of North Carolina, Wilmington, estimates an annual accretion on sediment due to river load on the order of 0.1 mm/yr.
- SETs data for Barnegat Bay indicate marsh vertical accretion rates of between -2 and 5.8 mm/yr.
  - The difference between river supplied sediment and vertical accretion can be attributed to organic matter production, resuspended mudflat sediments and marine sediments derived from erosion of coastal landforms. The contribution of the latter two is unknown.

- A USGS study of sedimentation in Assateague Island after Sandy offers a possible model for sediment supply to marshes (Smith et al, 2015).
  - Large storm events create overwash fans that can be the foundation of new marsh but also can degrade existing marsh if the deposit is too thick.
  - Sediment re-suspended and advected from the estuary, tidal flats, or marsh edge and onto the marsh during smaller storm conditions supplies the marsh with sediments.
  - Sediments are in a sense conserved and redistributed over time between the marsh and estuary bed.
- Existing sedimentation rates on tidal salt marshes are below the rate of sea level rise. This reinforces the need to retain as much sediment in the New Jersey back bays as possible.

Research Needs

With the threats of increased sea level and more intense storms, there is a need to determine how sedimentation patterns will impact managing navigation and community resilience. The following research needs are identified:

- Establish long-term measurements of sediment entering the system through all pathways.
- Develop or use models to quantify and predict sediment movement.
- Quantify how much sediment is needed to keep pace with sea level.
- Research the effects of turbidity and suspended sediment concentrations in the back bay environment.

Research Needs

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