SCENIC HUDSON'S LONG DOCK PARK CULTIVATING RESILIENCE: TRANSFORMING A POST-INDUSTRIAL BROWNFIELD INTO A FUNCTIONAL ECOSYSTEM

Chris Moyles[1] and Timothy Craul[2]

INTRODUCTION

Scenic Hudson's Long Dock Park is a resilient living work of art and a vibrant community asset for the Hudson River Valley. A 23-acre peninsula on the east side of the Hudson at Beacon, New York, the site includes the Peter J. Sharp Park and the Klara Sauer Hudson River Trail. Two decades in the making, beginning in 1997, it took a decade to plan and remediate, and, by its completion in early 2017, it will have taken just as long to build and recover.

In 1997, nonprofit Scenic Hudson, the largest environmental and land preservation group focused on the Hudson River Valley, started assembling the different ownership parcels of the Long Dock site. From 1999 to 2003, they engaged the Beacon community through a series of community meetings and workshops to articulate its vision for its waterfront and cleanup of the site began. From 2003 to 2007, the design team developed the architectural and site program for the project, restoration measures, and its physical expression with the client.

Working with the City and the New York State Department of Environmental Conservation (NYSDEC), the project completed the State Environmental Quality Review Act (SEQR) process, filing a Draft Environmental Impact Statement (DEIS) and received approval of the final EIS ensuring that there was significant environmental, social, or economic value. The NYSDEC and the U.S. Army Corps of Engineers (USACE) were also directly involved in oversight of the brownfield remediation and work within the Hudson River and site wetlands. With the SEQR process complete and approval of a mitigation plan from the USACE, the team worked with the City of Beacon to complete the site plan application process for construction. Our mandate was clear from the start—build resilience, but realize it incrementally.

The project's first phase, opened in 2009, included additional remediation and removal of contaminated soils, removal of invasive species, stabilization of the south shoreline, a test plot for different materials, a wetland boardwalk and interior pathways, installation of native plantings, and site-specific artwork. By 2014,

1. Landscape architect and principal at Reed Hilderbrand, LLC.
2. Soil scientist and founder of Craul Land Scientists, Inc.

the landscape's multiple character zones were complete: the established meadow, the connective network of trails and boardwalks, the working site infrastructure of wetlands with swales and seeps, the dynamic intertidal zone, and earthen buttresses. A new pavilion for kayak storage and rentals and an arts and environmental education center in the historic Red Barn were significant additions for the program and community engagement of the park (refer to Figure 1). Over the past summer of 2016, portions of the site originally designed as a LEED platinum eco-hotel and conference center are now being remediated and reconceived as a new civic plaza, amphitheater, overlook west deck, boardwalk at Quiet Harbor, and a shade structure with an area for food trucks.

Long Dock Park will continue to adjust and adapt to changing circumstances of ecology, climate change, flooding and sea level rise, and culture. Our original goals of renewing and revealing the historic waterfront, increasing public access to the river, restoring degraded environmental conditions, and demonstrating exemplary, environmentally sensitive development—these are complete. And the park was one of the first pilot projects for the Sustainable-SITES certification program and subsequently received SITES's highest rating of a SITES project at the time.

Even as we considered program, spatial organization, and aesthetics, our work also sought to create in Long Dock a functional and sustainable ecosystem. The park's design needed to initiate natural processes for the degraded post-industrial brownfield to function and sustain ecosystem services that had not existed before. The design of healthy soils, the integration of hydrology, and the establishment of native plant communities form the true story of the site's transformation from postindustrial ruin into a significant waterfront park.

KEYWORDS:
waterfront park, brownfield remediation, sustainable SITES, designing soil for the urban environment, stormwater treatment, invasive plant species

SITE HISTORY

Based on historic maps and records, a variety of industrial uses developed on the site starting as early as the late-1800s. The northern portion of the site was developed first with a wooden pier and dock over the tidal flats of the Hudson for ferry transportation of goods across the Hudson River from Beacon to Newburgh and back (Figure 2).

Support structures and storage barns appeared later, organized along an east-west drive across the site. In the early 1900s, several new structures occupied the northern area of the site; starting with the Long Dock Coal Company and Garret Storm Coal Yard from 1919 to 1927, a Transformer House from 1919 to 1946, the National Power Company in 1919, the Beacon Soap Company in1927, and the Central Hudson Steamboat Company (at the location of the concrete foundation at the west shoreline) from 1927 to 1946. The southern portion of the

FIGURE 1: Site Plan Illustrative (2014).

FIGURE 2: Map of Long Wharf, later known as Long Dock, c.1867, (Courtesy of Beacon Historical Society).

FIGURE 3: Sanborn Maps of Long Dock, 1889 (left) and 1919 (right), (Courtesy of Beacon Historical Society).Historical Society).

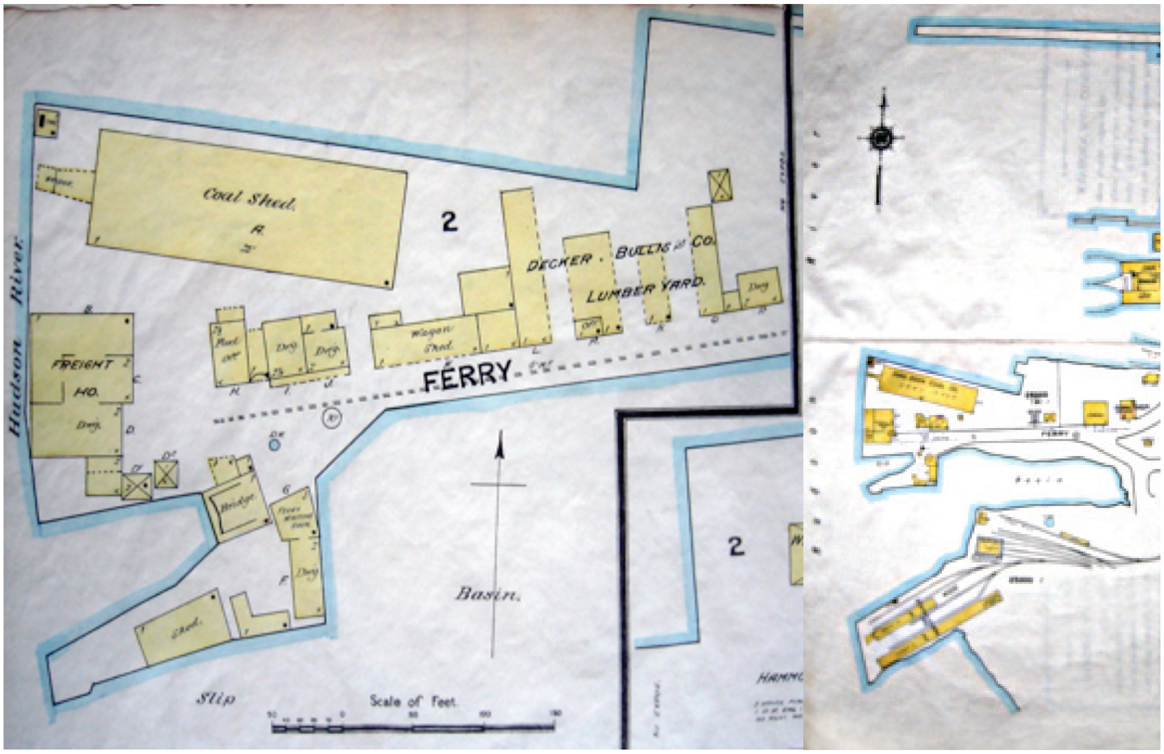
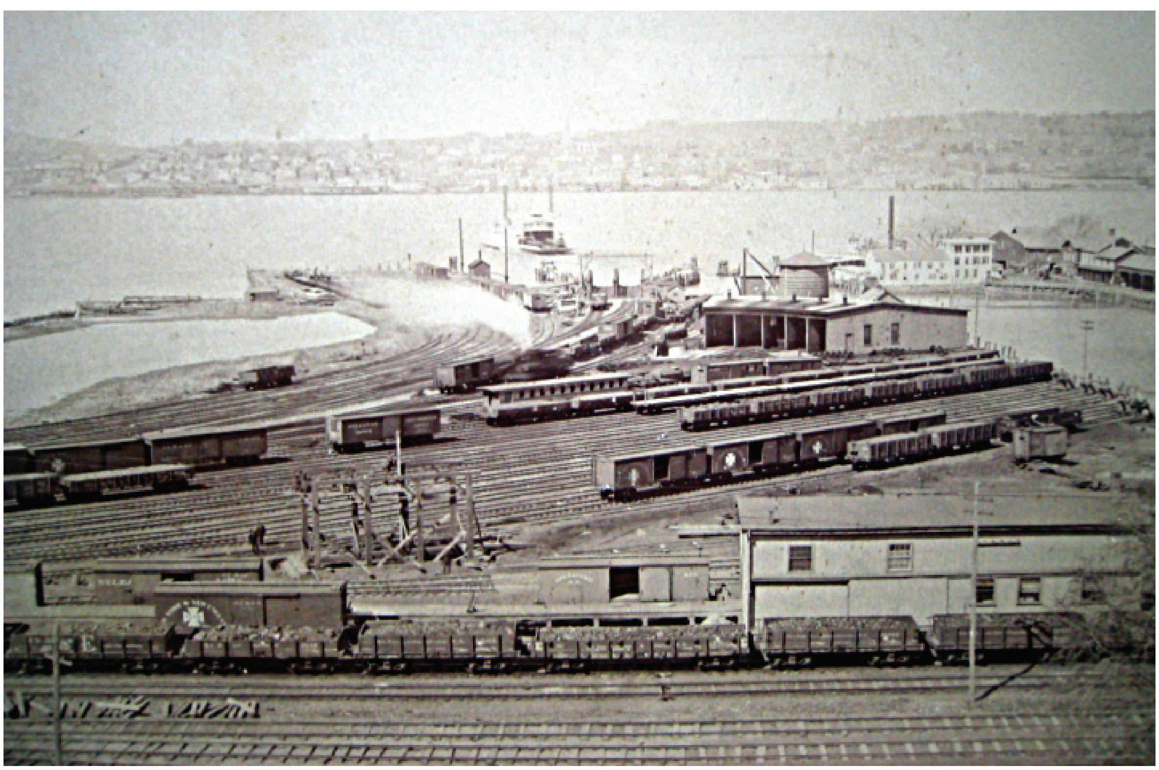


FIGURE 4: Image of Long Dock train yard, ca. 1914, (Courtesy of Beacon HistoricalSociety).



site was filled to serve as a train yard for the Beacon Metro North, starting around 1914, with a storage facility for coal and salt (Figure 3).

Red Flynn drive was constructed as an overpass of the railway to provide access to the site in the early 1900's, without having to cross the rail lines. The central portion of the site, a large basin of the Hudson River until 1936, was then gradually filled by 1960. This area became a salvage yard, which operated from approximately 1962 to 1983, and the Garret Storm Major Oil Storage Facility (MOSF), above ground petroleum storage tank structures, which operated from approximately 1936 to 1994. (Figure 4)

THE EXISTING/PRE-CONSTRUCTION SITE

The site is an irregularly shaped peninsula on the eastern shore of the Hudson River with Red Flynn Drive and the Metro North Railroad to the east. It extends approximately 1,200 feet westward from Red Flynn Drive and includes lands submerged in the Hudson River. The existing barn, moved to its current location in the early 2000s, is in the eastern portion of the site. Also present is what may have been a single-family dwelling. A concrete foundation is located at the western shoreline known as Rocket Point. South of Rocket Point is Quiet Harbor. A boathouse and two small storage sheds, utilized by the Dutchess Boat Club, was located on the north edge of Quiet Harbor. Beacon Point frames the south edge of Quiet Harbor.

FIGURE 5: Aerial image of Long Dock MOSF, 1957, (Courtesy of Beacon Historical Society).

The majority of the Beacon Point site had an underlayment, inches below the surface, of concrete decking slabs, approximately 10'0" wide and 12-14'0" long, covered with asphalt on one side. The slabs, debris from the repaving of the Interstate 84 Bridge between Beacon and Newburgh, were brought to the site as salvage. Their placement and distribution served as a de facto stabilization of the point from surges and withdraws. The soils below the slabs were

FIGURE 6: Existing Conditions Plan of Long Dock site.

coarse and very well drained — during rain events the joints between slabs became visible. Because of the thin soils atop of the slabs little if any vegetation was present. In some areas, particularly the south shoreline and the edge of the Quiet Harbor, trees (Acer negundo and Populus sp.) rooted and established in the joints between slabs.

The site vegetation types support an assemblage of upland and wetland habitats. The vegetation developed on largely inorganic fill and construction debris: brick, slag, and coal dust. Vegetation was a mix of grasses, forbs, shrubs, tree saplings, and vines in patches, throughout areas of bare soils. Plant establishment occurred in response to the pervasive disturbance by fill placement, railroad construction and operations, and the petroleum storage facility. Long-term use of heavy machinery resulted in vegetation by non-native invasive plants associated with disturbed, infertile substrates such as common reed (Phragmites austrails), mugwort (Artemisia vulgaris), and knotweed (Polygonum cuspidatum). Along the intertidal zone, successional species of mixed hardwoods populated the south shoreline, including black locust (Robinia pseudoacacia), cottonwood (Populus deltoides), and box elder maple (Acer negundo).

The existing and only vehicular access to the site, from Red Flynn Drive, descends from an elevation of thirty-two feet above mean sea level into the site at an elevation of five

FIGURE 7: Images of existing site conditions; debris from storm surge along south shoreline (left) concrete slabs at Wetland A (right).

feet above mean sea level. The ground plane of the site generally slopes from the northeast to the southwest, towards the Hudson River, with an elevation range of four to seven feet above mean sea level.

The soils of the site consist of very deep somewhat excessively drained to moderately well drained inert soils with brick, coal, and ash fragments that have been altered by cutting and filling. A dense clay layer at a depth of ten feet and sloping to a depth of fifteen feet appears to be native material forming a continuous confining layer.

Surface water flow is generally from north to south. Ground water elevations during low tide range from 0.25 feet above mean sea level to 2.15 feet and during high tide ranged from 2.05 feet to 3.0 feet above mean sea level. The overall direction of groundwater flow during low tide is southwest and during high tide is easterly. The entire site is within the FEMA floodplain, with exception of a portion of the entry drive from Red Flynn Drive. There were six separate areas of wetlands, Wetlands A, B, C, D, E, and F, totaling 2.9 acres, and no existing NYSDEC Freshwater Wetlands on the site. The six wetlands are characteristic of four distinct wetland community types: Tidal Slough- Wetland A, Tidal Marsh- Wetland B, Common Reed Stand- Wetland C, E, and F, and Tidal Emergent/Forested Wetland- Wetland D (Rudikoff, 2005).

ACTIONS FOR RECOVERY

From the beginning, it was clear that to create function and performance of the landscape and support the recreational, educational, and environmental objectives woven through the different zones of the site, the process for recovery needed to begin with; 1) site remediation — the removal of contaminated soils, debris and non-native invasive plant species; 2) soil preparation — the amendment and installation of healthy soils that imitate natural profiles to support plants and organisms; 3) site hydrology — integration and management of stormwater, flooding, and surges; and 4) native vegetative communities — creating and revitalizing uplands, lowland wetlands, meadows, and the riparian intertidal zones.

SITE REMEDIATION

Soil Contamination

The recovery of the site began with the removal of contaminated soils, debris, and non-native invasive plant species. The area of contaminated soils of greatest concern at the surface and deeper was around the Red Barn site. Soil remediation included the excavation and off-site disposal of soil/fill material containing concentrations of PCBs, metals, and SVOCs. At the former MOSF site, south of the Red Barn, implementation of an in-situ chemical oxidation treatment to reduce petroleum contamination was conducted and a cap over the entire area was installed to prevent human contact with the soil.

Remediation of contaminated soils began as early as 1999, when Scenic Hudson entered a voluntary cleanup agreement with the State for the remediation of petroleum-saturated soils. In 2001, 660 cubic yards of junk was removed from the salvage yard. Subsequently, Scenic Hudson engaged Ecosystems Strategies Inc., as the environment remediation consultant, and entered another voluntary cleanup agreement for remediation of PCB-contaminated soils and soils with heavy metals, to be completed during the first phase of construction. The northern portion of the site, formerly known as the "Beacon Salvage" property, and the central portion of the site, known as the "Garret Storm" property, were combined as a single site under the Brownfields Clean-up Program in May 2006.

A remedial investigation was conducted at the site in 2006 and 2007. Soil investigations by Ecosystems Strategies identified several areas of potential environmental concern, including elevated concentrations of metals in surface soils, west of the dwelling and to the east of the Red Barn, and elevated levels of PCBs in the salvage areas. The contaminants of concern included volatile organic compounds (VOC's), semi-volitile organic compounds (SVOC's), metals (arsenic, lead, mercury), and PCBs.

Contaminants in the soil associated with the former MOSF site contained elevated levels of VOC's and SVOC's. SVOC that extended from approximately 3 feet to 5 feet below the surface, while VOC contamination extended from approximately 3 to 20 feet. Contaminants at the salvage site included elevated levels of PCBs, metals (arsenic, lead, mercury), and SVOCs. PCB in the soils that was limited to the northeastern portion of the site from 0 to 3 feet below the surface. Arsenic contaminations in soil were also present in several areas throughout the site at 0 to 4 feet and extend to a depth of 10 feet in isolated areas on the eastern portion. Lead contamination was present in surface soils in the northern portion of the site as well as in subsurface soils from 7 to 9 feet below grade (Ecosystems Strategies, 2007).

Wetland A was impounded by the concrete slabs from Beacon Point and the historic dike or berm along the intertidal zone of the south shoreline. This berm was more than likely constructed as flood protection for the train yard. In the case of Wetlands C, E, and F, impermeable materials (fill, debris, concrete slabs, asphalt) underlay these shallow basins; precipitation was the only source of water supply. All of these wetlands were impounded pockets isolated from tidal and groundwater influences as sources of wetland hydrology. The quality — functions and values — of the site wetlands were severely compromised and limited by their size, predominance of non-native invasive species, low biodiversity, lack of nutrients, and inert substrates. Thus, these wetlands provided little if any flood storage and conveyance, water quality renovation, and functioned in very limited ways as wildlife habitat (Rudikoff, 2005).

Groundwater contamination was present in the area of the former MOSF. Low-levels of VOC's and SVOC's were present in groundwater within the area of the former MOSF. However, no site related surface water or sediment contamination was encountered during the investigation.

A remedial work plan was developed in February 2008 that addressed on-site contamination; no off-site exposures were identified by the investigation. The remedial program included: excavation and off-site disposal of soil/fill material identified as containing concentrations of PCBs, metals, and SVOCs that exceed the 6 NYCRR Part 375 Soil Cleanup Objectives for commercial land use. The volume of this material was approximately 8,000 to 11,500 cubic yards. Excavated areas were backfilled with clean fill (Ecosystems Strategies, 2007).

An in-situ chemical oxidation treatment was implemented to reduce petroleum contamination within the MOSF site. This treatment included the placement of monitoring and access wells throughout with periodic injections of an oxidant to bind petroleum contaminates. A demarcation fabric with a one-foot thick cap of soil was also installed over the entire site to eliminate human contact with the soil. The injections continued until the summer of 2016, when the treatment was determined to be ineffective, the hydrocarbons not binding to the oxidants, by the State. Monitoring concluded that there was no movement or leaching into the ground water.

Invasive Species Removal

The degradation of soils and lack of management over many years allowed invasive species to gain a significant foothold and dominate the site. These invasive species, if allowed to persist, would dominate the biogeochemical profile, disrupt ecosystem function and displace native species reducing diversity and habitat. Any new native species to be introduced would not be able to compete or thrive with the exotic invasive species. The primary invasive species of concern included common reed (Phragmites austrails), mugwort (Artemisia vulgaris), and knotweed (Polygonum cuspidatum). Other invasive trees, Norway Maple (Acer platanoides), shrubs, Japanese honeysuckle (Lonicera japonica) and Multiflora rose (Rosa multiflora), and vines, Bittersweet (Celastrus orbiculata), were also present.

In order to eliminate invasive species, a long-term removal and management plan was developed by the team. The plan included the cutting or mowing of plants starting in June and, as new growth occurred, the herbicide glyphosate was applied through spraying and/or wiping plants pending wind conditions on-site. This process was repeated over the entire site, every three weeks for a three-month period. A certified professional administered herbicide applications and all cut plants were bagged to prevent the spread of seed. After this period, spot treatments were applied if new growth or additional invasive plants were visible throughout the construction period. The treatment schedule also addressed any latent seed within the soil bank as well as invasion from the eastern edge of the site along the railroad. Generally, the edges of the site were persistently challenging while the interior, once invasive free and with healthy soils, tended to have greater resilience.

The long-term management of the invasive species post-construction by Scenic Hudson was also based on spot treatments of any new invasive plants present on-site. However, after construction of phase two, Scenic Hudson made an organizational policy change in the management and maintenance of its parks to not utilize herbicides, particularly glyphosate, over concern of potential residual effects. This has become a significant challenge in controlling new invasive plants. While recent studies in Long Island, New York, have shown that continual low cutting of mugwort and other invasive plants over a period of three to five or more years has resulted in eradication (Jordan et al., 2002), this has not proven to be the case at Long Dock. Other methods, such as vinegar treatments and volunteer weeding help to control the invasives but are a constant operational effort.

SOIL PREPARATION

Long Dock Geomorphology

The soil design for Scenic Hudson's Long Dock required taking into account a laundry list of geomorphological, pedological and biological conditions before getting into the actual planting soils. The geomorphology of the site is that it is not natural. What was referred to as Beacon Point had been made by filling in the Hudson River, then man and nature applied their powers to the soil/landscape resulting in pedological (soil) development that then dictated the biological environment. The final soil/landscape interaction needs to be understood within the context given by the geomorphology of the site.

The fill material are mostly local gravels, foundry slag, and any other form of hard fill that were readily available. Surface soil materials used were a mix of fine sands and gravels with some silt that was deposited from yearly flooding. What resulted was an extremely gravelly sandy loam with large portions of the fine earth particles in the fine to very fine sand range that results in higher density. With the industrial nature of the site from railroad operations to a junkyard, the soils were extensively contaminated and compacted. Concrete decking slabs were placed throughout Beacon Point in several layers thick. The reinforced concrete slabs had asphalt on one side that required removal due to the plant root harmful toxic hydrocarbon gases produced during weathering. In addition, the slabs prevent adequate rooting depth for anything other than turf. The depth of the soil on the surface of the concrete slabs was none to about a couple of inches.

Even though the Duchess County, New York Soil Survey mapped these soils at only the taxonomic great group level as Udorthents, smoothed, the geomorphology of the site has been modified by nature to follow textbook alluvial terrace characteristics (Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, 2012). Overland flow close to the uplands cause the wetlands that are enhanced and influenced by the current railroad grade and road. Adjacent to the river there are constructed dikes at the water's edge that have been modified by nature with successive flooding leading to a intertidal wetland about halfway down the southern point. The depth of useable productive topsoil was determined by natural flooding scour and deposition patterns leading to very little topsoil at the point, generally increasing closer to the uplands and depressions towards the east. A fluctuating subsurface water table height at around 5 feet and the amount of overland flow dictates the extent and viability of the wetlands.

The design for the site included an event lawn at Beacon Point, above the concrete slabs; a series of large berms was planned along with renovating the protective dike. The existing and created wetlands and the intertidal wetland were to be renovated and enhanced. The wetlands were to be cut deeper in the center to provide some open water for wildlife with planted shallows for a diverse habitat. Stormwater management includes water quality swales of the bio-infiltration type for the parking area. Slopes of the berm and the entry road slope were around 3:1 to a little less than 2:1.

PLANTING SOIL:

Reasons for Designing Planting Soil:

Soil is a fabric comprised of physical, chemical, and biologic interrelationships that define the efficiency at which plants can grow. Natural soil varies in its properties and characteristics across the landscape, but its composition, extent and performance is predictable by trained soil scientists (Craul & Craul, 2006). Urban Soils, unlike their country cousins, are highly variable, unpredictable, and are not as productive due to a plethora of detrimental external forces instituted by humankind.

Natural soil develops from the top down. The parent material is weathered, breaking big bits into smaller bits. Then particles of sand, silt, and clay adhere to form structure, fines are translocated, pore space increases, overall density decreases through animal engineers and weathering. Soil flora and fauna take hold in the loose surface pore spaces starting the process of organic deposition. Higher plants colonize through ever increasing succession of more complex ecological systems. The soil/plant/landscape system is not a stagnate sustainable equilibrium, but an ever charging symphony of counter balance between ecological factors. The same is true for urban soil, but the natural counter balance within the urban environment is often overwhelmed by grossly ranging conditions that a natural soil and plant community cannot easily overcome.

Designing a soil for the urban environment, one must look to nature, realizing that the soil properties need to change with environmental conditions common to the site in which it is placed. The designed soil must be able to handle extremes in moisture, temperature, and compaction forces in order to provide adequate media for plant growth. Unfortunately for the SITES requirements, there were no reference soils within Dutchess County, NY, that would be able to meet the physical requirements needed to overcome the site's restrictions.

Productive soil not only imparts healthy plant growth but decreases runoff, lowers maintenance costs, increases renovation of runoff contaminates, improves carbon sequestration rates, and results in active diverse soil organism population. Soil for use in urban revitalization construction requires resistance to compaction and allowance for wider soil moisture conditions to increase timeliness of landscape completion. This provides a starting point for controlled pedogenesis (soil formation) that maintains or enhances the landscape design over time.

Basic Soil Design Requirements

Each fine earth soil texture (<2.0mm) has limits of density that inhibit root elongation and overall pore space. Table 1 relates the limits of soil bulk density by fine earth soil textures on root growth and range in pore space.

Poorly graded sands have uniform particle sizes that react to compaction by not densifying past a certain point and maintaining a larger connective pore space than well graded particle size distributions that compact to higher densities. Therefore, similar soil textures can react differently to compactive forces. Particle size distribution therefore is more important than soil texture in soil design (Craul & Craul, 2006).

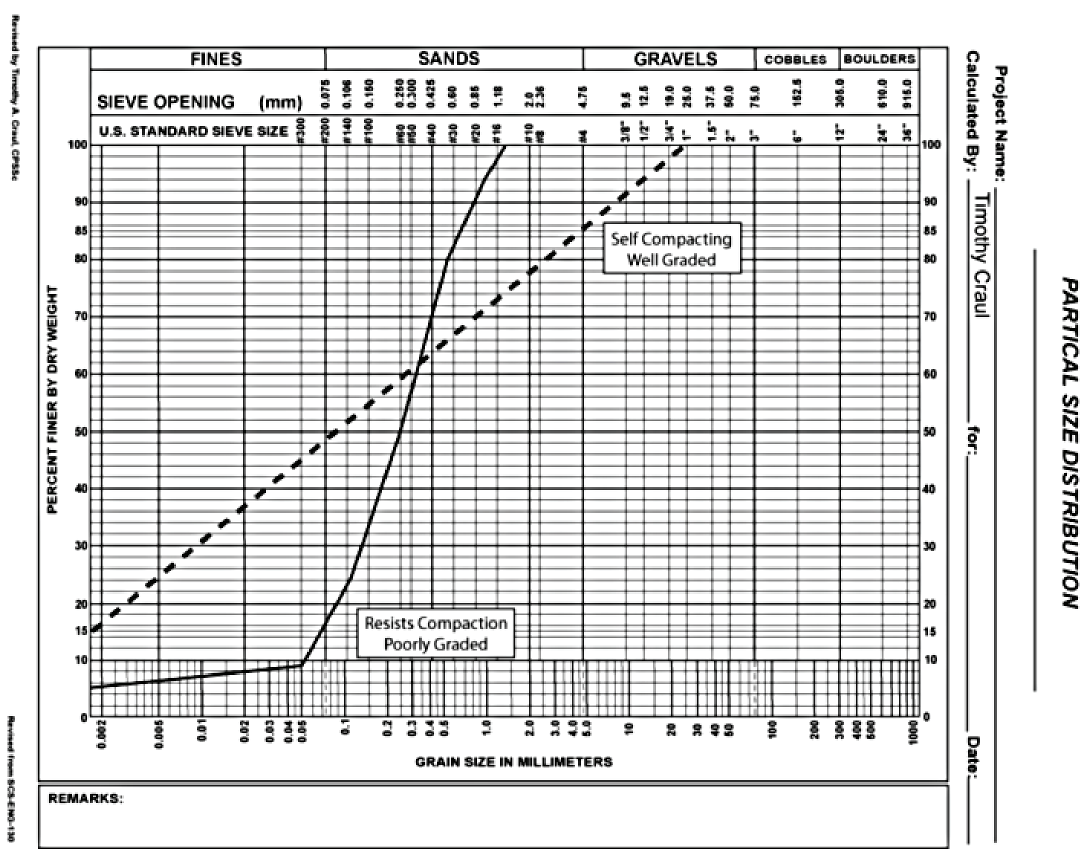
In Situ Soils, The Problem:

The topsoil east of the wetlands close to the railroad grade had slightly more tilth, but insufficient quantities to provide enough for the entire site. From the wetlands to the point to the

Table 1: Soil Bulk Density limits for Root Growth for various textures and pore space ranges. (U.S. Department of Agriculture, Natural Resources Conservation Service, 2000)

Soil Texture	Ideal Bulk Densities	Bulk Densities at which may affect root elongation	Bulk Densities that restrict root elongation	Pore Space Range
	g/cm^3	g/cm^3	g/cm^3	%
Sands, loamy sands	<1.60	1.69	1.80	32 – 40%
Sandy loams	<1.40	1.63	1.75	34 – 47%
Sandy clay loams, loams, clay loams	<1.40	1.60	1.70	36 – 47%
Silt, light silt loams	<1.30	1.60	1.70	36 – 51%
Heavy silt loams, silty clay loams	<1.10	1.55	1.65	38 – 58%
Sandy clays, sitly clays, clay loams (35-45% clay)	<1.10	1.49	1.58	40 – 58%
Clays (>45% clay)	<1.10	1.39	1.47	44 – 58%

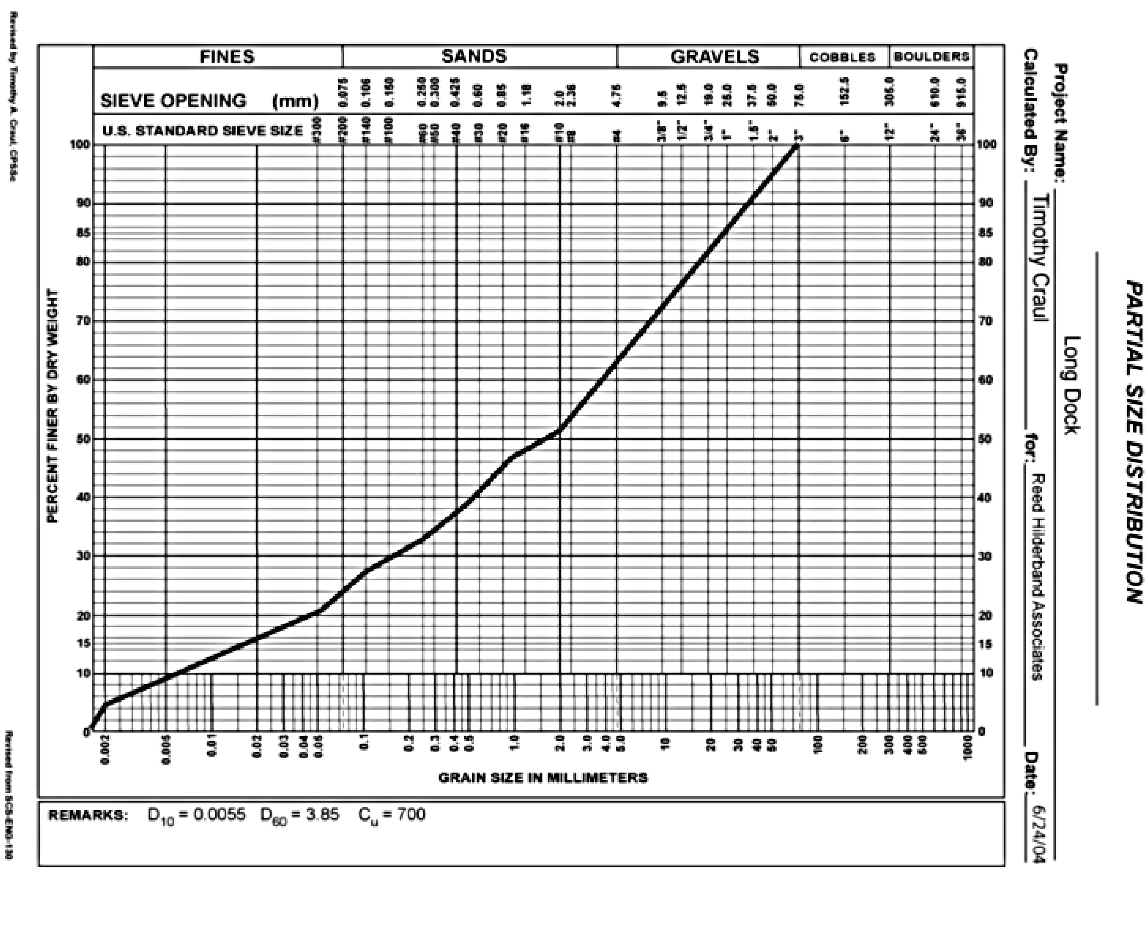
FIGURE 8: Similar soil textures with different particle size distributions where the poorly graded soil will have a higher maximum density than the well graded soil (Craul & Craul, 2006).



west did not have the characteristics to provide a healthy topsoil. The amount of rock fragments was in excess of 35 percent averaging around 48 percent. The particle size distribution was such that it was well graded with high contents of fine and very fine sands (Figure 9) that are very susceptible to compaction. The nutrient analysis showed very low contents of macronutrients, pH around 6.4 with a Cation Exchange Capacity (CEC) of 16.4 meq/100g and soil organic matter (SOM) around 12.7 percent. The SOM was measured using loss on ignition that might have measured left over coal and/or limestone which burned off at ignition temperatures leading to a misleading higher result. Field tests showed very little SOM outside of the wetland areas.

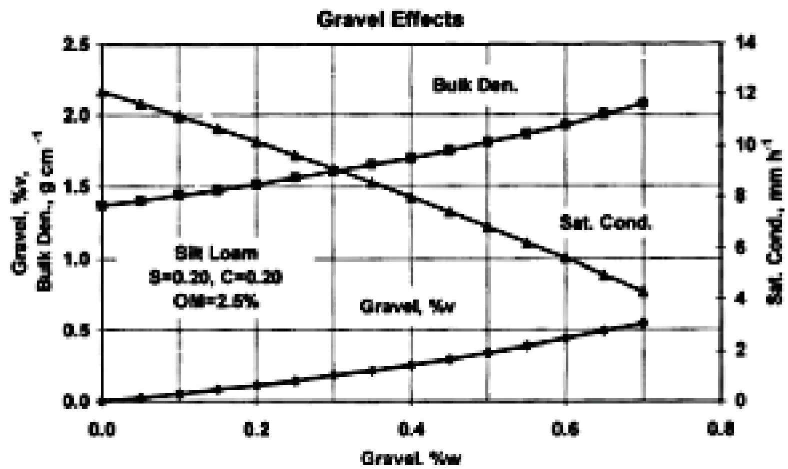
The large amount of rock fragments reduced water and nutrient holding capacity of the soil resulting in a less productive soil. Most natural soil textures compact to densities that restrict root elongation (Table 1). Reduction in root elongation restricts access to larger rooting volumes hence less water and nutrients. Addition of coarse fragments further reduces total Plant Available Water (PAW) [% at field capacity (0.33 KPa) – % at wilting point (15 KPa)] and saturated hydraulic conductivity (Ksat) while increasing overall soil bulk density (BD) (Saxton & Rawls, 2006).

FIGURE 9: Particle size distribution of exiting soils



In situ soil material was sufficient as a fill material to form the landforms, but not productive enough for the planting soil without costly screening and amendments. Therefore, a planting soil would have to be imported for those areas that have no topsoil and to cover the landforms. In addition, a large portion of the soil on site had contamination of not only dangerous chemicals, but also concrete, chunks of metal, and other leftovers from historic activities.

FIGURE 10: Example gravel estimates for gravel volume, bulk desnity and saturated conductivity versus gravel percent by weight (>2mm). From (Saxton & Rawls, 2006)



Long Dock Soil Design:

The planting soil that would be able to provide the landscape design goals of a viable ecological system that can equilibrate to the landform and further develop over time in a predetermined direction requires specifying certain soil properties. Not just any soil will work effectively.

Soil water and nutrients can be amended post construction but basic soil properties need to be designed and placed at construction. To encapsulate basic soil properties into one place that most all planting soils require see the following (Table 2) which is modified from Coder (2000) and in Craul and Craul (2006).

Specific conditions require some additional consideration during the soil design process. The soil will have to be heavy enough to withstand scouring, ruling out silty soils, porous enough to infiltrate sediment laden floodwaters without excessive clogging past what annual freeze-thaw and plant roots can offset, and not compact during construction in a wide range of moisture contents due to typically wet site conditions. In addition, there were some areas that required a structural soil to support tree roots under pavement. To meet these parameters, a poorly graded loamy sand was selected with less than 10 percent being retained above 2.0 mm to limit coarse fragments inhibiting water holding, more than 60 percent medium sand and coarser along with silt and clay percentages generally below 10 percent each within the topsoil, decreasing with lower horizons.

The soil profiles used consisted of two or three horizons that work together to provide a functioning soil profile based on natural profiles. Turf areas have a two horizon profile consisting of a coarse sand base (S3) of 6 inches topped with 6 inches of a poorly graded loamy sand topsoil (S1) that has approved compost added to bring soil organic matter (SOM) up to

Table 2: Soil Properties needed for Plant Growth.

Soil Resource		Requirements	
		Min	Max
Oxygen in soil atmosphere (for root survival)		3%	21%
Air pore space (for root growth)		25%	60%
Soil bulk density of the surface 24”		-	93.6 lbs/ft^3 (clays) 109.3 lbs/ft^3 (sands)
Penetration resistance (moist)‡		50 lbs/in^2	275 lbs/in^2 (clays) 300 lbs/in^2 (sands)
Water content (PAW)		12%	40%
Temperature limits for roots and soil biology		40°F/4°C	94°F/34°C
Soil pH		5.5	7.5
Soil Cation Exchange Capacity (CEC) of the surface 6”		8 meq/100g	>10 meq/100g
Soil organic matter content of surface 6” only		3%	10%
Soil organic matter content of subsoil		-	<1%
Soil coarse fragment content of the surface 6” (rocks etc. >75mm)		-	<20%

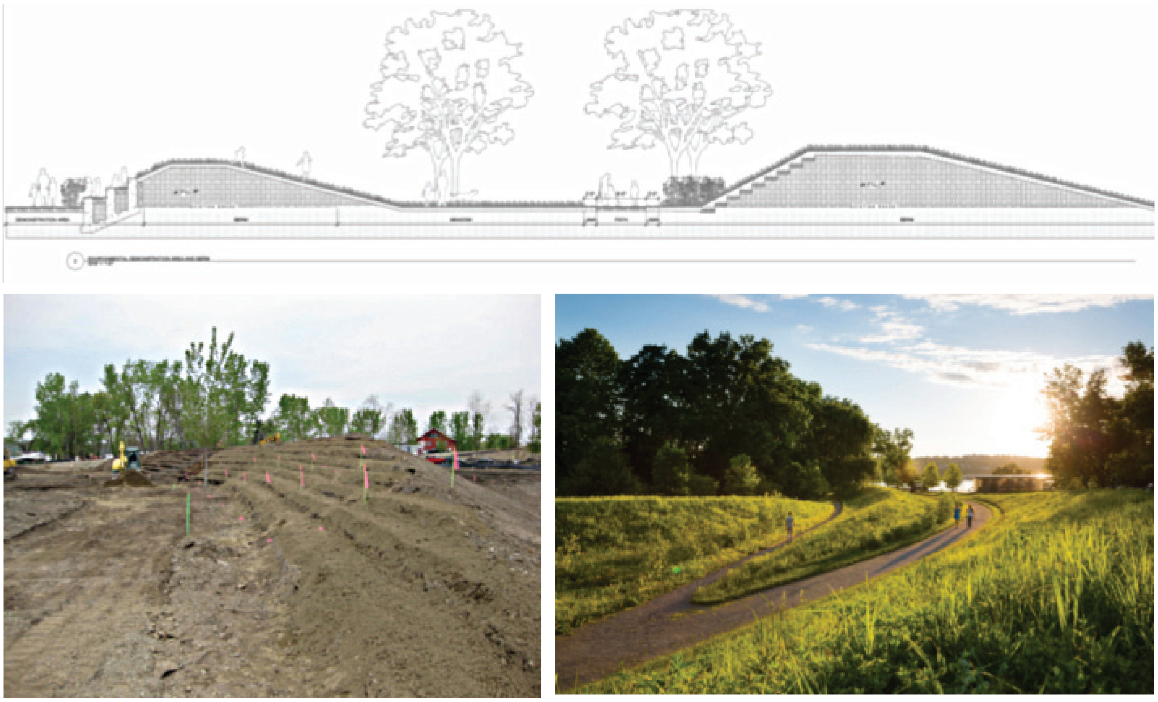
between 6 and 8 percent. Trees and shrubs received 6 inches of S3, 18 to 24 inches of a poorly graded loamy sand without SOM above 1 percent, and 6 inches of the S1 horizon. The wetlands received a topsoil of layer of 18 inches with SOM between 15 and 25 percent to mimic a mucky loamy sand. The rain gardens consisted of 18 inches of S3 material over a pea stone gravel base with 6 inches of S1 topsoil material. The S3 layer is present to drain excess water from the soil profile, but also to break the capillary rise of the fluctuating water table and to regulate the amount of water drained from the soil profiles above it due to the dissimilar matric potentials.

The planting soil was designed also to serve in multiple soil profiles from tree and shrubs, high use lawns, structural support, and rain garden to limit the amount of soil mixes required. Fortunately, the soil properties required for the project’s design were compatible across the different design elements.

Slopes:

All slopes that were greater than 2.5:1 had the subgrade terraced to provide stability at the planting soil subgrade interface. The terracing prevents rotational slides propagating at the base of the planting soil. Slopes less than 2.5:1 to the lower gradient 3:1 slopes received subgrade scarification of 3 to 4 inches deep that left parallel ridges following the slope contour.

FIGURE 11: Terraced subgrade of berm.



Stormwater Management Soils:

The water quality swales/bioretention basins were designed as an infiltration type that defers, infiltrates, and renovates runoff from the parking areas. The soil profile consists of a pea stone base approximately 18 inches above the high water table used for water storage, interrupting capillary rise from the subsurface fluctuating water table, and as a filter for the coarse sand (S3) infiltration sand. The profile was topped with 6 inches of topsoil (S1) to support plant growth. The pea stone also has a low water holding potential (matric) compared to the S3 material above. This allows moisture to perch at this interface regulating how much moisture is drained from the S3. The resulting soil moisture within the S3 at approximately 12 to 16 inches below the surface of between 16 to 20 percent moisture at the end of gravimetric water drainage (field capacity @ ≈ 0.33 KPa). The infiltration rates of these interconnected beds was around 8 inches/hour at the surface and withstood some sediment without clogging when plant roots, soil structure development and seasonal freeze thaw maintain preferential flow paths around root channels.

Meadow:

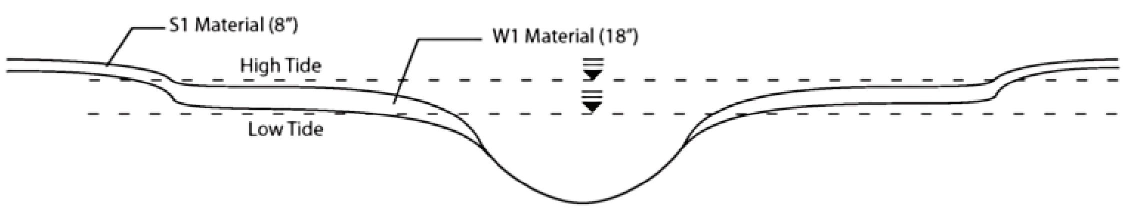
The meadow had sufficient reasonable soil, but after manipulation did not have enough SOM. These soils were highly compacted over the years, low in available nutrients, and high in gravels. These properties were very conducive for meadow mixes except for the compaction and SOM. To reduce compaction and enhance initial seed germination, approved mature compost at a rate of 3.1 CY/1000 ft2 was incorporated in the upper 6 inches using a Blecavator.

Structural Sand Based Soils

The soil particle size distribution designed for the basic S2 soil horizon used for regular planting soil was also designed to be used as a structural sand based soil to limit the number of mixes needed. The site's restricting parameters on soil characteristics also dictated that a coarse sand was used elsewhere. The S3 layer of 6 inches was placed over a scarified subgrade, then a 24-inch layer of S2 was placed in 6-inch lifts compacted to 95 percent of standard proctor, then geotextile laid on top with tree pit openings cut into the fabric and folded back over the base aggregate layer. The topsoil (S1) was placed in the tree pit opening after the tree had been planted.

Wetland Enhancement:

Both the existing and intertidal wetlands required removal of debris and other unwanted contaminates. The existing and created wetlands also needed to be excavated to provide a deep open water portion in the center with hydric soil conditions on either side that would eventually provide hummocky landforms that allow both saturated and ponded soil conditions for a diverse ecology.



A Optimal Wetland Cross Section

Scale = Not to Scale

The soil designed for this was to have high levels of SOM in order to start the hydric soil conversion by feeding the soil anaerobes and mimic typical saturated wetlands with high levels of under-decomposed organic matter leading to a USDA soil texture of a mucky loamy sand.

SITE HYDROLOGY

Due to its disposition, the site is regularly inundated by storm surges as well as upwelling of the Hudson. Winter ice floes and build-up are remarkably destructive. In addition to soils design, the stormwater management system and integration of the wetlands to capture, retain, treat, and release of storm runoff and surge inundation has proven to be necessary to optimize ecological function.

The plan created almost a half-acre of new wetlands and enhanced almost three quarters of an acre of existing wetlands to produce a richer and more diverse habitat on the site and to aid in stormwater management. Vegetated water quality swales and constructed interconnected wetlands were utilized for stormwater treatment to achieve zero additional post-construction runoff, and prevent erosion and sediment transport at the river's edge.

Stormwater management strategies, first developed as an integral part of the original plan, included treatment and reuse of gray water for the eco-hotel and conference center, capture of roof water to irrigate the green roof and circulate within the canal, water quality swales to capture and cleanse stormwater from the public deck and woodland parking and direct flows to the wetlands, then to the intertidal zone before release to the river. Many of these strategies were implemented as part of the site plan for phase two of the project, in order to not preclude potential future development of the northwestern portion of the site. In addition, pervious asphalt was employed for the parking area at the Red Barn due to its isolation from the meadow and south wetlands. The water quality swales were redesigned to be located along the new drive and parking north of the meadow. These swales were designed to receive drainage from the parking areas, cleanse and provide infiltration. They are interconnected in order to equalize in a large storm event and overflow to the meadow and ultimately to the wetlands.

The series of wetlands at the edge of the intertidal zone along the south shoreline provided a critical role in not only capturing and cleansing overland flows to the river, but also in slowing flood and surge events and scouring as water recedes. The creation of the new wetland also provided the opportunity to construct an outdoor classroom at its edge overlooking it and the Hudson.

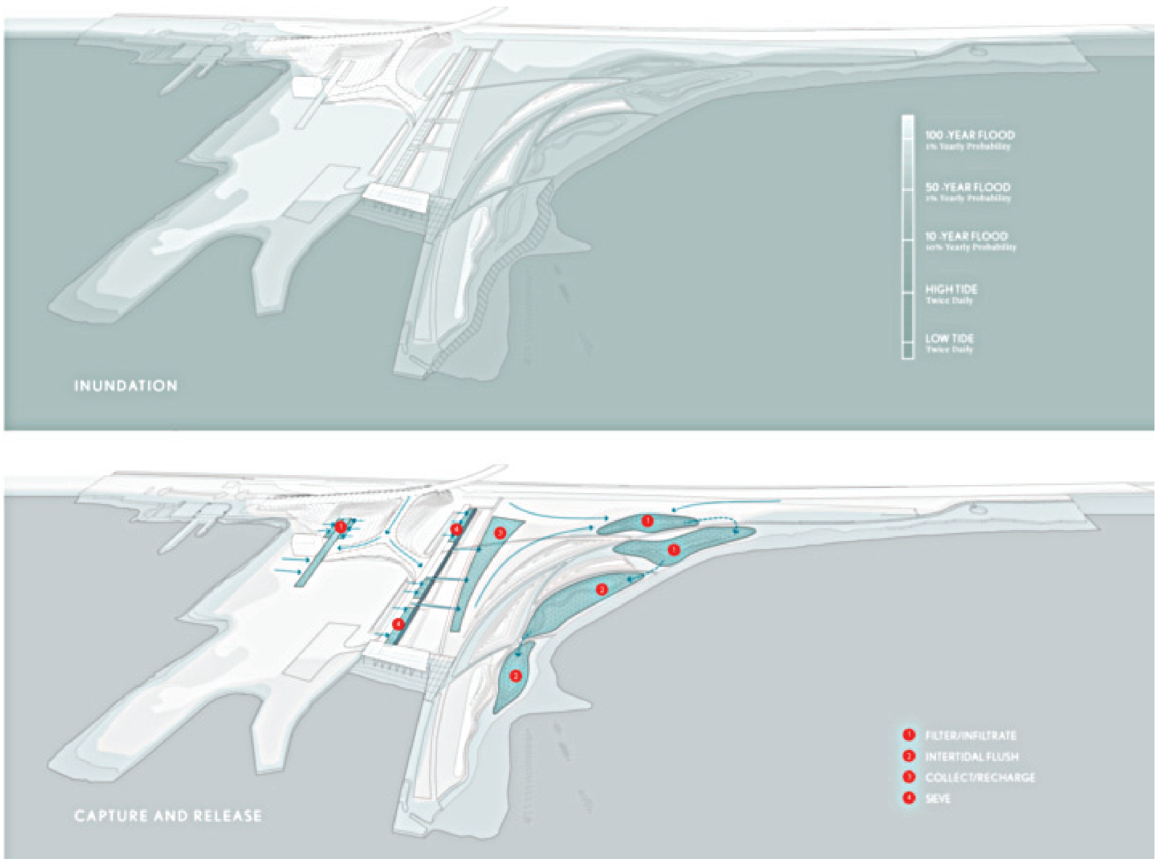
After invasive removal, grading and soil preparation followed with the excavation of a new wetland, enhancement of Wetland B and Wetland C, stabilization of Wetland D, and creation of water quality or bio-retention swales adjacent to parking. The tree and soil protection plan included protection fencing of the intertidal zone along the south shoreline that prohibited machinery in this zone. The existing wetlands were enhanced by removal of the impermeable existing soils and replenishment with an engineered soil strata of high organic content at the top, to support emergent vegetation and aquatic habitat and holding capacity, down to a fine course soil to bridge the existing and facilitate infiltration and air movement — hydrological flows occurred more vertical through capillary action than overland. The excavated soils from the site were used to create a series of sculpted berms to the north to buttress the site and provide further protection against floods and debris. The berms also provide spatial and visual separation of the wetlands and intertidal zone from the meadow.

Prior to planting, but subsequent to excavation and placement of soils, Wetland C was holding a greater volume of water than anticipated. It was assumed that the high level of SOM in the designed soil profile resulted in a slower subsurface conveyance between the interconnected wetlands through the water table. A french drain was installed between Wetland C and Wetland B to connect the hydrologic flow in the short-term. Over a period of a couple of years, the decomposition of organic matter through the growth of plants and organisms has naturally reconnected these wetlands.

There have been minor configuration and volume changes with the wetlands, enhanced and created, as a result of soil deposition, and erosion of the interior shelf in Wetland C, from different flood events post construction of the park. However; the wetlands and the intertidal zone, supported by functioning soils and thriving plants, have remained intact.

Overall the designed system greatly improved stormwater quantity and quality from the site prior to discharging into the Hudson. First, the site design decreased impervious cover by eighteen percent. Then the system of water quality/bioretention swales, enhancement and interconnection of the wetlands, the use of porous pavement, and the establishment of native meadow groundcover and wetland plants captured more than ninety percent of the stormwater volume.

FIGURE 12: Diagram of flooding events over the proposed site design (top) and over-land stormwater flows (bottom).



NATIVE PLANT COMMUNITIES

The recovery of the site, largely with native wetland and meadow grasses, and hardwood trees, and shrubs, was organized into the following zones of landscape character: Upland Canopy Zone, Lowland Wetlands, the Intertidal Zone, and the Meadow. The upland zones were focused on recapturing the diverse tree canopy habitat that occurs in upland regrowth conditions along the eastern shoreline of the Hudson. Parking areas related to recreational uses were designed to fit within this vegetative cover so as to minimize visual impacts and heat island effects. All parking areas were designed with pervious paving materials (reused concrete slabs found on-site), and runoff was captured and mitigated by vegetated water quality swales for cleansing and infiltration or runoff to the created wetlands.

The enhancement of existing wetlands and the creation of new wetlands produced a richer and more diverse habitat on the site and aided in stormwater management. The lowland wetlands, Wetlands A, B, C, and the created wetlands, were vegetated with a diverse palette

Table 3: Rerpresentative Plant List for the meadow and wetlands.

Representative Wetland Plant List

Wetland and Grassy Meadow (Seed):
Heath Aster (Aster erecoides)
Wild Indigo (Baptisia tinctoria)
Canada Lilly (Lilium canadensis)
Perennial Lupine (Lupinus perennis)
Evening Primrose (Onethera biennis)
Seaside Goldenrod (Solidago sempervirens)
Culver's Root (Veronicastrum virinicum)
Little Bluestem (Andropogon scoparius)
Big Bluestem (Andropogon gerardi)
Switch Grass (Panicum virgatum)
Indian Grass (Sorghastrum nutans)

Wetland Perennials (Plugs):
Fox Sedge (Carex vulpoinoidea)
Bristly/Cosmos Sedge (Carex comosa)
Hop Sedge (Carex lupulina)
Blunt Broom Sedge (Carex scoparia)
Soft Rush (Juncus effuses)
Green Bulrush (Scirpus atrovirens)
Softstem Bulrush (Scirpus validus)
Wool Grass (Scirpus cyperinus)
Swamp Milkweed (Aesclepias incarnate)
Flat Topped/Umbrella Aster (Aster umbellatus)
Square Stemmed Monkey Flower (Mimulas ringens)
Blue Vervain (Verbena hastate)
Sweetflag (Ascorus calamus)
Swamp Aster (Aster puniceaum)
New England Aster (Aster nova angilae)
Nodding Bur Marigold (Bidens cernus)
Blue Joint Grass (Calmagrostis canadensis)
Fringed Sedge (Carex crinite)
Lurid Sedge (Carex lurida)
Bearded Sedge (Carex comosa)
Fox Sedge (Carex vulpinoides)
White Turtlehead (Chelone glabra)
Joe-pye Weed (Eupatorium purpureum)
Manna Grass (Gycera canadensis)
Common Sneezeweed (Helenium autumnale)
Blue Flag Iris (Iris versicolor)
Cardinal Flower (Lobelia cardinalis)
Sensitive Fern (Onoclea sensibilis)
Cinnamon Fern (Osmunda cimmonea)
Arrow Arum (Peltandra virginica)
Pickerelweed (Pontederia cordata)
Green-headed Coneflower (Rudbeckia laciniata)
Duck Potato (Sagittaria latifolia)
Hardstem Bulrush (Scirpus acutus)
Chairmaker's Bulrush (Scirpus americanus)

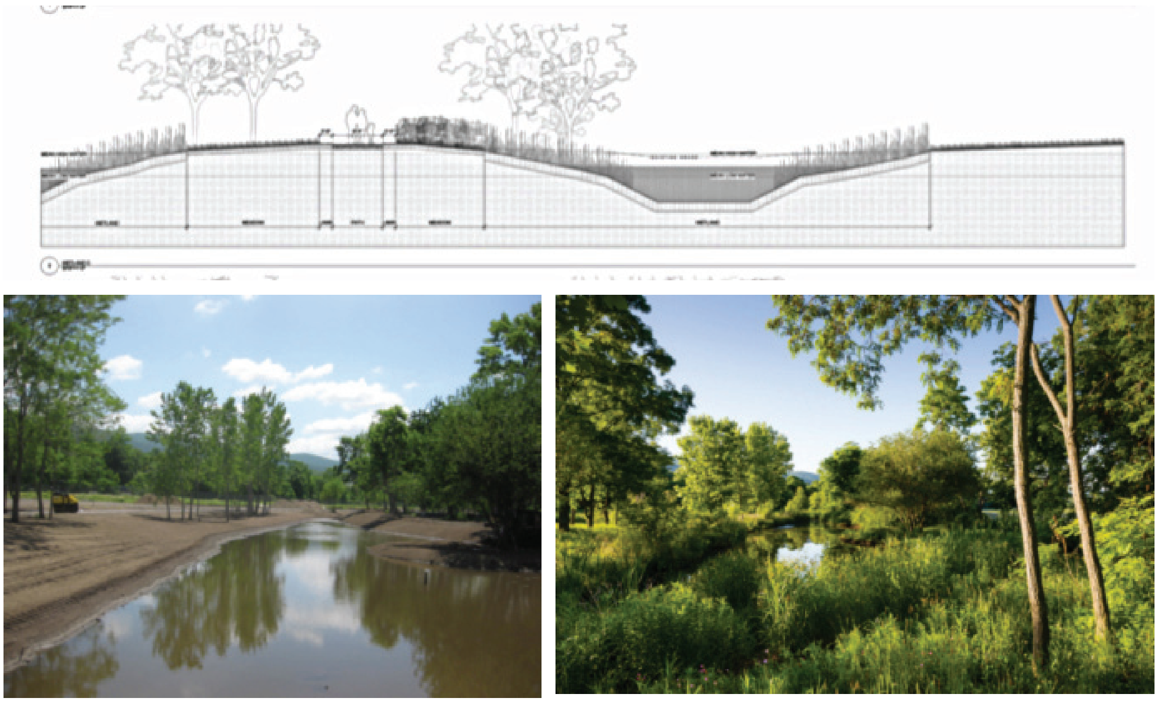
Wetland Shrubs:
Red Chokeberry (Aronia arbutifolia)
Buttonbush (Cephalanthus occidentalis)
Clethra (Clethra alnifolia)
Silky Dogwood (Cornus amonum)
Winterberry (Ilex verticillata)
Swamp Azalea (Rhododendron viscosum)
Arrowood Viburnum (Viburnum dentatum)
Sweetfern (Comptonia peregria)
Highbush Blueberry (Vaccinum corymbosum)

Wetland Trees:
Red Maple (Acer rubrum)
Serviceberry (Amelanchier arborea)
Gray Birch (Betula populifolia)
Black tupelo (Nyssa sylvatica)

of native hardwood trees, shrubs, and wetland and meadow plant species associated with two plant community types: Tidal Slough and Tidal Marsh. The shoreline intertidal zone received restoration measures to curtail erosion. The intertidal zone, Wetland D, was vegetated with Tidal Emergent/Forested Wetland type species to stabilize the south shoreline.

A large portion of the site was reserved to feature a constructed meadow. Some open lawn spaces at the end of Beacon Point and for the new North Shore were allocated to support more intensive levels of gathering and recreational activity. The meadow was designed as a warm season grass meadow with forbs and wildflowers to increase habitat and diversity consistent with the mission of Scenic Hudson and the use of the park. Jack Ahern, professor at the University of Massachusetts- Amherst, developed the approach and specification for its installation, establishment, and long-term management. The approach was to replicate the

FIGURE 13: Soil placement and planting of Wetland B.



natural processes of seed scarification over winter and provide for spring germination. Three seed mixes were designed: Grassy Meadow, Wetland Areas, and Shaded Woodland. Each seed mix included a cover crop of Annual Rye grass. The Annual Rye was cover crop to fill the open spaces, horizontally and vertically, and prevent weed seeds from invading. It also shaded the warm season grasses as they germinate. A regular mowing of the Annual Rye was scheduled to prevent self-seeding and so the Annual Rye would decease the following winter.

After confirmation of the removal of invasive species, the seedbed was prepared by hand raking for a late fall seeding before the ground froze. The warm season grass species germinated the following spring/summer. Mowing the meadow was proposed as important management practice during the first growing year – depending on amount of weeds present. The mowing favored meadow species over annual weeds that may be present in the seedbed. The first mowing was when the tallest growth approached 6”-8”, to cut the annual weed flower/seed heads, and continued every 3-4 weeks, as needed until late October. Once the meadow species became established they could out-compete the weeds.

Barnyardgrass (Echinonchloa crusgalli), a non-native invasive annual grass, invaded the meadow after the initial seeding. The Barnyardgrass was so pervasive that it required eradication of the entire meadow and wetland areas by cutting prior to going to seed. The meadow and wetland areas were reseeded and the establishment process started anew. Over the past few years the meadow has evolved from what was intended to be predominately a Little Bluestem meadow to what is currently an Indian Grass meadow in response to moisture and soil conditions. Little Bluestem, Big Bluestem, Switch Grass, and many of the wildflowers are present but constantly shifting and moving year to year.

The long-term management of the meadow includes annual mowing to prevent succession of woody species. A mid-spring mowing, before plants are actively growing and after the soil dries, has been preferred. This maintained plants standing over winter for visual interest, to benefit insects and birds, and provide a buffer from extreme weather and frost action on the soil. The mid-spring mowing also cuts some of the undesirable cool-season grasses that may invade the meadow.

The site vegetation, its plant populations and communities, has continued to grow and develop over the past few years. The event lawn areas have been maintained in a static condition, while the other zones of character have been allowed to be dynamic through succession and in response to the site and periodic disturbances. Vegetation relied primarily on seeding due to the large expansive areas and low construction budget. Wetland edges were planted with landscape plugs and seeded, where the bioretention/water quality swales were only planted with landscape plugs. Both the seeding and plugs established in a relatively short period. Trees and shrubs, fairly small in size, were planted to support the Intertidal Zone and to increase canopy and diversity in the Upland Canopy Zone. Successional areas, the edges between the Intertidal and Wetland Zones, were heavily planted with whips of Gray Birch (Betula populifolia) and existing cottonwoods (Populus deltoides), upwind, have been allowed to self-seed along with other native volunteers to create an evolving edge condition that replicates a natural meadow edge.

CONCLUSION

Long Dock Park has, over time and through natural processes, reached healthy and sustainable ecosystem function. The landscape is able to perform ecosystem services to sustain life and continually adjust to conditions of change. In order to build resiliency, we needed to anticipate change and understand that periodic disturbances, such as flooding, help build and diversify ecosystems. While the design of the park has created the spatial, aesthetic, and programmatic goals for use, it has more importantly provided the infrastructure to initiate natural processes. Healthy soils and the integration and interrelation of water enable ecosystem processes. A healthy soil was the medium that promoted growth of plants and organisms. The ability to utilize water as a resource and minimize its destructive capabilities enabled performance and sustained the landscape. The establishment of native vegetation provided

FIGURE 14: Looking over the created wetland to the south shoreline and the Hudson River beyond.

resiliency against disturbances and a diversity of habitat. Long Dock Park continues to prove its resiliency, having endured tropical storms Irene and Sandy, and significant bi-annual flooding, with a dynamic and ever-evolving landscape of diverse plant communities.

CLIENT

Scenic Hudson, Inc.
Steve Rosenberg- Senior Vice President
Margery Groten- Project Manager
Meg Rasmussen- Project Manager

DESIGN TEAM

Reed Hilderbrand, LLC.- Lead, Landscape Architect
Architecture Research Office- Architecture
Craul Land Scientists, Inc.- Soils Scientist
Jack Ahern- Meadow Design
Joesph Bridges- Biologist
Diveny Tung Schwalbe- Civil Engineering
McLaren Engineering Group- Marine Engineering
New England Environmental- Wetland Design
Silman Associates- Structural Engineers
Ecosystems Strategies- Environmental Consultants

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