Sediment

TEC Significance

Rivers and streams transport water and sediment. These two elements affect all the other ecosystem characteristics. Sediments play a key role in many processes among them light penetration, nutrient supply, and wetland maintenance. While there are localized places in the watershed where problematic sediments are harmful and are often among a variety of related insults, they are excessive in the Hudson River estuary only under rare conditions. Within the estuary, sediments impact navigation, recreation, aesthetics, aquatic vegetation, and biological communities. Sediment delivery is required to maintain wetlands experiencing sea level rise. Sediments transport nutrients and some contaminants. Dams and artificial water courses affect sediment transport and sediments reduce the functional lives of these structures. Because of these factors, decreasing sediment loads would benefit some characteristics and harm others.

Sediment is comprised of organic and inorganic particles suspended in the water column, suspended load, and of larger particles that, with sufficient energy, can roll or skip along the bottom, the bed load. Suspended sediment concentrations are being measured routinely in a few locations in the estuary but bed loads are not. Natural factors influencing sediment delivery include soil type, terrain slope, and precipitation patterns. Anthropogenic factors include impervious surfaces, amount of forest coverage, wetland treatment, and introduction of invasive species that can destabilize riparian areas. Other man-made factors include farming and construction practices, infrastructure such as roads and bridges, road drainage management, informal trails, and very significantly, dams. Intentional and inadvertent modifications have resulted in streams becoming disconnected from their floodplains where energy and sediments can be absorbed, and in unstable banks. There are robust techniques, called Natural Stream Channel Design (NSCD), for stream restoration that would reduce the impact of these factors (Rosgen, 2006).

Fine grained silts and clays and organic sediments may transport organic and inorganic contaminants including dioxins/furans, PCBs, and metals (see Contaminants TEC). Sediment in the estuary settles in shipping channels and berths increasing operating costs, particularly if chemically contaminated. New York state lists 78 dredging projects where a Beneficial Use Determination (BUD) has been made exempting the material from solid waste regulation. Of these, 10 are in the estuary but only one is designated for unrestricted use (see the Public Access and Navigation Safety and Natural Resource Interactions TEC narrative and summaries). Suspended sediment increases turbidity thereby reducing the area of the river bottom capable of supporting rooted vegetation (see the Shallow Water and Intertidal Habitats TEC). Wetlands need fresh sediment to bring in nutrients, to replenish eroded soils, and to adapt to sea level rise (see the Shallow Water and Intertidal Wetlands TEC and the Hudson River Shorelines and Riparian Areas TEC). Actions taken in the watershed to impact the delivery of sediment to the Hudson River estuary require evaluation of structures such as dams and roads (see the Tributary Connectivity and Barriers TEC).

Goal

Management of sediments is strengthened. Gaps in understanding the sources and transport of sediment are resolved. Excessive sediment transport in the estuary watershed is controlled by ecologically sound reconnection with floodplains and channel modifications to enhance soil stability. Sediment supply to and concentrations in the estuary are better understood and major pools/fluxes monitored.

TEC Context

Historical Context

It was estimated that modern average yearly soil losses in the Hudson watershed are eight times as much as they were before European settlement and half as much as during the peak of animal powered agriculture at the end of the 19^{th} and beginning of the 20^{th} Centuries (Swaney, Sherman, & Howrath, 1996). The high loss rates came about from deforestation and contemporary agricultural practices. Abandonment of marginal agricultural activities, replacement of draft animals and their fodder requirements with fossil fuel-powered machinery, and substitution of other materials for wood products have allowed forest recovery. The effect of the early 20^{th} Century big dams (for New York City drinking water, Barge Canal water supply, and hydroelectric power) on sediment transport is surely great but is poorly quantified.

Current State

The amounts of sediment entering the estuary vary greatly from year to year as a function of precipitation and streamflows. A study looking at the years 2002 to 2006 puts the average annual suspended sediment discharge to the lower Hudson River at 812,000 tons (Wall, Nystrom, & Litten, 2008). However, in 2011, the year of hurricanes Irene and Lee, over three million tons of suspended sediment was discharged. Climate predictions suggest increased frequency of high-intensity storms in northeast North America. The Irene and Lee storms were highly destructive in some regions of the Hudson Basin resulting in 10 deaths and $1.5 billion in property damages. Stream channels and adjacent infrastructure can be improved in ways that reduce property damage, increase human safety, reduce sediment mobilization, and enhance wildlife habitat and aesthetic values.

Models based on land cover, slope, and soil type predict stream “health” (expected ability of a land cover to perform the functions of groundwater filtering, soil retention, erosion control and flood reduction) and “vulnerability” (the contribution of riparian areas to runoff) (Meixler, 2009). Sediment yield from the landscape also varies greatly across different watersheds. For example, the sediment source module used as part of the Contaminant Assessment and Reduction Project (CARP) model predicted loading rates of 28 and 232 tons/square mile from the Upper Hudson and Wappingers Creek respectively (Hydroqual, 2007). Similar models run by others are fairly congruent, but field validation is limited.

Sediment deposition in the estuary is prevalent between Haverstraw and Peekskill and between Kingston and Albany (USACOE, 1974). During and after the 2011 hurricanes when the estuary was well monitored, it was found that significant sediment storage occurs; by 2016 about a million tons of Irene/Lee material measured as suspended sediment was still above Poughkeepsie (Nitsche & Kenna, 2016). Navigational channels are maintained at a depth of 32 feet and are heavily used by commercial and recreation vessels. While data are sparse, most sediment cores in the estuary show average PCB concentrations greater than 0.1 ppm which render them unsuitable for wetland restoration.

Of the 592 Hudson River basin waterbodies evaluated by the Waterbody Inventory/Priority Waterbodies List, 19% showed impacts from silt and sediment; nine percent had major impacts. The frequency of sediment-impacted waterbodies was greatest in the Mohawk River basin (32%) and lowest in the Upper Hudson (nine percent) (NYSDEC, 2017).

Trends and Drivers

Failure to manage sediments increases the costs of maintaining navigational channels. Stream instability, a primary contributor to excessive sediment transport, threatens public and private property. Uninformed measures taken to mitigate flooding may exacerbate soil erosion and have deleterious ecological impacts from changing flow and temperature patterns, disconnecting from flood plains, over-widening water courses, breaking connectivity for aquatic organisms, and smothering benthic organisms. It is possible that sedimentation behind some large dams has been faster than expected resulting in the burial of intakes and control structures. Sediment problems will be exacerbated by the increased frequency of high intensity storms predicted by climate change models. Nevertheless, sediment management is fragmented and underfunded. The Harbor Estuary Program's Regional Sediment Management Plan strongly recommended creation of State Sediment Management Advocates. These influential but non-regulatory Advocates would "coordinate and link sediment issues to all applicable programs, such as watershed management, stormwater management, brownfield revitalization, habitat restoration and protection, water quality enhancement, resource sustainability, and urban waterfront planning"(RSM Workgroup, 2008).

Land use and dams play major roles in sediment mobilization and transport. Between 1935 and 2005 Hudson basin counties saw 60% of agricultural acreage converted to other uses, mostly forest. Farming practices have also changed to reduce soil erosion. Many farmers practice soil conservation methods that were developed and popularized in the 20^{th} Century. The first half of the 20^{th} Century saw 81,000 acres of dam storage built – more dammed area than in the years preceding and following. It is likely that the big dams are still accumulating sediment. Sprawl and its attendant impervious surfaces (primarily paving) reduces infiltration thereby contributing to pulsed hydraulic loads that overload receiving bodies and cause erosion. Since the mid-20^{th} Century a variety of persistent synthetic chemicals have contaminated Estuary sediments. Some chemicals have been banned, strictly controlled, and partially removed.

Constraints

Sediment sources are diffuse; the entire watershed, which is mostly in private hands, is susceptible to erosion. Watershed modifications undertaken to increase stream stability are expensive, technically complicated, require cooperation of numerous landowners, and may be counterintuitive to local authorities who believe that the solutions to flooding are to deepen and straighten watercourses, remove streambank trees, and armor banks. The benefits of increasing landscape resilience are quickly forgotten after a flood. Effectors, such as climate and invasive species, are in flux. The transportation drainage channels that state and local highway departments have created and maintain are significant factors in the environment, but the departments are often focused on roads lacking resources to attend to non-transportation concerns. Sediment issues are susceptible to the "tragedy of the commons" problem whereby actions by upstream property owners can adversely impact downstream communities. Addressing sediment sources in the watershed by engineering would be very expensive and we usually lack credible and widely accepted monetary valuations of ecosystem services to justify the costs. Using Miexler's model of stream Health and Vulnerability, 1,600 Hudson Valley stream miles account for half of the "highly" of "very highly" vulnerable miles. Application of NSCD techniques cost Schoharie County Soil & Water $285/foot for the recent work on the Little Schoharie (exclusive of project design and land acquisition). At $285/foot, remediation of 1,600 miles would cost $2.4 billion.

More focused evaluations would surely narrow the scope of vulnerable miles, but costs will still be very high. Land acquisition in more densely populated regions will be much more expensive and more limited by development. New York City remediated some stream segments in the Catskills at the rate of $200/foot as a cheaper alternative to building and operating a drinking water filtration plant. Such clearly defined valuations are rare.

It is improbable that the amount of sediment available would be sufficient to maintain tidal wetlands in the face of sea level rise. The New York state Risk and Resiliency Act gives 14 inches as the “low-medium” estimate of sea level rise by the 2080s. Maintaining 7500 acres of wetlands would require an accretion rate of about 0.23 inches per year. At a high end of sediment entering the Hudson River estuary (one million tons per year), sufficient material would be available, if none went to riverine deposition areas or were discharged past the study area, to raise the wetlands by 0.67 inches per year. However, the area of the Hudson River bottom where sediment deposition occurs is almost seven times greater than the wetlands and most of the incoming suspended sediment is exported at least past Poughkeepsie.

Monitoring of sediment discharge is under pressure from funding agencies, chiefly the New York State Department of Environmental Conservation, due to its apparent lack of relevance for management. Continuous sediment monitoring is expensive to institute and maintain. Large events are unpredictable. While under consideration (Swietlik, 2003), there are currently no water quality standards for suspended sediment.

Action Table

Objectives	Quantifiable Actions	Completed
Objective 1: Management of sediments is strengthened	1A. The 20 Estuary County Soil & Water Districts are organized into a coalition to share expertise and resources to deal with the estuary watershed as a single unit	2020
	1B. Banks along major streams in each of the estuary's 65 HUC-10 sub-watersheds are evaluated for stability using Natural Stream Channel Design (NSCD) principles by trained observers	2030
	1C. Streams are ranked by potential for delivery of significant sediment loads and by feasibility of remediation	2070
	1D. 400 land landowner agreements or acquisitions enable access for stream restoration work	2070
	1E. Models are developed that allow managers to specify monetary value for ecosystem functions	2070
Objective 2: Gaps in understanding the sources and transport of sediment are resolved	2A. An Indicator Database for decision-aiding and adaptive sediment management in the estuary watershed is developed to identify and prioritize stream segments prone to instability	2020
Objective 3: Sediment supply to and concentrations in the	3A. Sediment monitoring is resumed on the Hudson River tributaries	2020

estuary are better understood and major pools/fluxes monitored	3B. Turbidity measurements are maintained at Cohoes (Mohawk River), Burtonsville (Schoharie Creek), and Mt. Marion (Esopus)	2070
	3C. Periodic surveys are conducted to map sediment deposition, sediment erosion, and sediment characteristics in the estuary	2020
Objective 4: Excessive sediment transport in the estuary's watershed is controlled by ecologically sound channel modification to enhance soil stability	4A. Highway departments in 20 estuary Counties apply vegetative cover to disturbed soil to reduce sediment transport from transportation drainage systems	2020
	4B. Functional but high hazard and unsafe dams are reinforced	2020
	4C. 1,600 vulnerable and 600 un"healthy" stream miles are remediated	2070
	4D. Remediated segments are monitored and maintained	2070

Action Narrative

Objective 1: Management of sediment is strengthened.

1A. Agencies with experience in working with landowners and managing soil erosion have the capability and expertise to identify and remediate unstable stream segments contributing excessive sediment. The Regional Sediment Management Plan strongly recommended that New York and New Jersey each appoint a Sediment Advocate. A coalition of agencies can provide part of the role of a Sediment Advocate. Since the Sediment TEC is looking at the entire watershed, more counties are counted than are only in the Hudson River estuary.

1B. Evaluation of stream stability requires training and certification. The principals and procedures for NSCD can be found in Rosgen's Watershed Assessment and River Stability. Specific information for field evaluation of stream stability can be found in Dave Rosgen's River Stability Field Guide(Rosgen, 2008).

1C. The "Indicator Database" is an index assigning erosion susceptibility to stream segments. The modeling framework for establishing such a database has been described for the Lake Champlain Basin Program (Howe, Howland, & Strouse, 2011). This action supports the Hudson River Action Agenda's statement, "Relatively little information exists on how land use in the watershed connects to the integrity and resiliency of the estuary."

1D. Stream restoration requires access to land in private hands. As an example, the recently completed restoration project on 5.3 miles of the Little Schoharie Creek required obtaining consent from 29 landowners involving an average holding of 35 acres. In many cases landowners want compensation for construction, monitoring, and maintenance access.

1E. A major impediment to funding capital projects benefiting the environment is a lack of ecosystem valuation tools. Ecosystem health, often denominated in terms of species diversity and abundance, is difficult to monetize.

Objective 2: Gaps in understanding the sources and transport of sediment are resolved.

2A. Sediment (suspended and bed load) fluxes can be measured with USGS methods or estimated by following NSCD stream evaluation procedures.

Objective 3: Sediment supply to and concentrations in the estuary are better understood and major pools/fluxes monitored.

This objective supports the Hudson River Estuary Program Action Agenda's call to characterize the hydrology and sediment loading by gauging and modeling.

3A. Sediment monitoring at stations in the estuary watershed provided important insights during the Irene/Lee events. Until deployment of more efficient monitoring techniques, these sites should be reinstated. Recommended sites are for the Upper Hudson at Waterford, on Normans Kill in Albany, on Catskill Creek at Catskill, the Rondout below the Wallkill River, Kinderhook Creek at Rossman, and the Roeliff Jansen Kill near Linlithgo.
3B. Turbidity measurements, a cheaper alternative to suspended sediment monitoring, were only initiated at Burtonsville in 2016. They would have been very valuable during Irene/Lee to quantify directly the loads coming from Schoharie Creek.
3C. Continue the Benthic Mapping project.

Objective 4: Excessive sediment transport in the estuary's watershed is controlled by ecologically sound channel modifications to enhance soil stability
4A. Transportation drainage ditches may conduct as much as a quarter of the rainfall in the Hudson River watershed. New York has about a million road culverts; 86% of which are owned by localities. Traditional hydraulic culvert design and over-deepening of drainage channels creates barriers to aquatic and terrestrial animal movements and can increase erosion (Schneider, 2014). Highway departments need more funding to better manage transportation drainage. Potential technologies for quickly establish vegetative cover include hydroseeding and compost erosion control blankets. Hydroseeding, the use of a truck-mounted sprayer to lay down a slurry of mulch (wood chips, straw, shredded paper), seed, and additives (colorants, fertilizers, tackifiers) along road-side ditches. Since 2009, the New York State Department of Environmental Conservation has awarded 13 counties state-wide $1,100,000 for hydroseeding along road-side ditches. As usual with engineered substitutions for environmental services, hydroseeding is costly ~$1,200/acre. As implied, compost blankets use compost instead of straw or wood chips. Tributary Connectivity and Barriers TEC can also benefit from improved ditches.
4B. The Mohawk River Watershed Coalition GIS tool, Mapper, shows several large dams rated "stability unsafe" (MRWC, 2017). Catastrophic failure of dams would have a significant impact on sediment delivery as well as on property and human life. Breaching of small obsolete mill dams may also be an important sediment source that could help raise wetlands or clog waterways necessitating dredging (Munoz & Panero, 2008). Tributary Connectivity and Barriers TEC can also benefit from dam modernization.
4C. The number of restorations required, feasible, and fundable is unknown. Without ecosystem valuation models, we lack a monetized value for the benefits of environmental restoration. Reductions in sediment loads can benefit Shallow Water and Intertidal Habitats TEC and Navigation Safety and Natural Resource Interactions TEC
4D. Funding and personnel for monitoring and maintenance is necessary. Success of NSCD projects can be assessed biologically by measuring species abundance and diversity.

Research Needs

- The 25 dams exceeding 20,000 acre-feet of design storage are evaluated for sediment trapping.
- Bed load measurements are made at Waterford, NY and near the Governor Mario M. Cuomo Bridge.
- Remote sensing technologies are capable of measuring soil transport. They should have sufficient precision to measure the change in volume of stream channels that occur over a span of five to ten years.

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