


TEANECK CREEK WETLAND RESTORATION PROJECT

FINAL REPORT
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NEW JERSEY WETLANDS MITIGATION COUNCIL

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RUTGERS
New Jersey Agricultural
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The Teaneck Creek Conservancy is a 501(c)3 non profit organization located at 20 Puffin Way, Teaneck, NJ 07666

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APPENDIX 1

Five papers based on the TCC restoration project submitted to the peer-reviewed journal, "Urban Habitats." These five (5) papers are currently in revision, and are scheduled for publication online in December, 2007.

APPENDIX 2

Conceptual Restoration Plans prepared by Rutgers University.

APPENDIX 3

Bergen County Freeholder Resolution No. 1550, Wetlands Research and Restoration Design Plan, October 17, 2007.

I. Executive Summary

The Teaneck Creek Conservancy (TCC) is located in Overpeck County Park and is surrounded by the highly urbanized Bergen County landscape. Degradation of the existing wetland system on the site has occurred at multiple periods over the last two centuries due to increasing human activities in the region. To reclaim this portion of the park for public use, TCC has installed a new 1.5 mile trail system, which was jointly funded by the Puffin Foundation, Ltd. and Bergen County. As part of the effort to restore degraded wetlands on the site, scientific studies have been undertaken to describe the site's current baseline conditions. This work is now informing the design of a restoration plan for the site. Specific goals have been established to restore/enhance 20 acres of fully functioning wetlands on the site and to replace invasive plant species with native vegetation appropriate for this riparian wetland system.

The project team, lead by Rutgers University and TRC Environmental Corporation, has been collecting data for the last three years in an effort to characterize existing conditions. Hydrologic studies have provided data that has been incorporated into an USEPA Surface Water Management Model (SWMM) to develop a water budget for the site and describe water movement into and through the site. An important fact that has emerged from this work is the recognition that a hydrologic connection between Teaneck Creek and the site's surface and groundwaters does not currently exist due to the presence of clay-fill material beneath large areas of the site and in berms adjacent to the creek. Soils have been characterized as native, dredge-clay, or unconsolidated fill and the location of these various soil types has been mapped. Plant species have been identified and maps developed showing the location of desirable native species versus areas that are dominated by invasive vegetation.

Based on the data obtained from this research, restoration design plans have been developed. The goal of the design is to protect high quality areas remaining on the TCC site, to restore new wetland areas through the removal of fill materials and lowering surface elevations, to reestablish hydrologic connections between the Teaneck Creek and the interior wetlands, and to make the site accessible to the local community and residents of Bergen County. As part of the design, a debris removal plan has been proposed to remove/relocate materials with as little disturbance to the site as possible, especially in areas where desirable vegetation is well established. The project site has been divided into four restoration zones, and specific objectives for each zone have been defined. The greatest area of disturbance during restoration work will occur in the highly disturbed southern portion of the property adjacent to DeGraw Avenue.

Due to the presence on the site of invasive plant species, an ongoing maintenance program involving both TCC and Bergen County must be initiated. It is of vital importance to establish a "No Invasive" buffer area around the undisturbed native vegetation in the northeastern corner of the site adjacent to Fycke Lane. Identification and removal of new invasive species must be undertaken by TCC volunteers, and Bergen County will provide routine support for mowing the trail grass buffers during and after the growing season. These activities are critical to protect the newly planted areas that have already been restored/enhanced, and to address ongoing maintenance issues once restoration commences.

Costs for the restoration (not including debris removal or remediation activities) are estimated to be $1,245,000. Various funding sources have been identified and are available to support this restoration work. When the restoration plan has been approved by TCC, Bergen County, the NJ Wetlands Mitigation Council, and the NJ Department of Environmental Protection Land Use Division, project partners intend to prepare and submit grant applications to the appropriate funding programs.

II. Background

The Teaneck Creek is a tributary of Overpeck Creek, and both water bodies flow through the 1200-acre Overpeck County Park prior to connecting with the estuarine portion of the Hackensack River. This park is located in highly urbanized (greater than 90% impervious cover) Bergen County. The 46-acre Teaneck Creek Conservancy site is located within the park (Fig. 1), and the non-profit conservancy, established in 2001, has a long-term lease from Bergen County to manage the site.

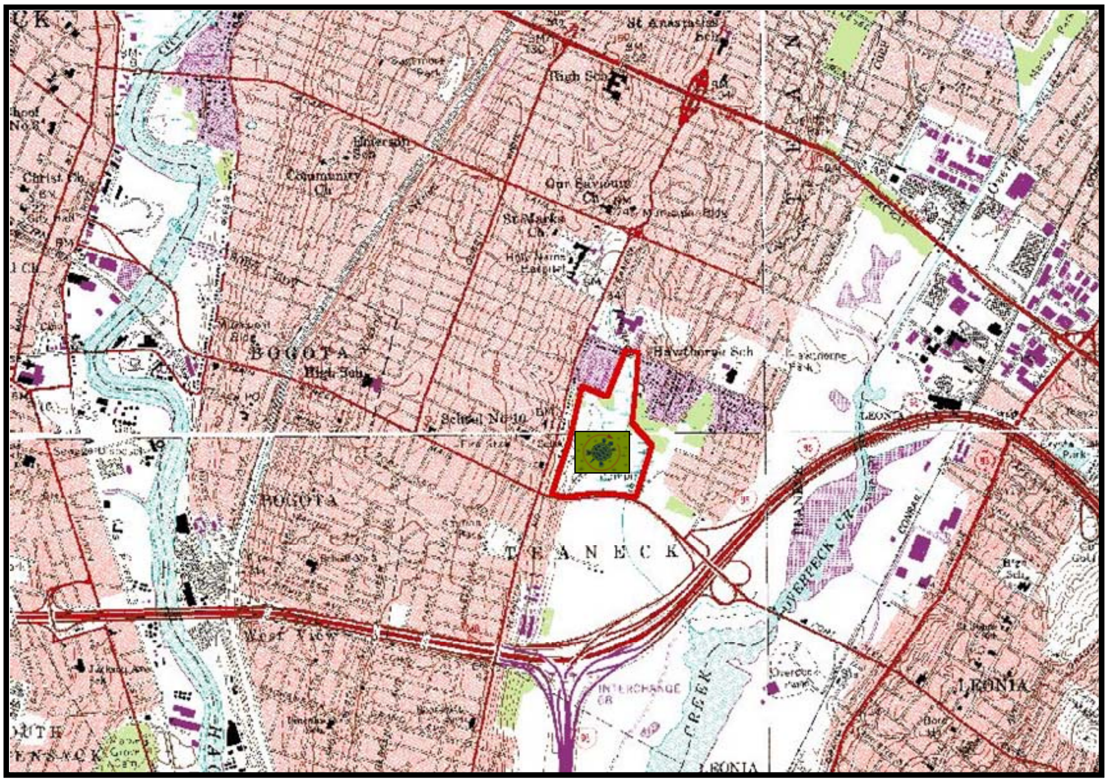

Figure 1.
Map showing location of Teaneck Creek Conservancy at the intersection of Routes 95 and 80.

The Teaneck Creek Conservancy site contains a diverse spectrum of habitats, ranging from upland forest to emergent marshes dominated by *Phragmites australis*. Degradation of the wetland areas has occurred as a result of past human disturbances, disruption of the natural hydrology, followed by colonization of invasive plant species.

The property has an extensive history of hydrologic disturbance (see Arnold, Appendix 1), culminating in the installation of a tidegate (1950s), channelization and placement of berms (1960s), and installation of stormwater connections with the Teaneck municipal drainage system. These human-induced changes have disconnected Teaneck Creek from local surface waters and downstream tidal pulses, while increasing the flow of stormwater runoff into the wetlands system (see Obropta et al., Appendix 1).

Figure 2.
Teaneck Creek 1.5 mile boardwalk and trail system completed in 2006.

During the past three years of research and restoration planning, preliminary park development and improvement efforts were initiated. Groundbreaking for a 1.5 mile walking trail system consisting of boardwalks, trails and an outdoor classroom for passive recreation and environmental education occurred in August, 2005. Work on this trail system was completed (Fig. 2), and the park officially opened to the general public in May, 2006. In addition to the development of passive recreation and environmental education programs, the project partners have committed to long-term restoration goals including the development of quality wildlife habitat on this restored site, which can serve as a model for the Overpeck Creek watershed and other highly urbanized areas in the NY/NJ metropolitan region.

This research and restoration effort began with the signing of a Memorandum of Understanding in 2003 by the Teaneck Creek Conservancy (TCC), the County of Bergen (the County), and Rutgers University (RU) for the purpose of establishing a long-term partnership to further restoration and research activities at the Conservancy site within Bergen County's Overpeck Park. In addition to TCC, the County, and RU Cooperative Extension Water Resources Program and Rutgers Environmental Research Clinic, project partners include TRC Environmental Corporation (TRC), and US Geological Survey (USGS). Funding to support this effort was provided by the New Jersey Wetlands Mitigation Council (NJWMC), which in 2004 awarded the Teaneck Creek Conservancy $300,000 to complete a baseline assessment of existing conditions on the TCC site that would inform efforts related to wetland creation/enhancement. In addition to the NJWMC funding, an additional $30,000 was provided to Dr. Ravit by the NJ Water Resources Research Institute (NJWRRI) to complete a study comparing local atmospheric nitrogen and carbon deposition with deposition at other locations within the State of NJ.

A. CHARACTERIZATION OF THE CURRENT SYSTEM

The overall goals of this first phase of the project were to prepare a plan for restoration/enhancement of 20 wetland acres, including creation of 4 to 6 additional wetland acres on disturbed areas of the site as part of the initial baseline research. The specific goals of the baseline characterization were to collect environmental data (Fig. 3) documenting existing site conditions and to develop a hydrologic model and water budget for this wetland system. Based on this data, restoration design plans including a planting and invasive species control plan have been prepared, and project partners are prepared to complete the environmental permitting process (for a discussion of the restoration challenges see Ravit et al., Appendix 1).

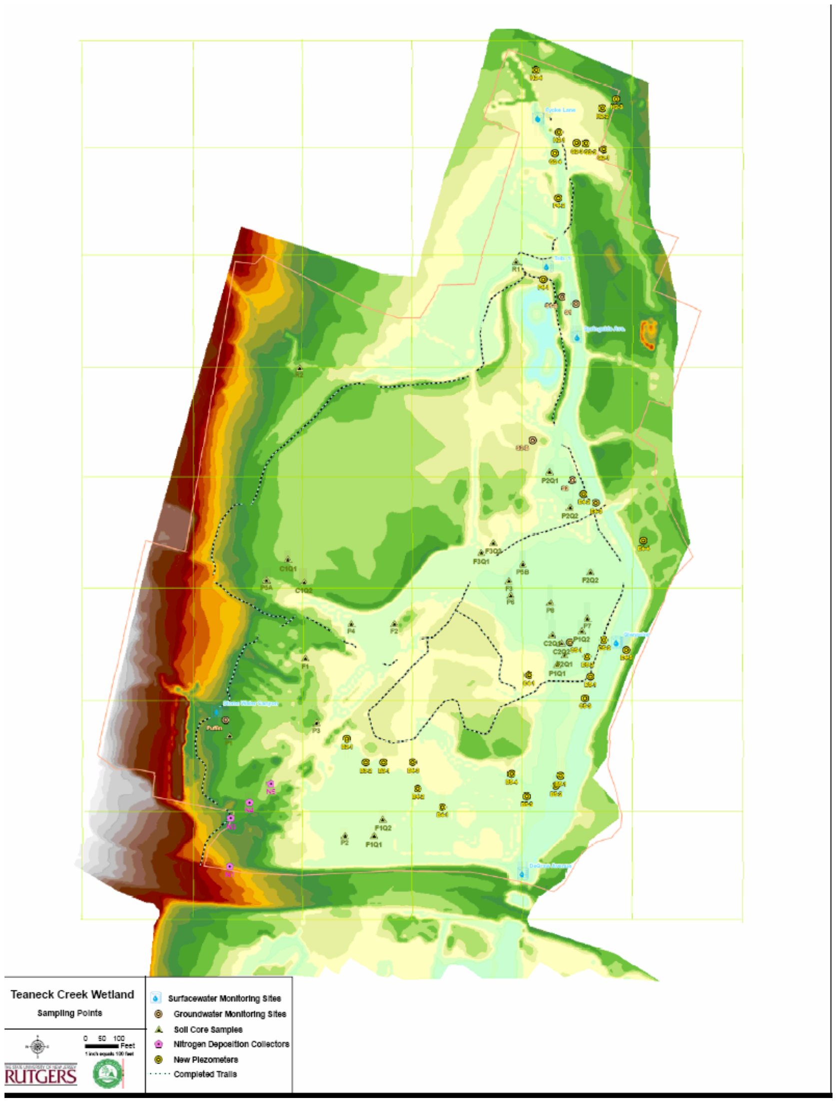

Figure 3.
Sampling locations within the Teaneck Creek Conservancy.

Critical components in the baseline characterization included research and documentation of the current hydrology through surface water and groundwater sampling, description of existing soil conditions, and a detailed surveying of vegetation species and patterns across the 46-acre site.

1. HYDROLOGY

Surface water samples were collected quarterly over a two year period (January, 2005 – February, 2007), and these samples were analyzed by USGS to determine nitrogen and phosphorus concentrations and loadings. Flow measurements, under low and high (stormwater) flows, were obtained during all sampling events. Over forty (40) groundwater wells were installed to measure water movement and groundwater levels throughout the system (2005, 2006). Thirty (30) groundwater wells were measured on a weekly basis (2006) to determine the current height of the water table at various locations throughout the potential restoration site. A pressure transducer was installed on the bridge at DeGraw Ave. to measure water height on an hourly basis. All data collected from these sampling events has been made available to project partners and funders at www.rerc.rutgers.edu/Teaneckcreek/data (password protected).

Measurements showing a lack of groundwater movement indicate that a ***hydrologic connection does not currently exist between groundwater and the Teaneck Creek***. During high tide the creek fills with fresh water flowing in from upstream. This is a result of the downstream tidegate closing, which restricts both the release of water from the system and the upstream flow of saline waters from the Hackensack River. Due to this human alteration, the Teaneck Creek wetlands do not currently experience typical tidally-influenced flushing.

The data obtained from these hydrologic sampling events, in combination with the Township of Teaneck storm sewer data, was entered into a USEPA (Fig. 4) Surface Water Management Model (SWMM).

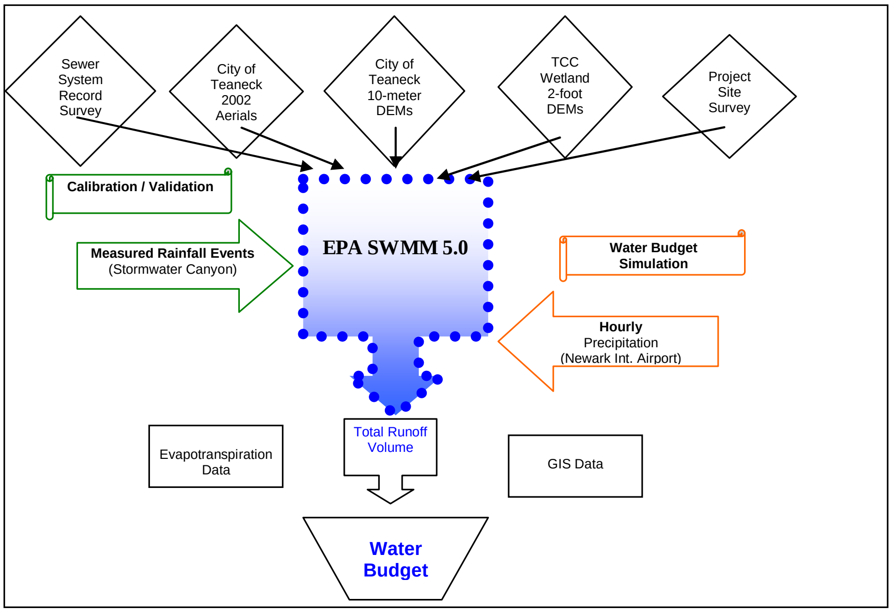

Figure 4.
A diagrammatic representation of the USEPA SWMM model used to calculate the TCC water budget.

Based on the inputs of water to the Teaneck Creek wetlands (storm sewer flows and precipitation) and water outflows (evapotranspiration), an average water budget was calculated for the system (Fig. 5).

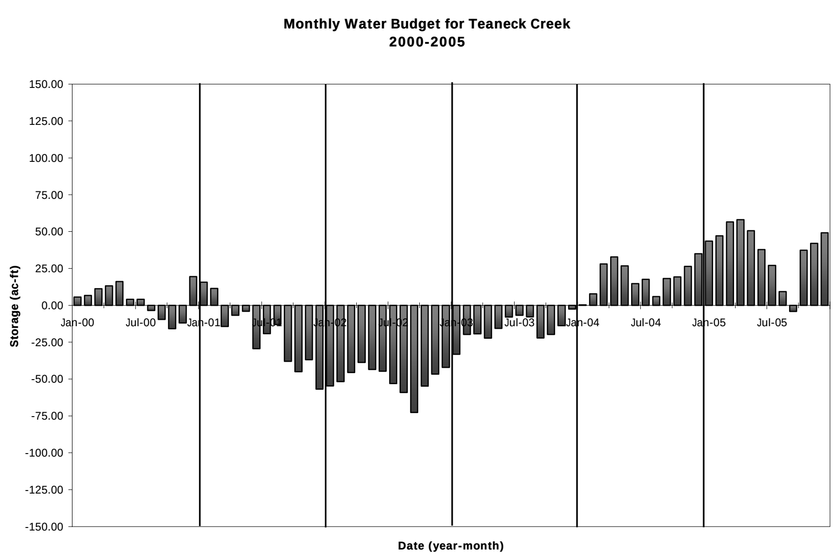

Figure 5.
Average monthly water budget for the Teaneck Creek system (2000-2005)

The water budget calculation shows that during the summer months and under drought conditions (2001-2002), due to the lack of a groundwater connection, evapotranspiration exceeds water inputs and decreases the overall system water volume creating a net loss, or water deficit. During the fall, winter, and spring storm periods precipitation that normally occurs provides the water volume necessary to support a riparian wetland system (for a discussion of the complete system hydrologic data see Obropta et al., Appendix 1).

The SWMM model was utilized to describe surface water movements through the various sub-basins of the Teaneck Creek wetland system (Fig. 6).

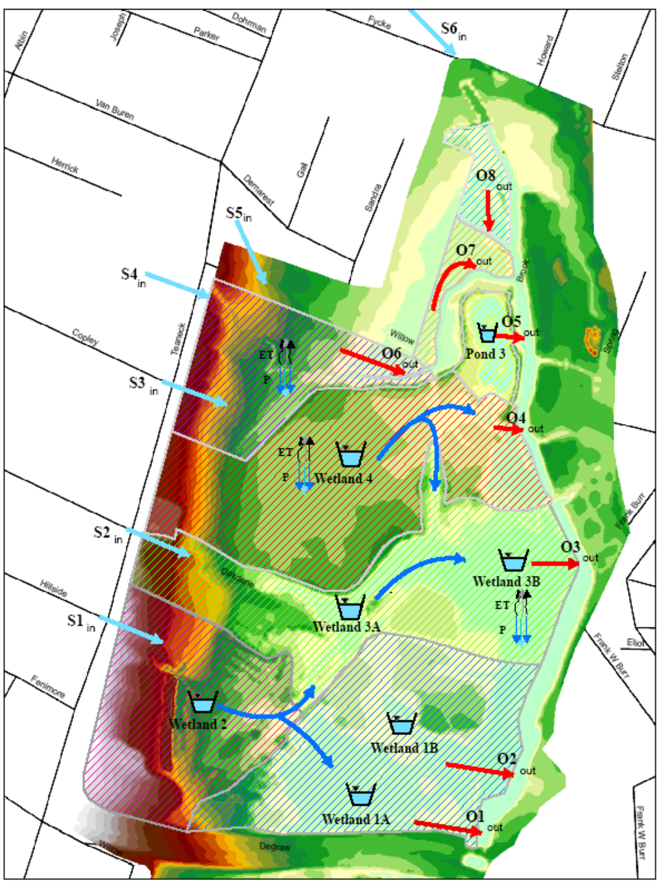

Figure 6
Surface water flows into and out of the Teaneck Creek wetlands.

2. SOILS

The soils found within the boundaries of the TCC consist of organic wetland (hydric) soils, red clay dredge material, and unconsolidated fill materials that were previously deposited on the site (Fig. 7).

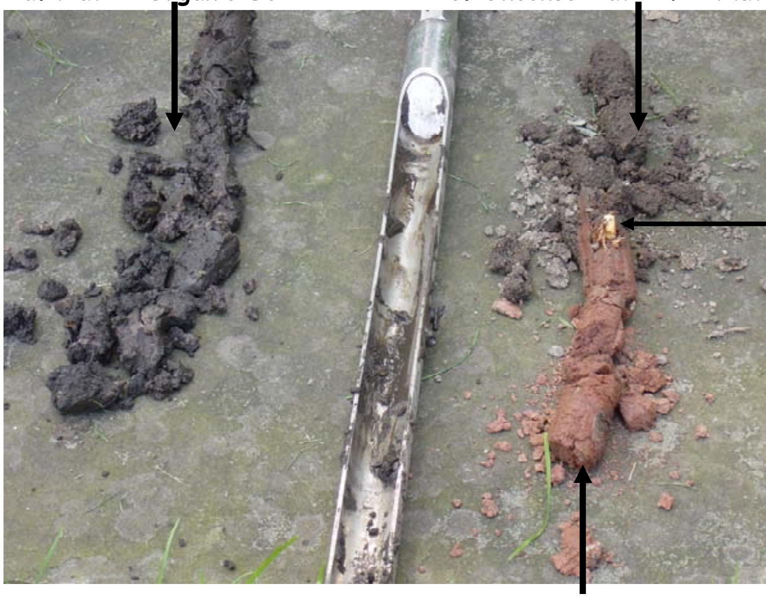

Figure 7
Soil cores taken from three locations within the Teaneck Creek Conservancy.

The hydrologic properties of these three materials vary considerably. Native hydric organic soils may retain 2-3 times their weight in water, increasing the flood storage capacity of the wetlands, and creating highly saturated conditions. The dredged-fill clay berms that line the Teaneck Creek prevent water movement between the creek and any surface water and/or groundwater located behind the berms on upland portions of the site. The unconsolidated fill materials allow water to move quickly downward, creating drier conditions within the surface soil rooting zone.

These various hydrologic conditions affect the type(s) of wetland or upland vegetation capable of surviving at various locations within the site.

3. VEGETATION

To obtain a coarse-scale view of the existing vegetation at the TCC site, a grid system was established using GIS equipment. These 100 m x 100 m sampling grids were visited at least three times during the growing season (2006), and multiple traverses were made through the sampling grid to identify all plant species within each grid square. As part of this observation, an estimate was made the abundance of

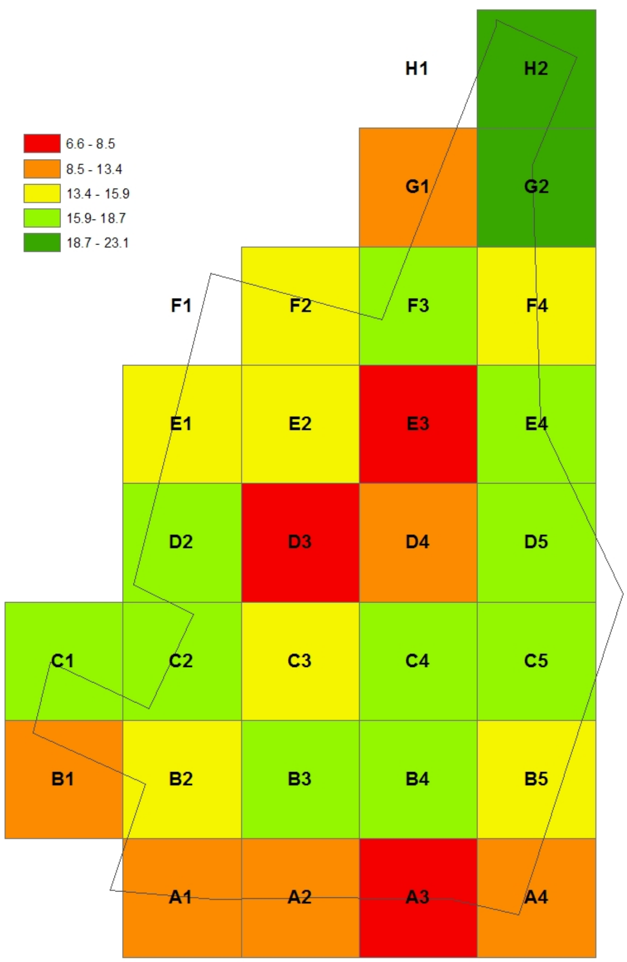

Figure 8
Teaneck Creek Floristic Quality Index

each plant species based on a five-level scale (rare, occasional, frequent, common, and abundant). After the vegetation in each sampling unit was completed, the New Jersey Coefficient of Conservation (NJ CC) was applied to each species. This coefficient describes the habitat requirements for a particular species, including its sensitivity to disturbance. The NJ CC for all species within each sample grid was used to calculate a Floristic Quality Assessment Index (FQAI) for the grid (Fig. 8).

The soil quality was also characterized by the soil type and source of the dominant substrate material (native, dredge-fill, fill with debris, and mixed) within each sampling grid (Fig. 9). Specific locations were also identified where debris piles are located within the existing wetland configuration.

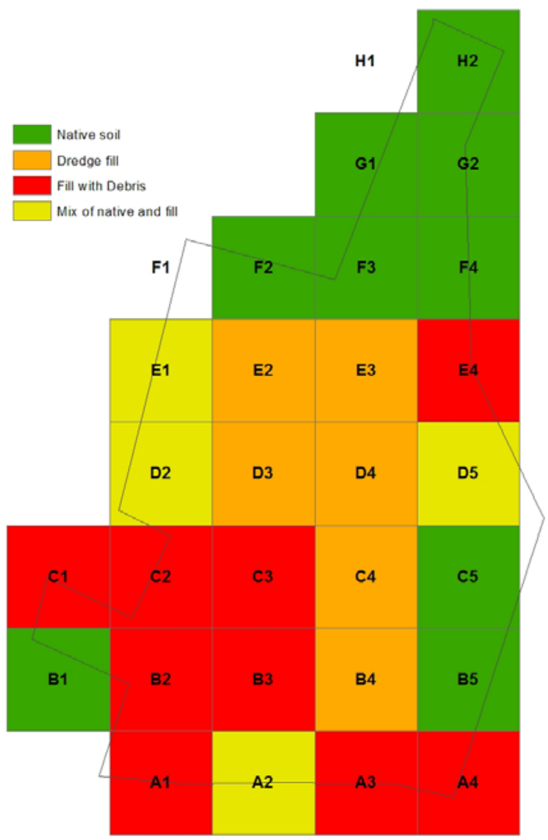

Figure 9
Teaneck Creek soil characterization

III. RESTORATION CONCEPT PLANS

A. RESTORATION ISSUES

The initial baseline characterization phase of the TCC restoration project is now complete. The data obtained over the past three years has been used to develop the restoration plans included in this report. The wetland restoration plans require review and approval from TCC management and Bergen County, prior to presentation to the NJWMC. Upon review and approval by the NJWMC, the Restoration Plan is to be submitted to the NJDEP Land Use Regulation Program to obtain the permits required for wetland restoration, landfill closure, site remediation, entrance improvements, and construction of a parking area.

To achieve 20 acres of restored/enhanced wetlands there must be an increase in flooding, and subsequent retention of water on additional acreage within the TCC site. To achieve increased wetland acreage, changes must occur in the topography of the system, and these changes must take into account removal of debris, the water flow patterns of the six storm water inputs, the inter sub-basin water movements, and surface flows from the Teaneck Creek. The overall restoration strategy is to lower the surface elevations, remove specific types of debris, and establish a connection with Teaneck Creek surface waters, while protecting native vegetation and soils, and creating as little disruption to the site as possible.

B. DESIGN

1. DESIGN RATIONAL

Approximately 26 acres of the site are currently mapped by the State of NJ as consisting of historic fill. In addition, illegal dumping of construction debris has occurred on the property. Due to the presence of heavily vegetated wetland areas and the overall objective of wetlands habitat enhancement, disturbance and/or capping of historic fill and debris piles is being minimized to maintain native vegetation communities. The proposed restoration activities focus on reconnecting the hydrologic system, including surface/storm water inputs located along Teaneck Road and Degraw Avenue, through a series of wetland basins on the property, and reestablishing the hydrologic connections with Teaneck Creek. Restoration activities have been proposed in four unique zones across the site (Figure 10). These zones were determined using the information generated by the hydrologic modeling, soils characterization, and vegetation surveys. Specific restoration initiatives will be required for each zone.

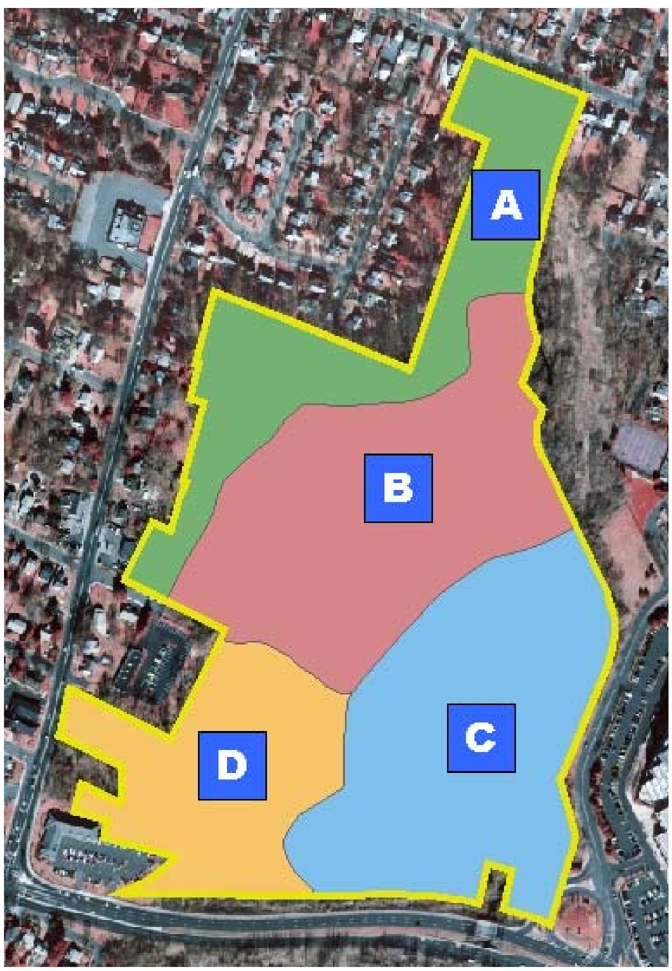

Figure 10
Proposed Restoration Zones

ZONE A (~ 9 acres)

As identified in the vegetation survey, this area contains the highest quality forested wetland vegetation matrix on the TCC site. Restoration efforts in this area will be focused solely on preventing any invasive species incursion into the area, while reestablishing additional native forested wetland plant communities.

ZONE B (~ 15 acres)

This zone is dominated by an extensive stand of *Phragmites australis*. The plant is thriving in large ponded areas that have formed due to the inflow of runoff into low-lying depressions located in the middle of the property. Restoration efforts in this zone are targeted to containing the spread of this plant, which is known to be helpful in removing excess nutrients and sequestering contaminants. We will continue to evaluate any beneficial role that *Phragmites* might be playing in this system, while using cutting and appropriate herbicide applications to contain further spread of the plant. Large scale earth disturbance or earth moving activities are not recommended in this zone as access to this portion of the site is limited, and would require extensive disturbance to the surrounding high quality habitat areas.

ZONE C (~ 14 acres)

This area of the site contains both forested wetland habitat as well as stands of *Phragmites australis*. As its location is proximate to Teaneck Creek, restoration efforts are to include the disturbance required to reestablish hydrologic connections through the existing berm. Where appropriate, reestablishment of this hydrologic connection will promote regular flushing of wetland areas during smaller, more frequent storm events, and connect wetland areas in Zones B and D. Invasive species management to control *Phragmites australis* and *Polygonum cuspidatum* is necessary, along with debris removal and localized excavation to support the proposed wetland creation in Restoration Zone D.

ZONE D (~ 8 acres)

This area will require the greatest disturbance in order to meet the restoration goals established for the TCC site. Upland woodland areas totaling nearly three (3) acres will be preserved, while nearly five (5) acres of this zone located at the southern portion of the property proximate to DeGraw Avenue will be cleared and reconfigured into a series of wetland basins. As part of the planned wetlands habitat enhancement program, existing channels and basins will be widened and deepened to provide the hydrology needed to support native vegetation in the previously disturbed areas. To

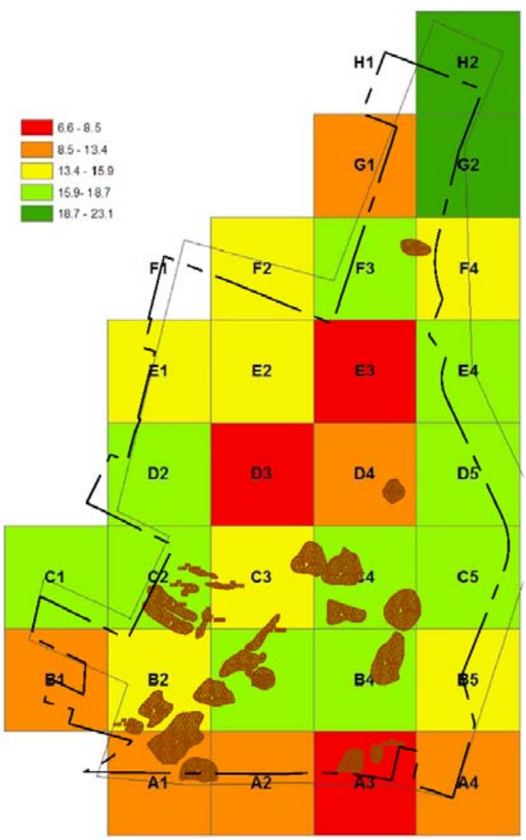

Figure 11
Floristic Quality and Debris Removal Areas

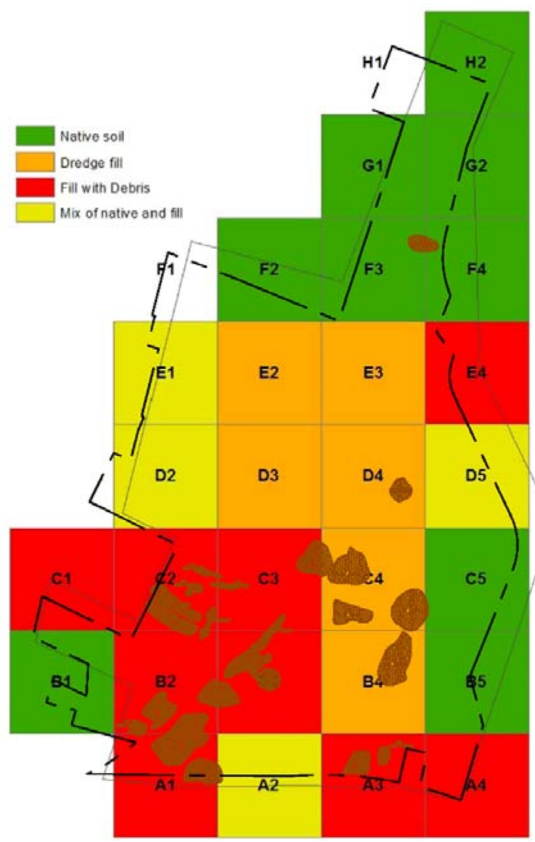

Figure 12
Soils and Debris Removal Areas

create these wetland channels and basins, excavation of an estimated 1,000 to 6,000 cubic yards of soil (characterized as either historic fill, dredge spoils, or sediments) in an area totaling approximately five (5) acres is required. These wetlands extend the residence time of stormwater flowing onto the site, thus providing the hydrology necessary to support a more diverse riparian forested wetland ecosystem (Figure 13).

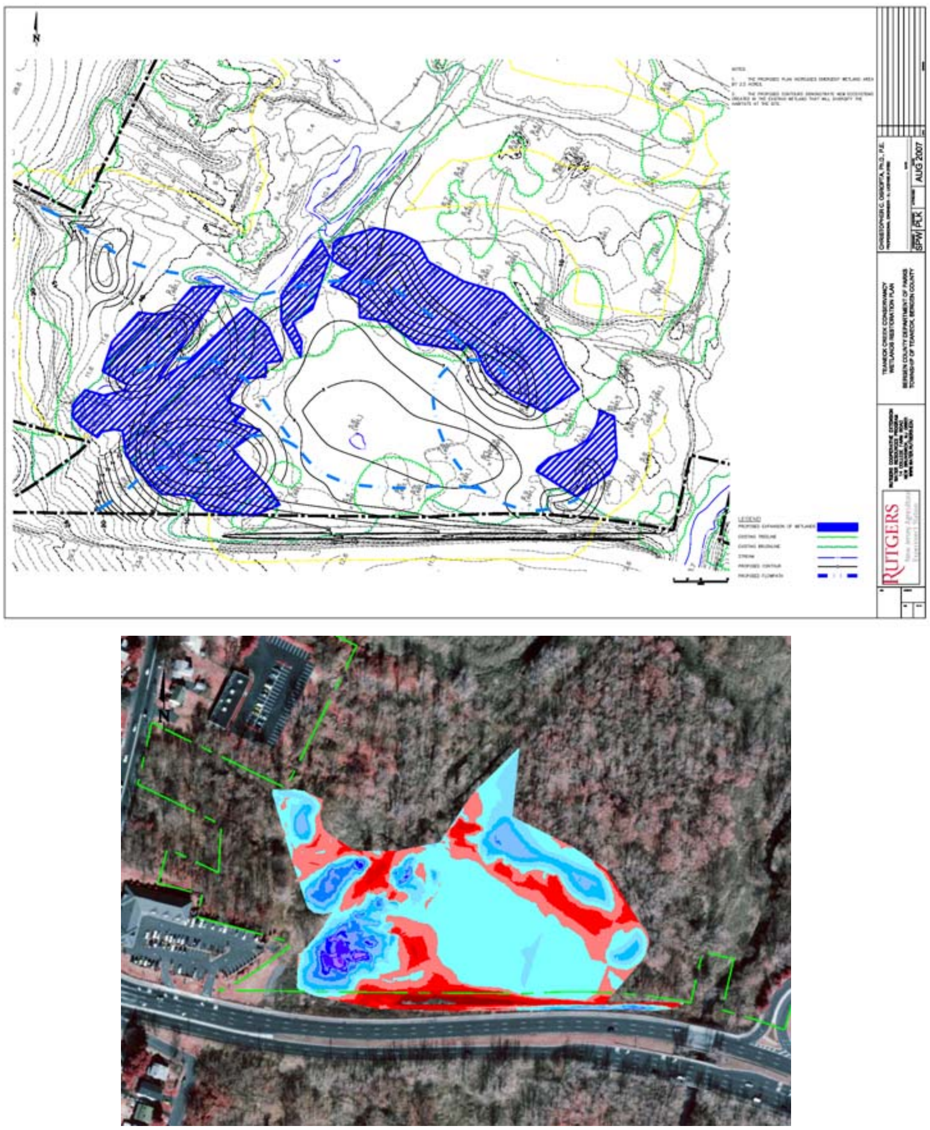

Figure 13
Wetland Basin Plan and Areas of Excavation
(Blue=Cut and Red = Fill)

2. DEBRIS REMOVAL

As the baseline characterization has documented, the hydrology of Teaneck Creek is currently freshwater tidal with surface water runoff supporting the wetland systems across the 46-acre site. Surficial debris including brick, glass, concrete, roofing materials, lumber, automotive parts and appliances are located on portions of the TCC site, with the bulk of this material located on the southerly section of the property. Project partners are surveying, mapping and estimating the volume of obvious areas of debris requiring removal or relocation (Figure 14).

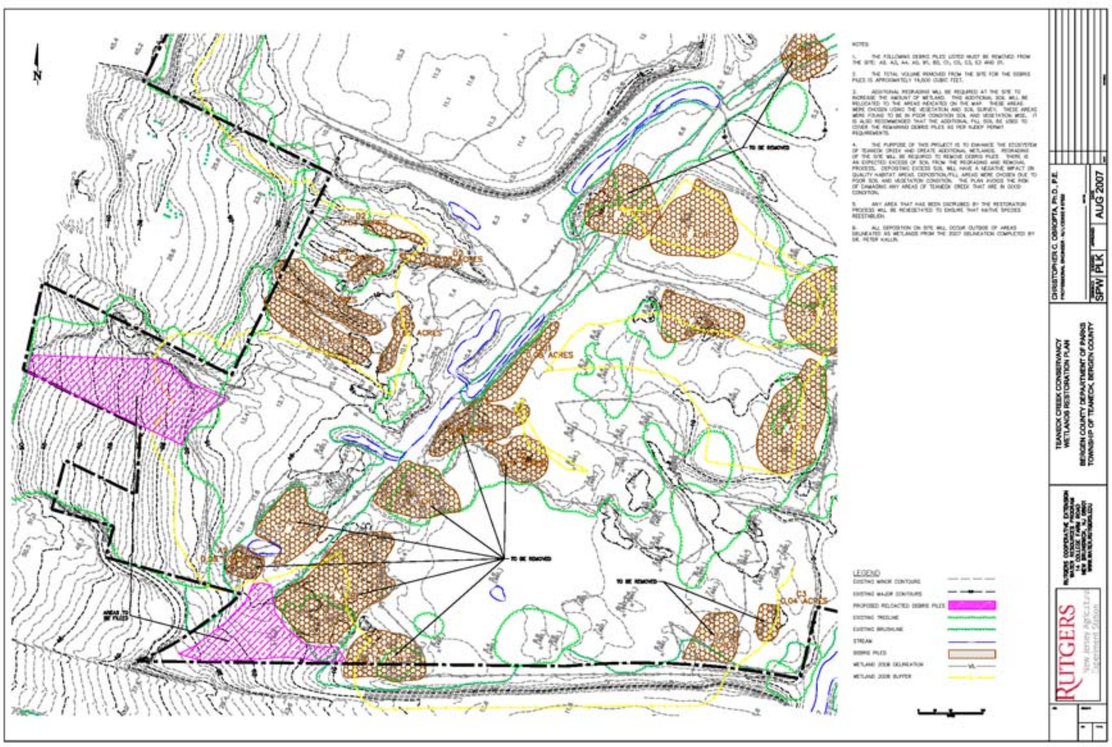

Figure 14
Debris Removal Plan

Debris requiring off-site disposal at a regulated landfill includes items such as tires, asphalt, automotive parts, drums, appliances, municipal solid waste (garbage) and such bulky materials as may pose an environmental or safety hazard. Close inspection of this debris has not revealed any deleterious materials.

However, concrete, wood and other construction debris may be relocated to upland portions of the site and capped with either the excavation soils or with certified clean fill as required by NJDEP. The capped areas will then be permanently stabilized with native vegetation. All activities involving relocating and removing debris will be done under oversight by the NJDEP. A detailed investigation and remediation approach, in close coordination with the NJDEP Solid Waste Program, is warranted, as the properties have been identified as "pre-1982 landfills".

The proposed wetland expansion is being planned for the southern portion of the property, where historical dumping of construction debris filled and raised the elevation of riparian wetland areas. The restoration plan requires extensive clearing and disturbance of approximately 5-6 acres of vegetation and soils near the southern portion of the site. This area receives extensive surface water runoff from the surrounding urban watershed during storm events. Areas currently filled and/or dominated by *Phragmites australis* are to be restored to a variety of hydrologic conditions to increase residence time and mitigate "flashy" hydrograph responses. Reestablished connections with Teaneck Creek will support regular flushing during smaller more frequent storm events, and will increase the diversity of habitats through variations in the hydrologic regime. This diverse habitat will support a variety of healthy native vegetative communities.

This area is targeted due to the extent of historical disturbance to soils and hydrology as evaluated through the research completed over the past three years. This work indicates much of this region of the site has been filled with debris and/or contains historic fill/dredge fill. While pockets of native vegetation have established, they are cut off from adjacent communities and hydrologic connections by extensive

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stands of invasive species such as colonies of Japanese knotweed and *Phragmites* in addition to scattered piles of debris. The proposed activities focus on reconnecting the hydrologic system from surface/storm water inputs located along Teaneck Road and Degraw Avenue through a series of wetland basins on the property and flowing into the Teaneck Creek.

C. ESTIMATED RESTORATION COSTS

A preliminary estimate of the costs associated with the proposed restoration includes the planting of appropriate native vegetation, management of invasive vegetation, as well as long-term monitoring and maintenance (Figure 15).

Figure 15. Preliminary Estimate of Restoration Costs*

Restoration Activity	Approximate Acreage	Cost per Acre	Total Cost
Phragmites/Invasive Management	14	$12,500	$175,000
Emergent Wetland Plantings	**6**	$20,000	$120,000
Forested Wetland Plantings	**10**	$32,500	$325,000
Wetland Enhancement	**4**	$14,000	$56,000
Mobilization & Construction	20	$14,000	$280,000
Monitoring & Maintenance	20	$2,000	$40,000
25% Contingency			$249,000
TOTAL			**$1,245,000**

** Costs do not include debris removal or remediation activities*

Potential funding sources have been identified to support the next phases of the project. Specifically, the State HDSRF (NJEDA Hazardous Discharge Site Remediation Fund) monies to address additional investigation and remedial action requirements; Federal monies through the USEPA Brownfields Grants program; and the NRCS Wildlife Habitat Incentives Program for restoration activities including planting and invasive species management.

Because multiple agencies are involved in the permitting and funding process, close coordination by the project partners is required for the construction phase of the TCC restoration to begin. Key project milestones include submission of the HDSRF grant application and subsequent preparation, approval, and completion of site investigation and remedial actions plans (summer 2007), NJWMC approval of the restoration concept plan (fall 2007), NJDEP LURP permit application submission (fall/winter 2007), and authorization of LURP permits (spring 2008). Once plans are completed, additional funding sources will be approached. Once the plans are approved, it is anticipated that the restoration will be completed within five (5) years. Bergen County Department of Parks will take the lead in managing and coordinating the required site investigation work, remedial and landfill closure activities, and securing funding for these activities. The Teaneck Creek Conservancy will be responsible for management of the wetlands restoration design and permitting, ongoing program development, fundraising for construction of the Glenpointe pedestrian bridge, entrances and parking area, and fundraising for habitat restoration.

D. ONGOING MAINTAINENCE ISSUES

The efforts of the TCC volunteers have resulted in the restoration of five (5) wetland acres within the 46-acre Conservancy site. Ongoing maintenance will now be required to sustain these newly restored wetlands. The initial restoration areas include successful establishment of native wetland vegetation adjacent to the outdoor classroom and plantings of riparian shrubs along the banks of a small tributary of Teaneck Creek. Due to the presence of the highly invasive species present on the TCC site (see Ravit et al., Appendix 1 for discussion of vegetation) and the presence of Japanese knotweed upstream of the site (see Bergstrom et al., Appendix 1 for discussion of upstream disturbances) constant vigilance is required to protect these new native plantings. The

Conservancy will also confront maintenance issues when the larger wetland areas are restored/created in subsequent years of stewardship.

Because the Teaneck Creek restoration within Overpeck Park is the result of a successful partnership between Bergen County and the non-profit Conservancy, it is appropriate that ongoing maintenance issues be jointly addressed by these two entities. During a meeting held at the Teaneck Creek Conservancy offices (October 10, 2007) representatives from the Conservancy, Bergen County, Rutgers and TRC identified high priority maintenance issues that currently need to be addressed. As a result of the discussions at this meeting, all parties agreed that there are certain maintenance activities that require resources more readily available at the County level, versus other activities that are more appropriately conducted by the dedicated Conservancy volunteers. While the following list is not meant to be inclusive of future maintenance questions that may arise, we believe this outline (see Table 1 for a summary) is an appropriate starting point to deal with sustaining and enhancing the restoration work that is already in place.

Activities that require the use of heavy machinery and/or permits are **more easily addressed by the Bergen County Parks Department**. This ongoing work would include:

<u>Trail Maintenance</u>

1. Mowing of a buffer adjacent to the Blue and Red Trails
    a. Twice annually (pre and post growing season, May and September respectively)
    b. Minimum of 2 ft. on either side of the walking trail
    c. Maximum of 4 ft. on either side of the walking trail if the area is heavily surrounded with aggressive vegetation, particularly *Phragmites australis* (Blue Trail)

2. Surfacing
    a. Re-chipping every 2-3 years
    b. Re-surfacing of the stone dust every 5 years as needed

Invasive Species Control

1. Herbicide application to irradiate/control aggressive invasive species

Tree Care

1. Removal of large dead trees and limbs

Activities that require routine inspection of the Conservancy site and/or large groups of people to accomplish an objective are **more easily performed by the Conservancy** volunteers and/or staff, including:

Restoration Vegetation Support

1. Planting of appropriate wetlands plants within the various restoration zones
2. Weeding and clearing to provide the restoration plantings with conditions that will help to ensure their survival and sustainability

Trail Maintenance

1. Removal of invasive species growing in the trail buffer areas and/or the Blue and Red Trails
2. All maintenance of the Green Trail

Invasive Species Control

1. Creation and maintenance of "buffer zones" adjacent to restored areas – any invasive species found within these buffer zones require immediate removal
2. Weeding of the restored areas to remove invasive species, including overgrowing vines
3. Knotweed maintenance through the USFWS grant

4. Targeted species removal
    a. Any removal activities other than application of regulated herbicides, including cutting and weeding

Tree Care

1. Pruning
2. Removal of small debris from the trails and/or Teaneck Creek

General Clean Up

1. Periodic clean up of litter within the Conservancy grounds, Teaneck Creek, and its tributaries
2. Periodic clean up of litter that may accumulate as a result of stormwater runoff into the Conservancy site

TABLE 1. A SUMMARY OF MAINTENANCE RESPONSIBILITIES

Activity	Conservancy	County
Trail Maintenance	Green Trail – all maintenance activities	Mowing buffer zones (Red, Blue Trails) – spring & fall annually
	Buffer Zone Invasive removal	Re-chipping (every 2-3 years)
	Trail Invasive removal	Re-surfacing stone dust (5 years as needed)
Invasive Species Control	Restoration area buffer zone creation and maintenance	Target species removal – herbicide application
	Weeding of restored areas	
	Target species removal – cutting, mowing, weeding	
	USFWS Knotweed control	
Tree Care	Pruning	Clearing and removal of large debris
	Clearing and removal of small debris	
Vegetation Restoration	Planting of appropriate native wetland species in the various restoration zones	
General Clean Up	Litter clean up on the Conservancy grounds and in the Teaneck Creek	
	Litter clean up from surface runoff	

Invasive Species

Particularly problematic in wetland restorations is the control of invasive species. We suggest that dealing with invasive plants must be at the top of the Conservancy's priority list because volunteers are most familiar with the site and are on site most frequently. The references below to "invasive" species refer specifically to *Phragmites australis* (common reed), *Polygonum cuspidatum* (Japanese knotweed), *Polygonum perfoliatum* (mile-a-minute vine), *Rosa multiflora* (multiflora rose), *Ampelopsis brevipedunculata* (porcelainberry), *Lythrum salicaria* (purple loosestrife), and *Alliaria petiolata* (garlic mustard). We note that this list will change over time and require updating as current species are removed from the Conservancy site (or contained) and new invaders enter. Activities critical to the successful control of invaders include:

- Identification of new invasive species as a priority for all parties working at or visiting the park. The key to controlling aggressive invaders is to spot them early on in the invasion process and remove them before they can become established. In many instances this function is performed by volunteers who are frequently on the site and will notice changes more quickly than infrequent visitors. A volunteer should be identified who will "own" this task, and who can mobilize help to remove invasives when needed.

- Establishment of a "No Invasives" buffer to protect the native area located in the northeastern corner of the site adjacent to Fycke Lane. This area should be clearly delineated, and surveyed on a monthly basis. Should invasives be seen within the buffer zone volunteers must be immediately mobilized to remove them (including root systems) before they can establish.

Due to global warming many invasive species are moving northward, and the New England region has been especially active in dealing with this threat. Two helpful web sites that describe both the invasive plants themselves and volunteer efforts to stop the spread of these species can be found at http://nbii-nin.ciesin.columbia.edu/ipane/ and http://www.newfs.org/conserve/invasive.htm.

E. RESTORATION SUMMARY

Because of the research and site evaluations completed over the past three years, this project has produced a restoration plan that will provide for the development of a diverse mosaic of riparian wetlands at TCC. This mosaic will include emergent freshwater tidal wetlands, forested/shrub wetlands and wetland meadows. The site will contain transition areas between each type of wetland as well as upland transition/buffer areas around all wetlands, typical of a riparian flood plain habitat. Together, these individual wetlands and associated uplands will provide a wide variety of habitats that will combine into a fully functioning riparian, forested wetland system.

APPENDIX 1

Papers based on the TCC restoration project were submitted to the peer-reviewed journal Urban Habitats. These five (5) papers are currently *In Revision*, and are scheduled for publication online in December, 2007.

The Urban Wetlands of the Teaneck Creek Conservancy: A Historical Perspective and a Restoration Vision for the Future

by Mary Arnold

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Abstract

The wetlands of Bergen County, NJ have been impacted by humans since being formed after the Wisconsin glacier retreated approximately 10,000 years ago. Damage to the wetlands of the Teaneck Creek was especially severe during reclamation projects undertaken during the 19^{th} and 20^{th} centuries in support of the increasingly urbanized human population. Today these wetlands are surrounded by land use that is 95% urban, and the 46 acre site owned by Bergen County Overpeck Park, and managed by the Teaneck Creek Conservancy, serves as a stormwater sump for the surrounding land. The goal of the Conservancy, established in 2001, is to protect the site's remaining undisturbed wetlands and to re-establish functioning wetlands, through hydrological changes, removal of invasive plants, and planting of native species, in approximately 15 acres that are currently impaired. The restoration project is an interdisciplinary collaboration between the Teaneck Creek Conservancy, Bergen County, and Rutgers University. This historical perspective and vision of the future provides a background for the following papers in this issue.

Key Words: Urban restoration, urban wetland, urbanization, riparian forested, urban habitat, urban ecosystem

Abstract

In the United States humans have attempted to control many natural systems. Radical environmental alterations in the northeastern U.S., particularly in the 19th and 20th centuries by industry, transportation entities, growth of the population, and various cultural lifestyles, have set in motion accelerating changes to local ecosystems. Elton's work (1969) set forth the dangers of human ignorance and disregard for indigenous natural systems and their ecology, of which humans are an integral part.

Over previous centuries the lands and waters of Teaneck Creek, in what is now Teaneck, New Jersey, have been utilized in multiple ways: as Lenape Indian homeland and Colonial farmland, for real estate development and dumping (Taylor 1977), and today as restored park and urban wetlands. The Teaneck Creek Conservancy (hereafter the Conservancy) project, which is highlighted in this issue, is based upon an ecological, multidisciplinary, and community-based approach to urban wetland restoration. This approach acknowledges the need for an in depth understanding of anthropogenically influenced site conditions. It also recognizes the necessity for participation by local communities and forward-looking government representatives in the reclamation, enhancement, and protection of natural resources that enhance urban quality of life.

The project was initiated in 1998 by businessman Perry Rosenstein, and his wife, Gladys Miller-Rosenstein, Executive Director of the Puffin Foundation Ltd., and the wetland science and research being conducted here is the result of their leadership and vision. The Rosenstein's initial intention was to protect the land behind the Puffin building from development after surveyors' flags were observed on the property. When it was discovered that Bergen County owned this land, the idea was conceived to transform the tract into a publicly accessible park. The nonprofit Conservancy was incorporated in 2001, and subsequently led a series of 17 community meetings over an 18-month period that engaged residents, children, and elected officials in their cause. To move the project forward, the Puffin Foundation provided the initial support required for community organizing, landscape architecture, and the trail system. Goals for the project that were proposed to Bergen County included the creation of a park that would uniquely use art and landscape design to integrate the natural, historical, and cultural history of the

area. Two other project goals were the mitigation of the site's degraded wetland areas and the reintroduction of native plant species (TCC 2001). In 2002 the Conservancy negotiated a long-term (99-year) lease with Bergen County to develop and manage the 46 acre site for the purposes of public recreation, outdoor education, cultural programming, and the restoration of natural resources (TCC 2002). In 2004, the Bergen County Freeholders passed a Resolution authorizing a memorandum of understanding between the County, the Conservancy, and Rutgers University to support the protection, restoration, and study of wetlands at the Conservancy (MOU 2005). The stage was set for the reclamation of this NY-NJ Harbor Estuary Program Priority Restoration Site.

A Historical Perspective

The story of how Teaneck Creek wetlands declined and were reclaimed begins in the 1600's, when the Lenape Indian leader, Sachem Oratam deeded more than 2,000 acres to Dutch colonist Sarah Kiersted (Kiersted 1669). Oratam gave Kiersted the property to honor her important contributions as his interpreter in his dealings with the Dutch, including the Governor of New York, Peter Stuyvesant. According to the Sarah Kiersted Patent, the confirmation of Kiersted's ownership granted by the English Governor Philip Carteret (1669), when Oratam deeded the property to Kiersted there existed a diverse ecosystem with a wealth of water resources including "woods, pastures, fields, Meadows, Pools, Ponds, Islands, Creeks, Marshes, River." The water-rich ecosystem contained tributaries to the Hackensack River and provided habitat for "Hawking, Hunting fowling, fishing." These natural resources, which provided food for the Colonists, are described in the Patent as part of the "Gaines and Proffits" of Oratam's valuable gift. By the time the Conservancy was incorporated, 335 years after Oratam gave away this land, the property had been a dump site and degraded wetland, surrounded by "Keep Out" signs, for half a century.

Teaneck Creek's wetlands declined during the 19th and 20th century eras of industrialization and urbanization, which included the routine draining and filling of marshlands. *Draining for Profit and Draining for Health* (Waring 1882), written by the engineer who created the drainage system in Central Park, sums up the common perception of wetlands as wasteland. Waring described the NJ Meadowlands - of which the wetlands of Teaneck Creek are a historic remnant - as "pest" lands that offered huge financial potential if drained for development. "A single tract, over 20,000 acres in extent, the center of which is not seven miles from the heart of New York City, skirts the Hackensack River, serving as a barrier to intercourse between the town and the country… constituting a nuisance and an eyesore … virgin lands, replete with every element of fertility, capable of producing enough food for the support of millions of human being… all allowed to remain worse than useless…The inherent wealth of the land is locked up, and all of its bad effects are produced, by the water with which it is constantly soaked or overflowed." Bergen County's Preliminary Assessment Report (PAR 2006) to the NJDEP Division of Responsible Party Site Remediation describes the site's earlier land uses. The Sanborn Map (1926 through 1957) shows that, among other uses, parts of the site were used by a laundry, a construction company, a dance hall, and residences. For 40 years, until the late 1930's, a trolley line ran through the site.

In the early 1950's Bergen County developed a plan for the wetlands of the Teaneck and Overpeck Creeks, when they proposed filling the wetlands with municipal waste and clean dredge, and then redeveloping the area as a 1,000 acre park. Overpeck Creek was widened and deepened through dredging, and tidal gates were constructed along the creek in the vicinity of the New Jersey Turnpike Overpass. The Township of Teaneck transferred property for the creation of the public park and public recreation area (Deed 1951). Elevations of the land surrounding the creeks were raised above the water level by placement of sanitary waste and dredge materials from Overpeck Creek. These activities resulted in the Teaneck Creek being cut off from the tidal flow of the Hackensack River, leaving only the waters backing up when downstream tide gates closed as the tidal pulse in this newly created freshwater system.

At the time of the transfer of the Conservancy acreage, the environmental issue of concern to the Township was that they be allowed to continue to use the property as a waste dump and storm water sump. The transfer deed includes the following provisions:

(a) the right to use any or all of the premises for the disposal of garbage, ashes, refuse and fill through any agency, contractor or licensee engaged to remove such material for the Township of Teaneck now and in the future; (b) the right to continue the operation, maintenance and enlargement of all existing disposal plants, sewage pumping stations, sanitary and storm drains, rights of way, and to increase or provide new facilities as it may deem advisable; (c) the same rights and privileges granted to the Bergen County Sewer Authorities (Deed 1951). After the land transfer, the 46 acres became known as "Area 1." Although the wetlands of Teaneck Creek were spared being filled with the municipal waste, as occurred in the Overpeck Creek wetlands of the park, "Area 1" experienced further degradation from dumping and filling by private companies and by the NJ Department of Transportation, which used the site in the 1960's as a staging and disposal area for dredge and construction debris materials, while building the New Jersey Turnpike and Interstate 80 (Fig. 1).

Non-indigenous fill materials, including construction debris and dredge spoils, were deposited on portions of the site, mainly on the southerly and easterly sides (PAR 2006). Fill and buried materials deposited on the site in the 1960's were primarily domestic waste, including cans, bottles, clothing, and plastic, while the surficial debris included brick, glass, concrete, roofing materials, lumber, automotive parts, and appliances. An existing Area of Concern (PAR 2006) is groundwater contamination, which includes benzene, tert-butyl alcohol, and methyl-tertiary-butyl-ether (MTBE) that leaked from underground storage tanks on adjacent properties - two gas stations - located along the western edge of the Conservancy. The NJDEP has ongoing oversight for the groundwater contamination, which is currently being remediated.

Since the project began in 2001, using only hand tools, volunteers have removed literally tons of debris from the site, including automotive parts, construction debris, and discarded household appliances. The remaining fill is too heavy to lift or is located in inaccessible areas. Some concrete debris has been recycled into artworks by local artist Ariane Burgess, who led volunteers in the creation of a Peace Labyrinth built from blocks of concrete found on site (Fig. 2), and artist Lynne Hull who created concrete "Migration

Mileposts" (Fig. 3) that celebrate the birds which pass through the site when migrating along the Atlantic Flyway, as documented by DNA or radio telemetry. Teaneck artist Richard K. Mills' "Concrete Jungle" lies among other huge slabs of concrete roadway next to Dragonfly Pond, an open water area (Fig. 4).

Teaneck Creek Conservancy Today

Today the Conservancy's 46 acres are virtually the only undeveloped land in the Teaneck Creek watershed. In this highly urbanized area, the Teaneck Creek is a component of the municipal storm water system, serving as the discharge point for six storm water outfalls, which drain directly into the Conservancy site. The red shale substrate, channelization and berming of the creek, and the clay dredge and debris filling the wetlands impede the connectivity of the creek and groundwater sources, and today it is mainly precipitation and storm water that feed the site's wetlands. In addition to the storm water inputs, we discovered that a local hospital is permitted to pump 100,000 gallons of groundwater day^{-1} into the Teaneck Creek in order to keep the hospital basement dry (Holy Name Hospital, pers comm). The banks of the Teaneck Creek are cut and filled, eroded, and sometimes blown out during storms. The resulting siltation, as well as nonpoint source and thermal pollution, degrade the water quality. Benthic studies (Serra 2001) revealed poor water quality, which supported only pollution tolerant species: aquatic worms, black fly larvae, midge larvae, pouch, and other snails. Nonetheless, with its unique freshwater wetland system, Teaneck Creek does support aquatic and other wildlife.

Wildlife observation is a popular visitor activity at the Conservancy. Killifish (*Fundulous*), mosquito fish (*Gambusia affinis*), green frogs (*Rana clamitans*), bull frogs (*Lithobates catesbeianus*), snapping turtles (*Chelydra serpentina*), and eastern box turtles (*Terrapene carolina carolina*) have been observed on site (identified by P. Warny, NY State Museum, B. Ballengee, ecological artist, M. McClary, Fairleigh Dickinson University). Resident bird species are numerous, as are migratory birds (Table 1). Other species observed at the Conservancy include Red Fox (*Vulpes vulpes*), White-tailed Deer

(*Odocoileus virginianus*), and Coyote (*Canis latrans*). Based on detailed site investigation, Rutgers scientists and engineers anticipate that storm water retrofits and planned wetland and creek enhancements will improve water quality, biodiversity, and wildlife habitat at the site.

When the planning began for permitting the trail system in 2003, Dr. Steven Handel was invited to make a field visit to the Conservancy and to offer his suggestions for the restoration. After trekking through a degraded jungle of *Phragmites australis, Alliaria petiolata, Polygonum cuspidatum, and Rosa multiflora,* growing among piles of clay dredge, asphalt, and broken concrete, Dr. Handel discovered an undisturbed area on the northeastern edge of the site. He pointed out the seeps, vernal pools, and native plant species that included *Viburnam dentatum* and *Symplocarpus foetidus*, which he called "the New Jersey of 350 years ago." Even in degraded areas of the property we observed remnants of native vegetation that would have been familiar to the Dutch colonists, including *Erythronium americanum* and *Allium tricoccum*. Dr. Handel advised that the undisturbed wetland fragment be guarded against invasive plants through selective weeding, and that the undisturbed remnant become the model for restoration of the remaining 46 acres.

The concerns expressed by project scientists, including the role of natural restorative processes in landscape architecture, the protection of still intact natural resources, and the importance of restoring degraded resources, have informed every aspect of the project, including the design of recreational and educational facilities, the creation and placement of ecological art, the design and delivery of educational programs, the volunteer stewardship and park maintenance, and the planning of natural resource restorations. An example of this approach occurred when project participants planned to build the Puffin Outdoor Classroom within the pristine northeastern wetland to enable school children to appreciate the natural beauty and diversity of this area. These non-scientists were ultimately persuaded that they were going to destroy what they treasured - the highest quality natural resources on the property. We redesigned the classroom and relocated it to an area that was already disturbed and covered by

Phragmites. The classroom that opened to the public in May 2006 is now adjacent to the pristine site, which can be directly observed from the classroom (Fig. 5). The Puffin Outdoor Classroom, the trails, boardwalks, and bridges were designed and sited by scientists, engineers, and landscape architects to touch the landscape lightly and leave water flows unimpeded (Fig. 6). The trail system is only six feet in width, and elevated boardwalks are made of recycled plastic lumber that does not pollute water resources.

The restoration of the Teaneck Creek wetlands is based on an understanding of the function(s) and value of urban wetlands, which are being studied on a long-term basis by Rutgers scientists working on this project. Environmental awareness and Federal environmental legislation have provided a legal, regulatory, and funding foundation for the project. Our focus on creating local access to degraded and underutilized public land propelled revitalization of the site, and enlightened State of New Jersey environmental polices and programs are supporting this restoration:

- Green Acres Program provided the first major public funding ($50,000). The public benefits created by the 1.25-mile loop trail system made all aspects of the project easier to justify and fund. The Conservancy received a total of $685,000 from the Green Acres Program, matched by the Puffin Foundation Ltd., Bergen County Parks, Bergen County Open Space Trust Fund, and a Federal HUD grant. Green Acres' staff forced the solid waste cleanup (2006), by refusing to disburse additional funds until an agreement with Bergen County to address the clean up was completed.
- Wetlands protection legislation to protect freshwater wetlands, was passed in 1987, creating the NJ Wetlands Mitigation Council (NJWMC). The baseline research work of Rutgers University scientists, which will provide a basis for development of the Restoration Plan, was funded by a $300,000 NJWMC grant.
- New Jersey's Brownfield and Contaminated Site Remediation Act of 1997 is aiding this Brownfields to Greenfields project. The NJ Dept. of Community Affairs-led Brownfields Restoration Implementation Team (BRIT) has played a critical role in the permitting and implementation of the wetland enhancement through facilitation of funding, coordination, and support from multiple State agencies.

Conclusion

All that has happened at the Teaneck Creek Conservancy has been accomplished in only six years through the efforts of local citizens and enlightened government representatives, who were guided by professional scientists and engineers. For other degraded wetlands in the Teaneck and Overpeck Creek watersheds, as well as wetlands in other urban areas, this project provides a model of science in the public interest in partnership with public stewardship of natural resources. As you will see in the following articles, a holistic approach is reflected in the science, site investigation, and research. As degraded as this place was when we arrived, as difficult as the work has been at many points, citizens have reclaimed and, with the help of the scientists working with us, will transform the lands and waters of Teaneck Creek from a dump to a unique wetland restoration and a renewed civic space.

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Table 1. Birds sighted within the Teaneck Creek Conservancy boundaries. Identification by Richard Engsberg, NJ Audubon Society and Dr. Peter Kallin, Rutgers University.

Common Name	Scientific Name	Type
American Robin	*Turdus migratorius*	Resident
Black and White Warbler	*Mniotilta varia*	Resident
Black-capped Chickadee	*Poecile atricapilla*	Migrant
Black-throated Blue Warbler	*Dendroica caerulescens*	Migrant
Blue Jay	*Cyanocitta cristata*	Migrant
Blue-headed Vireo	*Vireo solitarius*	Migrant
Cape May Warbler	*Dendroica tigrina*	Resident
Connecticut Warbler	*Oporonis agilis*	Resident
Dark-eyed Junco	*Junco hyemalis*	Migrant
Downey Woodpecker	*Picoides pubescens*	Migrant
Eastern Phoebe	*Sayornis phoebe*	Resident
Eastern Towhee	*Pipilo erythrophthalmus*	Migrant
Gray Catbird	*Dumetella carolinensis*	Migrant
Great Blue Heron	*Ardea herodias*	Resident
Great Egret	*Ardea alba*	Resident
Green Heron	*Butorides virescens*	Resident
Hairy Woodpecker	*Picoides villosus*	Migrant
Magnolia Warbler	*Dendroica magnolia*	Migrant
Mourning Dove	*Zenaida macroura*	Resident
Northern Cardinal	*Cardinalis cardinalis*	Migrant
Northern Parula	*Parula americana*	Migrant
Palm Warbler	*Dendroica palmarum*	Migrant
Red-bellied Woodpecker	*Melanerpes carolinus*	Migrant
Red-tailed Hawk	*Buteo jamaicensis*	Resident
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Resident
Ruby-crowned Kinglet	*Regulus calendula*	Migrant
Sharp-shinned Hawk	*Accipiter striatus*	Resident
Swamp Sparrows	*Melospiza Georgiana*	Migrant
White-throated Sparrow	*Zonotrichia albicollis*	Migrant
Woodcock	*Scolopax minor*	Resident
Yellow-bellied Sapsucker	*Sphyrapicus varius*	Resident
Yellow-rumped Warbler	*Dendroica coronata*	Migrant

Figure 1. Increasing urbanization of the land use surrounding Teaneck Creek Conservancy wetlands 1954 to 1995 (photo courtesy of Richard K. Mills).

Figure 2. The Turtle Peace Labyrinth walk was constructed from concrete debris found on site at the Teaneck Creek Conservancy. To create the labyrinth pathway, volunteers relocated the pieces of rubble by hand from their original location on the banks of the creek to the site of a form ball field (photo courtesy of Richard K. Mills).

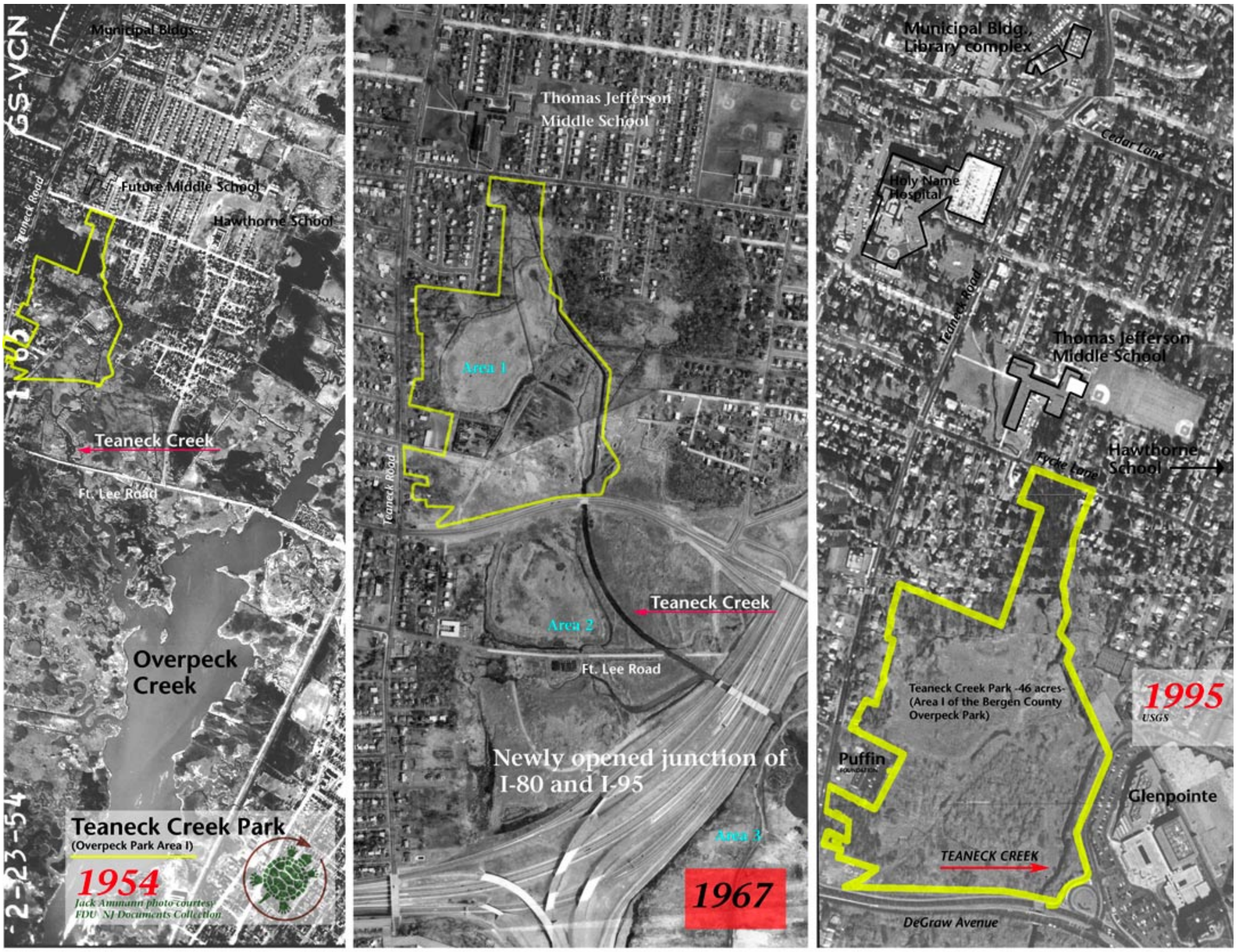
Figure 3. Engraved and painted concrete rubble Migration Milepost depicting species observed on the Teaneck Creek Conservancy site using the Atlantic Flyway as their migratory route.

Figure 4. Concrete Jungle sculpture garden created by Artist-in-Residence Richard K. Mills from Teaneck Creek Conservancy debris.

Figure 5. The Puffin Outdoor Classroom located in an area formerly degraded and dominated by *Phragmites alterniflora*. After the *Phragmites* were removed, native tree, shrub, and herbaceous species were planted by local volunteers, project scientists, and engineers.

Figure 6. Local school children visit Teaneck Creek and walk through the Conservancy site on the newly built trail system, July 2006.

Fig. 1.



Wetlands Disturbance by Highway Construction
Teaneck Creek Conservancy 2003 (Area 1)

Fig. 2.

Fig. 3.

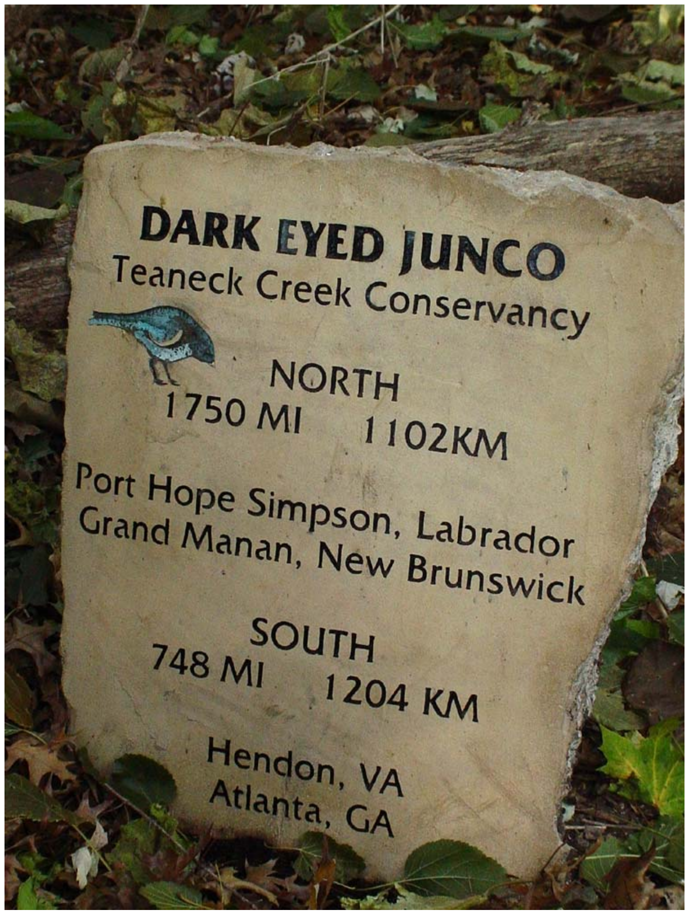

DARK EYED JUNCO
Teaneck Creek Conservancy
NORTH
1750 MI 1102KM
Port Hope Simpson, Labrador
Grand Manan, New Brunswick
SOUTH
748 MI 1204 KM
Hendon, VA
Atlanta, GA

Fig. 4.

Fig. 5.

Fig. 6.

Restoration of a Forested Riparian Wetland Ecosystem: A Baseline Characterization Approach to Wetland Enhancement in an Urban Watershed

by Beth Ravit[1], Christopher Obropta[1, 2], and Peter Kallin[2]

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Abstract

More acres of forested wetlands were lost during the 20th century than any other category of wetland, yet restoration or creation of this wetland type has been notably unsuccessful. Restoration of riparian forested wetlands that are located within highly urbanized landscapes is particularly problematic due to the stresses placed on the wetland by historical alterations and disturbances, and by current watershed land uses. The Teaneck Creek Conservancy has partnered with scientists and engineers at Rutgers University to provide a baseline characterization of the 46-acre Conservancy site located within Bergen County, New Jersey's Overpeck Park. The project goal is to rehabilitate 20-acres of forest and scrub shrub wetland by establishing hydrologic conditions typically found in a temperate forested riparian corridor, on a site whose surrounding land use is categorized as 95% urban. To achieve the project goal hydrologic connections must be reestablished between the creek and the interior surface and groundwaters, surface elevations must be lowered, historical debris removed, and native vegetation established to replace invasive species. This paper reviews briefly the current status of forested wetland restoration and the obstacles to achieving successful restoration of these ecosystems. We also describe the baseline characterization being conducting for the Teaneck Creek project to support efforts to establish a sustainable urban wetland system on the Conservancy site.

Key Words: Urban wetland, urbanization, riparian forested, restoration, hydrology

Introduction

Wetlands provide ecosystem level functions whose value to humans is well documented (Costanza et al. 1997). Wetland functions related to improvement of water quality, flood storage capacity, nitrogen retention and removal, wildlife habitat, and the general preservation of diminishing open space (Hammer 1997, Richardson & Vespraskas 2001) are of particular importance when a wetland is situated in a highly urbanized area, as is the Teaneck Creek watershed. The 46-acre Teaneck Creek Conservancy (hereafter Conservancy) restoration site is in Bergen County, New Jersey Overpeck Park, which is located within the New York-New Jersey megalopolis, one of the most densely populated urban regions in the world. The Teaneck Creek and its wetland system is surrounded by land use that is categorized as 95% urban (Fig. 1). Over the past two centuries these wetlands were the recipient of multiple anthropogenic impacts, and have served as a repository for multiple layers of various fill materials (Arnold, this volume). The effects of this historic degradation are critical factors in determining whether and how the wetlands on this site can be restored/enhanced (Wolin et al. 2005), and they dictate, to some degree, the actions required to achieve an increase in sustainable wetland acreage (Zedler 1999).

Scientific research to characterize existing hydrology, vegetation, and soils on the Conservancy site has been ongoing since 2003, and the data collected will serve as the basis for developing a Conceptual Restoration Plan. While it is obviously not possible to actually "restore" the Teaneck Creek watershed to some previously pristine state (Zedler & Leach 1998), our overall goal is to establish hydrologic conditions typically found in a New Jersey (NJ) temperate forested riparian corridor. For the purposes of this project, we are defining "restoration" as the establishment of 20-acres of forested and scrub/shrub wetlands within the 46-acre site. Although we acknowledge this the term is not the usual definition of "restoration," for the sake of simplicity, we will use this term to refer to the project's objective. Specific goals for the project include protecting existing high quality native areas, creating new wetland acreage through the removal of fill materials and the lowering of surface elevations, and re-establishing a hydrological connection between Teaneck Creek and the interior wetlands and groundwater.

Sustainable wetland ecosystems require specific combinations of water supply, topography, and soil characteristics (NRC 2001), and to determine the success of a wetland restoration or enhancement project, these inter-related attributes are typically compared to a specific wetland reference site. As we develop the restoration strategy for this site, our team is aware of the lack of success experienced by managers both across the U.S and in NJ, who have attempted to restore shrub swamp and forested wetland ecosystems. These two wetland types have been characterized as particularly difficult to restore (NRC 2001, Balzano et al. 2002, Minikin & Ladd 2003), in part because of the time and conditions needed to establish woody plants; the degree of difficulty encountered has been documented by the scientific community (NRC 2001), the U.S. Fish & Wildlife Service (Dahl 2000, 2005), the US Army Corps of Engineers (Minkin & Ladd 2003), and the State of New Jersey (Balzano et al. 2002, ITRC 2005).

Although a gap exists in the peer-reviewed scientific literature describing successful restorations of forested riparian wetlands, reviews of regulatory permit information (Grayson et al. 1999, Dahl 2000, Sudol & Ambrose 2002, GAO 2005) and analysis of NJ wetland mitigation compliance (Balzano et al. 2002) verify that the success rate in restoring/creating freshwater riparian wetland systems is abysmally low. In the 2003 US Army Corps of Engineers (USACE) study of overall wetland losses in New England (Minkin & Ladd 2003), forested wetlands accounted for 50% of all wetlands lost in this region (180 acres). However, the mitigation success to offset these losses totaled less than 20 acres. Field evaluation of 90 NJ freshwater wetland mitigation sites found only 1% of the proposed forested wetland acreage was achieved (Balzano et al. 2002).

In addition to the lack of reliable data with respect to successful riparian wetland restoration, there is a similar lack of data with respect to restoration of wetlands situated in highly urbanized areas. Despite some recent studies of urban wetlands (Ehrenfeld 2004, 2005, Burns et al. 2005, Wolin et al. 2005), the effects of surrounding urban land use on wetland hydrology, vegetation, and biogeochemical (Lamers et al. 2006) functions are not yet well understood. Urban wetlands differ from wetlands found in more natural settings in certain fundamental ways, including altered natural hydrology, high levels of human-caused site disturbance, and the frequent presence of invasive plant species

(Guntenspergen & Dunn 1998, Ehrenfeld 2000). Urban wetlands may also experience continued anthropogenic disturbances after restoration work has been completed (Grayson et al. 1999, Magee & Kentula 2005).

Goals of the Teaneck Creek Wetland Restoration

Structural goals for this project include: 1) re-establishing a hydrologic connection between Teaneck Creek and the site's interior surface and ground waters; 2) the restoration of approximately 20 wetland acres to include riparian forest, scrub shrub, and emergent water wetlands in locations where each type is sustainable under the given hydrologic regime and microtopography; and 3) within each wetland type, the establishment and survival of an appropriate native plant community. We will be using an onsite area where consistently saturated organic soils support diverse native vegetation as a reference wetland to judge the project's success. In addition to this onsite reference, we will identify a forested wetland site adjacent to the Tenakill Brook in Bergen County, NJ for an off site reference. It is anticipated that achievement of the project goals will increase the residence time of Teaneck Creek water in the site's wetlands. Increased residence time will potentially increase the amount of nitrogen that these wetlands remove prior to water movement downstream into the lower estuary of the Hackensack River, where high porewater nitrogen levels have been observed in the salt marsh sediments (Ravit et al. *in press*).

Important factors to consider in meeting the project objectives are the current and historical alterations of the TCC wetlands and their surrounding urban hydrology, the large monospecific stands of *Phragmites australis*, the dominance of other aggressively invasive plants, and the large areas covered by the various historic fill materials. This paper will review issues related to freshwater wetland restoration, the conditions we encountered at Teaneck Creek, and the baseline characterization our team is using to develop a Conceptual Restoration Plan for the Conservancy site. Other papers in this volume discuss specific data related to the system's hydrology (Obropta et al.) and vegetation (Ravit et al.), and the effects of two disturbed upstream properties on the Conservancy restoration site (Bergstrom et al.).

Issues in Forested Riparian Wetland 'Restoration/Creation'

The TCC wetland degradation is historical, and so this project is not being undertaken as mitigation for wetland loss. However, today wetland fill permits allowing destruction of existing wetlands require compensatory mitigation. We use the term ‘restoration/creation’ because much of the available data with respect to management of forested riparian wetlands have been collected in conjunction with the USACE permitting process. Required mitigation may be achieved through restoration, creation, enhancement, and/or preservation of other wetlands, in order to compensate for the functions provided by the lost wetlands.

The greatest overall U.S. wetland losses have occurred in emergent and forested freshwater wetlands (Fig. 2a), whose total acreage decreased by 6.9% in the decade prior to 1997 (Dahl 2000). Although forested wetlands accounted for up to 50% of wetland losses (Dahl 2000), the percentage of field-confirmed mitigation for these losses was only 5% (Minkin & Ladd 2003). More recent analyses (Robb 2002, GAO 2005) have found failure rates of over 70% with respect to forested wetland restoration/creation. In a USACE study (Minkin & Ladd 2003) forested wetland impacts in New England totaled 178-acres, and the proposed “in-kind” mitigation was 25-acres; however, the actual successful forested wetland mitigation achieved was 0.5-acres. Analysis by the US Department of the Interior (Dahl 2005) found increases of wetland acreage in the freshwater forested category (1998 – 2004) were due solely to natural succession that resulted in the movement of wetland acreage from the ‘shrub’ to the ‘forested’ category, with a corresponding decrease in shrub wetland acreage (Fig. 2b).

Deciduous forested wetlands are the most abundant type of NJ wetland, equaling approximately 1/3 of the state’s total wetland area (Ehrenfeld 2005). NJ’s success rate in the mitigation of riparian and scrub/shrub wetland acreage has mirrored the national trends. Field evaluation of 90 wetland mitigation sites concluded that although 41% of the mitigation projects proposed were forested freshwater, only 1% of the proposed acreage was achieved after an average of six years (Balzano et al. 2002). The reasons for the lack of success in restoring/creating shrub and riparian forested wetlands tend to fall into three broad categories: the typography, hydrology, and soils required to achieve targeted parameters.

In the Conservancy wetlands these factors will be influenced to some degree by the stream channel itself, the adjacent upland land use (Zedler & Leach 1998), inputs from the overall catchment area (Mensing et al. 1998), and any surrounding anthropogenic disturbances, which may continue to occur post restoration (Burns et al. 2005, Wolin et al. 2005).

Hydrology

Hydrology is the dominant factor governing a wetland's type, development, maintenance, and functional attributes (Bedford 1996, NRC 2001). Hydrologic differences result from interactions between the wetland landscape and the hydrologic cycle, which in turn are driven by local climate conditions (Bedford 1996). Having a known and reliable water source is the most difficult factor to achieve when establishing wetlands (Minkin & Ladd 2003, Bedford 1996) and many wetland projects have been deemed unsuccessful because they lack suitable hydrology (Mitsch & Wilson 1996, NRC 2001, Balzano et al. 2002). As the degree of wetland degradation increases, the difficulties in restoring appropriate hydrology also increase (NRC 2001).

In NJ forested wetlands located in the Piedmont floodplain, a stable water table is primarily governed by the groundwater supply and source, which may be augmented by periodic over bank flooding (Stolt et al. 2000). While the hydrology of undisturbed riparian wetlands is controlled by periodic river flooding, groundwater discharge and infiltrating, and precipitation (Wassen et al. 2002), urban wetlands typically have the additional factor of stormwater runoff inputs (Burns et al. 2005). Impervious surfaces and storm sewers accelerate the rate of stormwater movement into streams that drain into urban wetlands, where flow rates have been reported that are up to three-fold greater than the flows in undisturbed catchments (Burns et al. 2005). This is particularly true in densely populated locations such as Teaneck Creek, where the wetland is draining a highly developed regional catchment area of almost 300-acres (Bergstrom et al. this volume). In addition to determining flow rates, the water source will determine the nutrient and contaminant loadings entering an urban wetland.

Increases in surface water inputs can change the hydrology of an urban wetland, including the hydrograph, residence time, and temporal water variations (Bedford 1996, Zedler & Leach 1998), and urban hydrologic patterns are often quite different from the patterns found in natural wetland systems. An urban hydrologic pattern often seen is increased “flashiness” – the rapid movement of water through urban storm systems into the wetland stream(s), followed by a rapid elevation of stream water height, accelerated water flows through the stream, and then a rapid return to low flow water levels (Burns et al. 2005). Flashiness can also destabilize the stream channel (Sudduth & Meyer 2005), resulting in downcutting that can contribute to increased drainage of the wetland’s subsurface water between storm events.

Restored/constructed freshwater wetlands have a tendency to exhibit greater “wetness,” due to wetland engineers opting for a saturation period of 12.5% of the time. This is the upper limit of a transition zone described by Clark & Bonforado (1981), whose range provided characterizations of upland versus wetland habitat; if a site is saturated less than 5% of the time it displays upland characteristics, and if saturated more than 12.5% of the time it will exhibit wetland characteristics. The USACE incorporated the 12.5% definition into their 1987 wetland delineation manual, and so wetland restorers use the conservative end of this scale, which results in wetter projects (Dahl 2005). This is especially problematic when attempting to restore forested riparian systems. If soils are too wet to support tree species, forested wetlands will not establish, and in fact, wetlands that have been restored/created are often wetter than planned (NRC 2001).

Vegetation

Wetland plant communities are structured by fine-scale hydrologic conditions, and plant species cover is strongly correlated with mean water table depth, which may be altered or obscured by urban disturbances (Magee & Kentula 2005, Dwire et al. 2006). Predictors of wetland vegetation include water depth, inundation duration, and seasonal patterns of flooding, particularly with respect to woody plants because reducing peak water flows enhances wetland succession from herbaceous to woody species (Toner & Keddy 1997). Differences of as little as 6” in the depth to the water table can shift inundated wet meadow plant communities to moist meadow communities, which are not inundated (Dwire et al. 2006).

While relatively little data have been collected with respect to plant communities in forested urban wetland systems, diversity has been found to be both quite high (Toner & Keddy 1997, Magee et al. 1999, Ehrenfeld 2005), as well as species poor. In a set of 21 urban wetlands in northeastern NJ, species richness ranged from 29 to 119 species at a given site, and 15% of the species observed were exotic (Ehrenfeld 2005). Magee et al. (1999) observed high species richness (356 plant taxa) in urban wetlands, but more than 50% of these species were non-native. Total vegetative cover is often lower in created versus natural wetlands, and the proportions of upland versus wetland species often differ. Structural and functional differences may result due to the wetland's age, species recruitment, and normal successional patterns (Grayson et al. 1999). Restoration success can be hampered by inappropriate actions of local property caretakers post-restoration, such as the practices of cutting wetland shrubs or regular mowing of newly created forested areas in an effort to give an advantage to woody seedlings (Minkin & Ladd 2003).

Deep flooding and long periods of ponding or standing water can decrease vegetation diversity and/or shrub densities, but conversely these conditions may also decrease the number of invasive species able to establish (Ehrenfeld 2005, Dwire et al. 2006). In the few studies available, the majority of invasives observed were either upland or facultative upland species (Ehrenfeld 2005), suggesting that less saturated conditions may allow invasives to establish to the detriment of the native wetland plant communities. Invasive species, particularly *Phragmites australis* (common reed), *Lythrum salicaria* (purple loosestrife), and *Rosa multiflora* (multiflora rose) were found to be common problems in eight restored New England wetlands (Minkin & Ladd 2003). Another problem is the introduction of cultivated varieties of native species, and the effect of these alien genotypes on wetland functions and/or other native species (Minkin & Ladd 2003). Heavy inputs of stormwater runoff can also potentially favor the dominance of invasive species (Joy Zedler *personal communication*). Wetland plants are affected by the amount of sedimentation and by nutrient inputs, both of which can enhance the growth of invasive species (Woo & Zedler 2002, Mahaney et al. 2004).

Soils

Undisturbed riparian wetland soils in the northeastern U.S. are often wet, acidic, and highly organic. However, soil characteristics that are important to nutrient cycling processes have been shown to be quite different in restored/constructed forested wetlands. Soil organic matter is often two-fold higher, and while sand may account for two-thirds or more of the surface soil in restored/constructed systems, it is typically a negligible component of natural wetland soils (Campbell et al. 2002, Bruland & Richardson 2005). The proportion of silt and clay, often higher in natural wetlands, determines the soil particle size, which in turn determines permeability and porosity, and is inversely proportional to water holding capacity (Stolt et al. 2000). The cation exchange capacity (CEC), and levels of organic C and N have been found to be five- to ten-fold higher in natural wetlands, and constructed wetlands typically exhibit a higher proportion of basic cations (Ca, Mg), and a higher pH than natural wetlands (Stolt et al. 2000).

Soil compaction appears to be common in wetland restoration projects, and constructed wetlands often exhibit a reduction of both large scale and microtopography, as well as an increase in the amount of low relief (Stolt et al. 2000). When an activity destroys fine-scale features such as microtopography (Stolt et al. 2000, Bruland & Richardson 2005), this reduction will result in a concomitant reduction of the "wetness" gradient that supports diverse plant species. The bulk density of soils in natural wetlands can range from 2-fold to an order of magnitude lower than the bulk density found in the constructed/restored wetlands soils, although the number of studies looking at this factor is small (Campbell et al. 2002, Bruland & Richardson 2005).

Location and Surrounding Land Use

Landscape position dictates the site hydrology and type of wetland that can be successfully restored and sustained (NRC 2001). However, degradation of the surrounding land can compromise wetland establishment and functionality, and so expectations and goals for urban freshwater wetland restorations need to be scaled to the surrounding landscape (Wolin et al. 2005). Parkyn et al. (2003) found isolated stretches of riparian buffer restoration produced few consistent improvements in water quality, habitat, or stream invertebrate communities. They suggest that "patches" of restoration may not be large enough to improve overall function of a given ecosystem, and so if upstream areas and/or tributaries remain disturbed, downstream restorations may face a continued risk. Location of compensatory wetland sites adjacent to roadways, highways, parking lots, and industrial development can alter hydrology and water quality (Guntenspergen & Dunn 1998), increasing the degree of difficulty in successfully establishing certain wetland functional targets (Minkin & Ladd 2003), and surrounding land use has been found to be a major determinant in species assemblages (Magee et al. 1999). Conversely, wetlands adjacent to anthropogenic disturbances may be highly functional in retention of flood waters, nutrients, and sediments (Guntenspergen & Dunn 1998). Because a large hospital complex and a public school are directly upstream of the TCC restoration site and have permitted discharges into the creek, land use on these two parcels directly affects the water quality in Teaneck Creek's wetlands (Bergstrom et al., this volume).

Teaneck Creek Conservancy Restoration Area

The Teaneck Creek wetlands are situated adjacent to two major urban roadways (DeGraw Ave. on the southern boundary and Teaneck Rd. on the western boundary) at the northern terminus of the New Jersey turnpike (Interstate Rt. 95), and the eastern terminus of Interstate Rt. 80. The creek headwaters are located on property owned by Holy Name Hospital. Runoff from the hospital parking lots and parking deck, which uses urea to deice in winter, drains directly into Teaneck Creek. The hospital also has NJDEP permitted discharges allowing both heated waters from an onsite sterilization facility, as well as 100,000 gal day^{-1} of pumped groundwater, to be piped directly into Teaneck Creek. South of the hospital the creek flows under Teaneck Rd., through the lawn of Thomas Jefferson Middle School, and under Fycke Lane where it enters the wetland system. The stream bank on school property is in need of stabilization (Bergstrom et al. this volume) and is currently lined with the invasive plant Japanese knotweed (*Polygonum cuspidatum*), which periodically is cut by the school district and left to float downstream into the restoration site.

Site Characteristics

The topography of this system is characterized by a series of low lying sub-watersheds (Obropta et al. this volume), higher elevations due to the presence of various fill materials, a straightened creek channel with an adjacent clay fill berm that forms a "levee," and on the upland side of the berm, depressions with standing water containing monospecific stands of *Phragmites australis* (Fig. 3). Teaneck Creek flows into Overpeck Creek, which is connected to the lower Hackensack River, a tidal estuarine system. The Teaneck Creek connection with the lower estuary has been altered due to the installation of tide gates seven miles south of the site. These gates close during incoming tides, and so the creek does not experience a typical tidal flushing. Twice daily when the tide gates close, the waters flowing downstream are retained in the system until the tide changes and the gates reopen, creating a backwater effect that produces a daily tidal pulse (Obropta et al. this volume). When high tides coincide with precipitation events, it is common for the creek banks in the southern portion of the site to overflow (Fig. 4c). Although Teaneck Creek is only 1.5 miles in length, the hydrology in the Fycke Lane northern section is completely different from that in the DeGraw Ave. southern section. During low-level storm intensities the Fycke Lane waters rise quickly, but this section only overtops the stream banks during major storm events. When a storm ends, the Fycke Lane stream waters quickly return to their low level (Fig. 4b), resulting in a very "flashy" hydrograph for this portion of the creek.

The hydrologic interface between the Teaneck Creek, its tributaries, the groundwater, and the standing water depressions is unlike the connection found in a non-disturbed riparian corridor. In addition to two small tributary streams, there are six pipes that directly discharge stormwater from the Township of Teaneck into the wetland (Fig. 4a). There are small groundwater seeps in some areas, but across most of the site, the hydrologic connection between the groundwater and the creek has been eliminated due to the presence of underlying natural clay layers and clay fill dredge material (Obropta et al. this volume). In essence, much of the wetlands on this site appear to be functioning as perched bogs (Joan Ehrenfeld, *personal communication*), dominated by precipitation and stormwater inputs.

The vegetation on the site (Ravit et al. this volume) is dominated by *Phragmites australis*, which is thriving in large ponded areas that have formed in low-lying depressions. The newest invasive species to arrive in the system ca. 2005 is Mile-a-minute vine (*Polygonom perfoliatum*) that now appears to be overpowering the *Phragmites* in certain sections (Fig. 5a). In spite of the large areas covered by invasive monocultures, a forested wetland remains intact in the northeastern portion of the site (Steven Handel *personal communication*), where native wetland vegetation is thriving (Fig. 5b). The hydric soils in this remnant area are continually saturated and standing water is found here after a storm event. In spite of the site's invasive plant coverage (40%

of the species observed covering approximately 40% of the site), total species diversity was found to be high (245 plant species).

A site assessment was completed for Bergen County in 1999. As part of this assessment, soil samples were collected from test pits throughout the site, and the soils were classified as Udorthents (Fig. 6). No soil profile was observed in these soil borings, and the only hydric soils were located in the forested northeastern corner of the site adjacent to Fycke Lane. A cross section detailing the site soils (Fig. 7) shows the presence of sand and clay fill material above the organic mat. However, "patches" of various substrates are scattered throughout the 46-acres, and include: 1) unconsolidated fill materials; 2) clay dredge sediments placed on the site as fill; 3) reduced organic wetland soils; and 4) in the northern portion of the stream bank, sand (Fig. 8). In addition there is a large area on the southern border of the site adjacent to DeGraw Ave. where construction debris, including asphalt and concrete, and discarded large household items have been illegally dumped (Fig. 9). The wetland delineation completed in 2006 (Fig. 10) shows that the majority of the site has been classified as wetland.

Baseline Site Characterization

To ensure a sustainable wetland restoration, the Interstate Technology Regulatory Council (ITRC 2005) recommends a thorough assessment of the wetlands being restored to "understand the hydrology, soil, and plants and how they interact to affect the functions or values provided by the wetlands." This is a factor in the decision by the New Jersey Wetlands Mitigation Council (NJWMC) to fund a scientific baseline assessment prior to development of the Conceptual Restoration Plan, in the hopes that the Teaneck Creek restoration would not be another freshwater riparian wetland failure. During the three year study the Conservancy site has been characterized with respect to:

1) Surface water inputs, hydrologic flow rates, and nutrient loadings
2) Groundwater depths to water table, flow rates, and nutrient loadings
3) Presence, abundance, and location of native and invasive vegetation
4) Soil characteristics associated with various hydrologic regimes on the site
5) Sediment denitrification potential pre-restoration

These activities have been coordinated through the Rutgers Environmental Research Clinic (www.rerc.rutgers.edu). Rutgers University has also contracted with the US Geological Service (USGS) to train students in accepted hydrologic sampling techniques. Stormwater samples have been collected quarterly over the last two years and analyzed in the USGS laboratories (Obropta et al. this volume). Shallow groundwater monitoring wells, reaching a depth of 40 cm below the soil surface, were installed at 30 locations (Fig. 10) within the TCC site. To install these wells a soil core was excavated using a hand auger, and a PVC shallow groundwater well containing screened holes to allow water movement into the well was placed in the hole. The excavated area remaining around the well was filled with sand, the sand and the adjacent soil surface were then capped with bentonite clay to preclude movement of water into the well from the surface, and the well was capped. Hydrology data has now been collected for over a year at each well by measuring depths of inundation and depths to groundwater on a weekly basis.

Analysis of soil samples was conducted to determine moisture content, nutrients, conductivity, pH, and micronutrients. These samples were collected at the locations where groundwater wells were installed, prior to placement of the wells (Fig. 10). Samples were obtained using a corer 25 cm in length and 10 cm in diameter. Results of these analyses indicate a high degree of heterogeneity related to the hydrology and the amount and type of fill material present at each sampling location. Soil organic carbon proportions ranged from 2% to 22%, TKN values ranged from 0.08% to 0.57%, and ammonia concentrations ranged from 0.1 to 11.0 ppm. Soil pH varied from 6 to 7.85, and we hypothesize that the high end of this range is due to the decomposition of the concrete debris. The soil categories range from “clay” to “sandy loam.” In addition to the clay fill material forming the creek bank berms, there are natural clay layers and lenses under most of the site at depths varying from 1 to 4 feet.

A vegetation analysis was also completed (see Ravit et al. this volume). The site was organized into a series of 32 grids, and each grid was surveyed to determine the presence or absence and the abundance of both native and invasive vegetation. Plant Stewardship (PSI) and Floristic Indices (FI) were subsequently calculated for each grid. Data related to the plant species, depths to the water table, and soil properties are now being analyzed to determine which native plants might be sustainable in the different subwatersheds of the site given the various combinations of hydrology and soils.

Because N leaving this system can contribute to high rates of eutrophication in the lower Hackensack River estuary we chose to target a decrease in N transport out of the system as a functional restoration goal. Denitrification rates are now being analyzed in soil samples taken from multiple locations on the site (Fig. 10), and these rates will be used to calculate changes in denitrification potential of the Conservancy wetlands pre- and post-restoration. We were also able to secure funding from the New Jersey Water Resources Research Institute (NJWRRI), which supported a study to characterize the contribution of atmospheric deposition of carbon and nitrogen loadings to the site (Ravit et al. 2006). Samples were collected quarterly during 2005-2006 and analyzed for wet and dry deposition of organic and inorganic (nitrate, ammonia) N compounds. Wet deposition of inorganic N was ten-fold greater than dry deposition, and the range of nutrient concentrations measured was similar to the regional signals found for the New York-New Jersey region by Lovett et al. (2000), Meyers et al. (2001), and Seitzinger et al. (2005). When dry particle N deposition was compared among samples taken at various distances from the DeGraw Ave. roadway, inorganic N concentrations 20-50% higher were found at the roadside versus 100 meters away from the road.

To achieve our goal of 20-acres of rehabilitated wetlands there must be an increase in flooding, and a subsequent retention of water by additional acreage within the TCC site. To achieve increased wetland acreage, changes must occur in the topography of the system, and these changes will take into account removal of debris, the water flow patterns of the six storm water inputs, the inter sub-basin water movements, and surface flows from the Teaneck Creek. The results of the baseline studies are being incorporated into a Conceptual Restoration Plan for the TCC site, which will include detailed grading plans, planting plans, and invasive species control plans. A secondary long-term project goal is to develop an Urban Wetland Model capable of describing the relationship between hydrology, vegetation, and soil denitrification within this urban wetland system.

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Figure 1. Arial photograph of Teaneck Creek Conservancy wetlands and the surrounding urban land use. Photo courtesy of Bergen County Parks Dept.

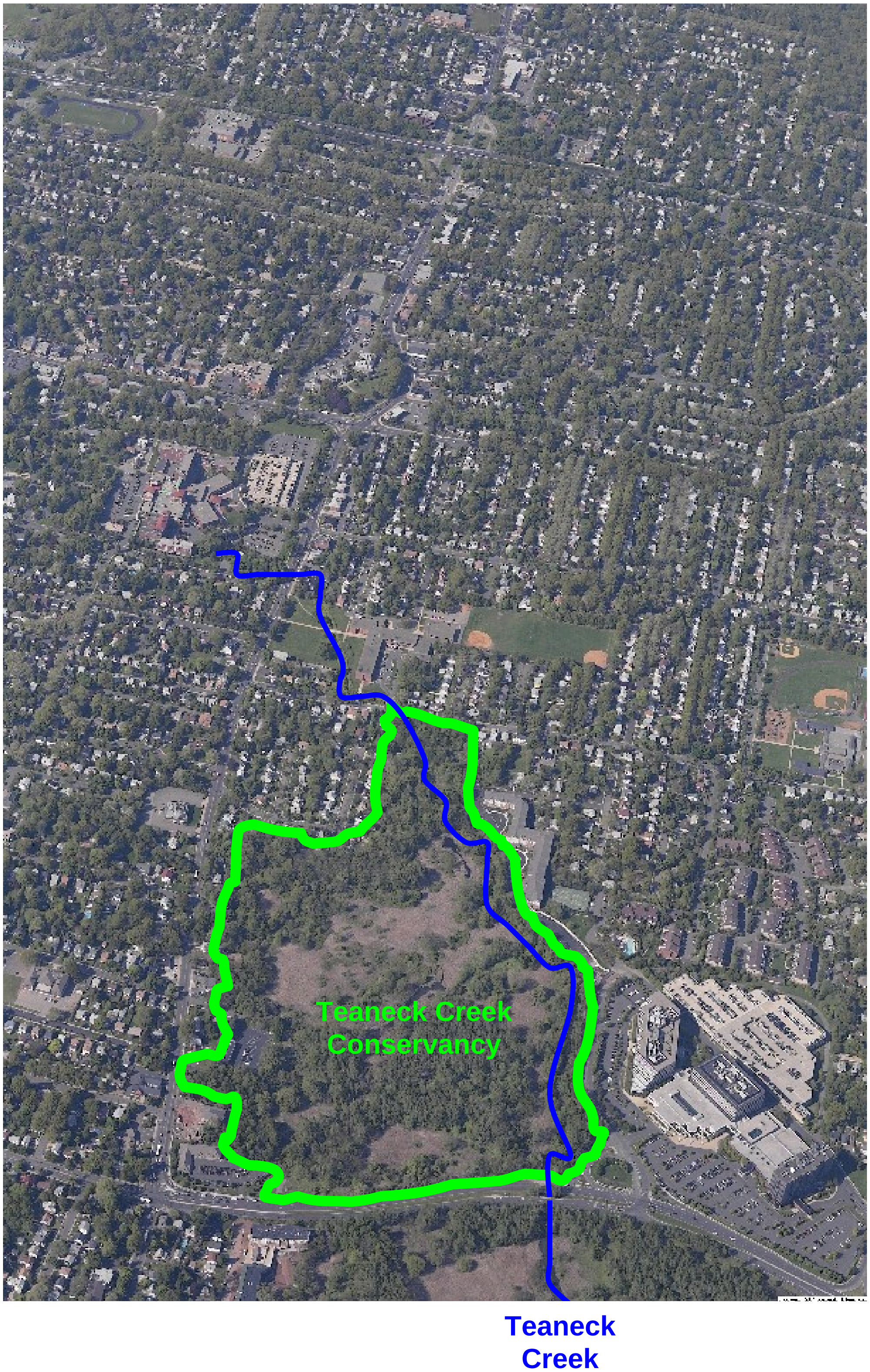
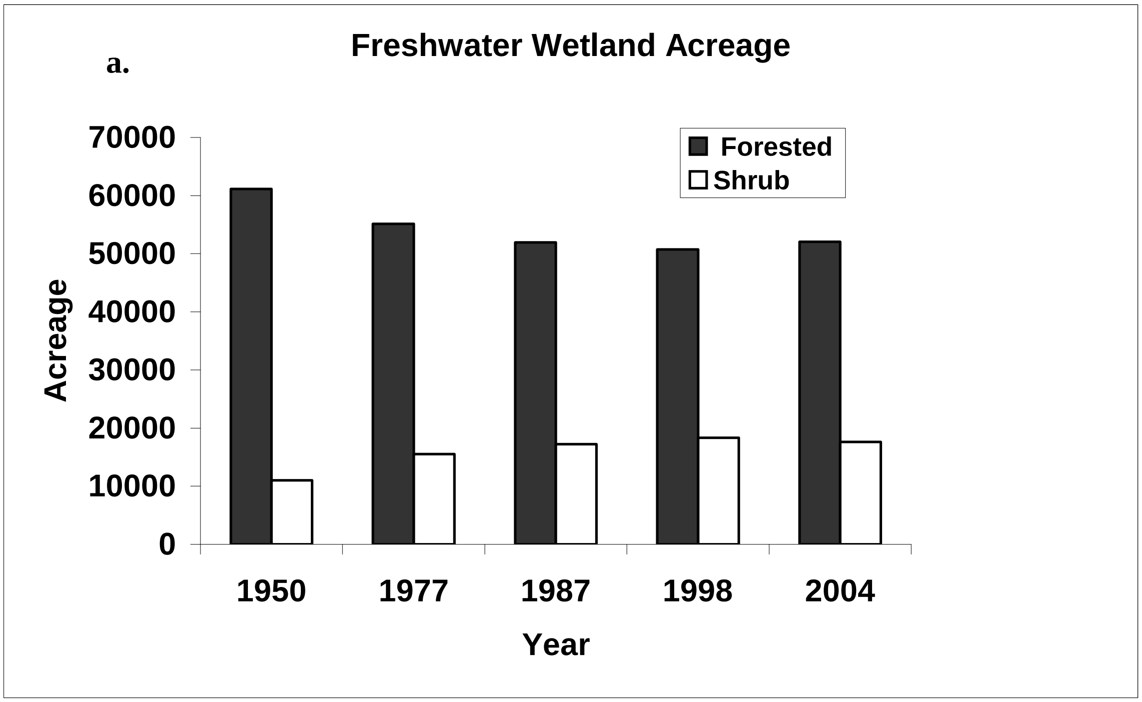


Figure 2. U.S. freshwater forested and scrub shrub wetland acreage A) from 1950 through 2004 and B) U.S. forested and scrub shrub wetland acreage in 1998 and 2004. Data reproduced from Dahl (2005).



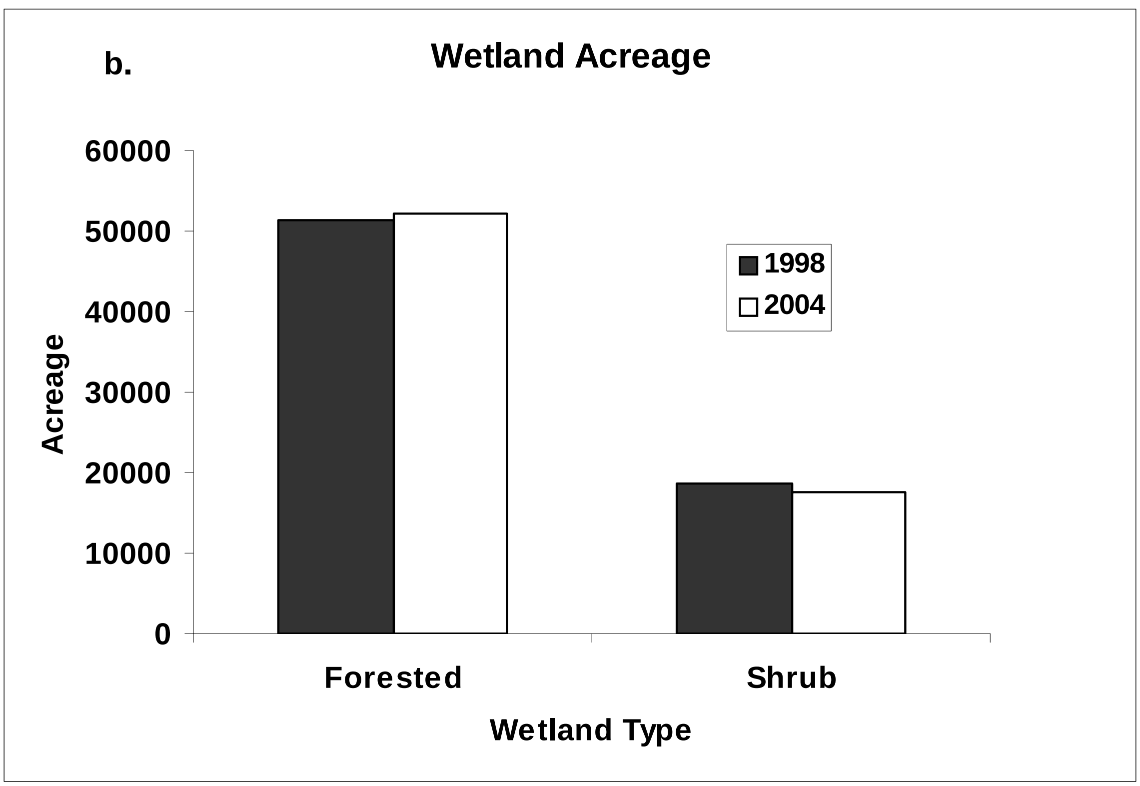


Figure 3. *Phragmites australis* monocultures in Teaneck Creek ponded depression areas.

Figure 4. a) Six storm drains empty urban runoff directly into the Teaneck Creek. During a storm event, the b) northern portion of Teaneck Creek adjacent to Fycke Lane exhibits "flashy" hydrology, while the c) southern stretch experiences bank overflows. Photos b and c were taken within 10 minutes of each other following an intense storm on September 29, 2005.

a. "Stormwater Canyon" adjacent to Teaneck Rd.

b. Fycke Lane Bridge

c. Glenpointe Overbank Flows

Figure 5. Examples of Teaneck Creek vegetation: a) Common reed (*Phragmites australis*) overgrown with Porcelain Berry (*Ampelopsis brevipedunculata*) overgrown by Mile-a-Minute vine (*Polygonum perfoliatum*) and b) native forested wetland vegetation.

Figure 6. Teaneck Creek Conservancy site map showing the 1999 soil test pit soil categorizations (Note cross section I-I').

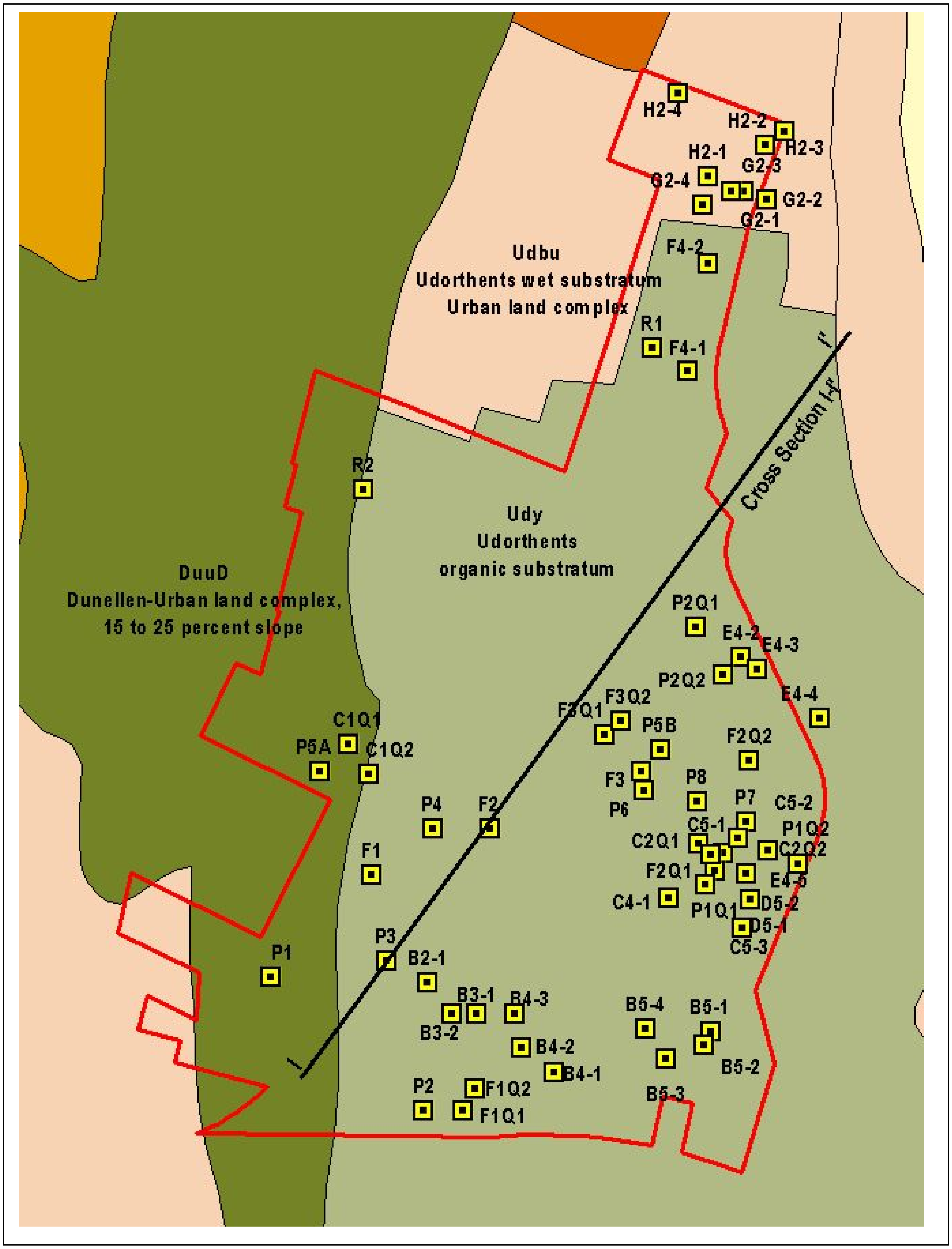


Figure 7. Teaneck Creek Conservancy 1999 soil test pit cross section showing substrate materials.

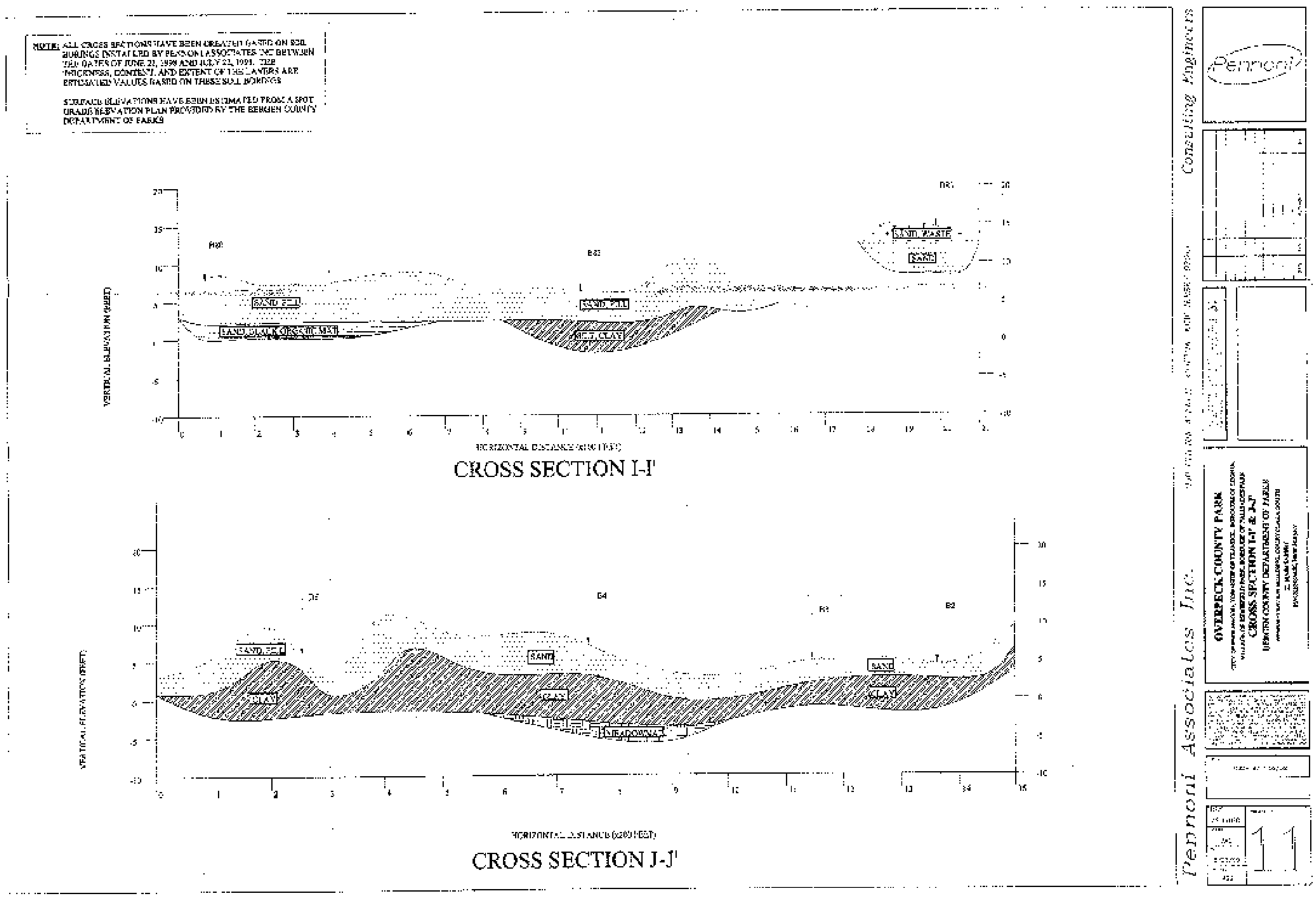


Figure 8. Soil cores obtained from a) undisturbed location with native wetland vegetation and hydric soils, b) and c) from an area vegetated with monospecific stands of common reed (*Phragmites australis).*

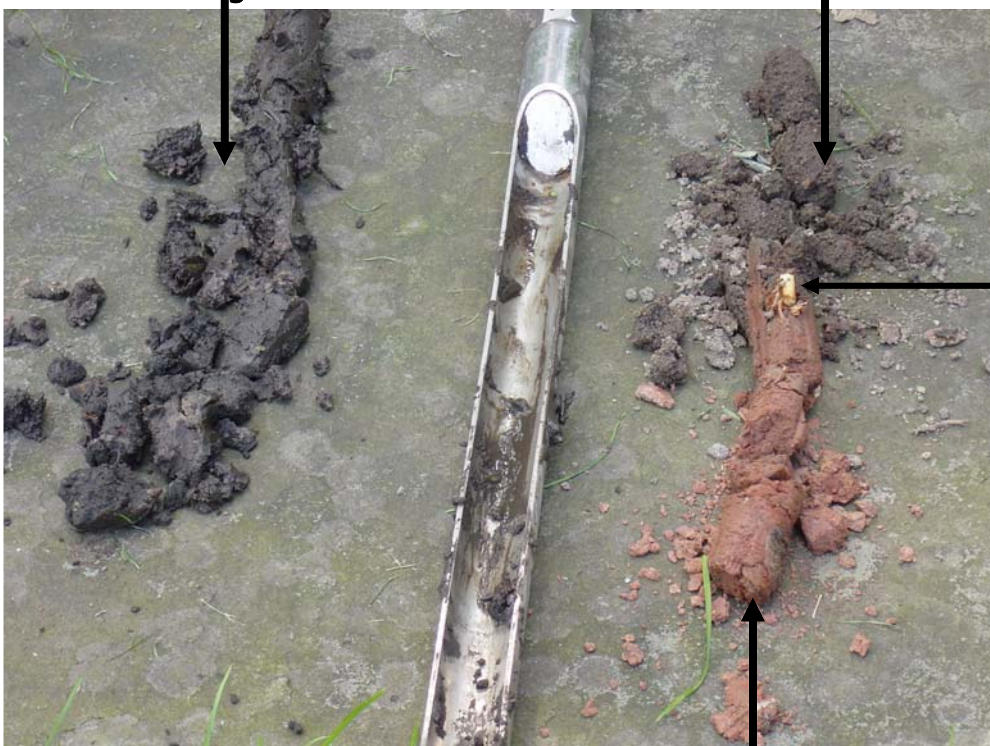


Figure 9. Discarded refrigerator debris serves as a "natural" planter for garlic mustard (*Alliaria petiolata*).

Figure 10. Teaneck Creek Conservancy site map showing the wetland delineation completed in 2006. Circles indicate location of shallow groundwater wells and soil sampling locations.

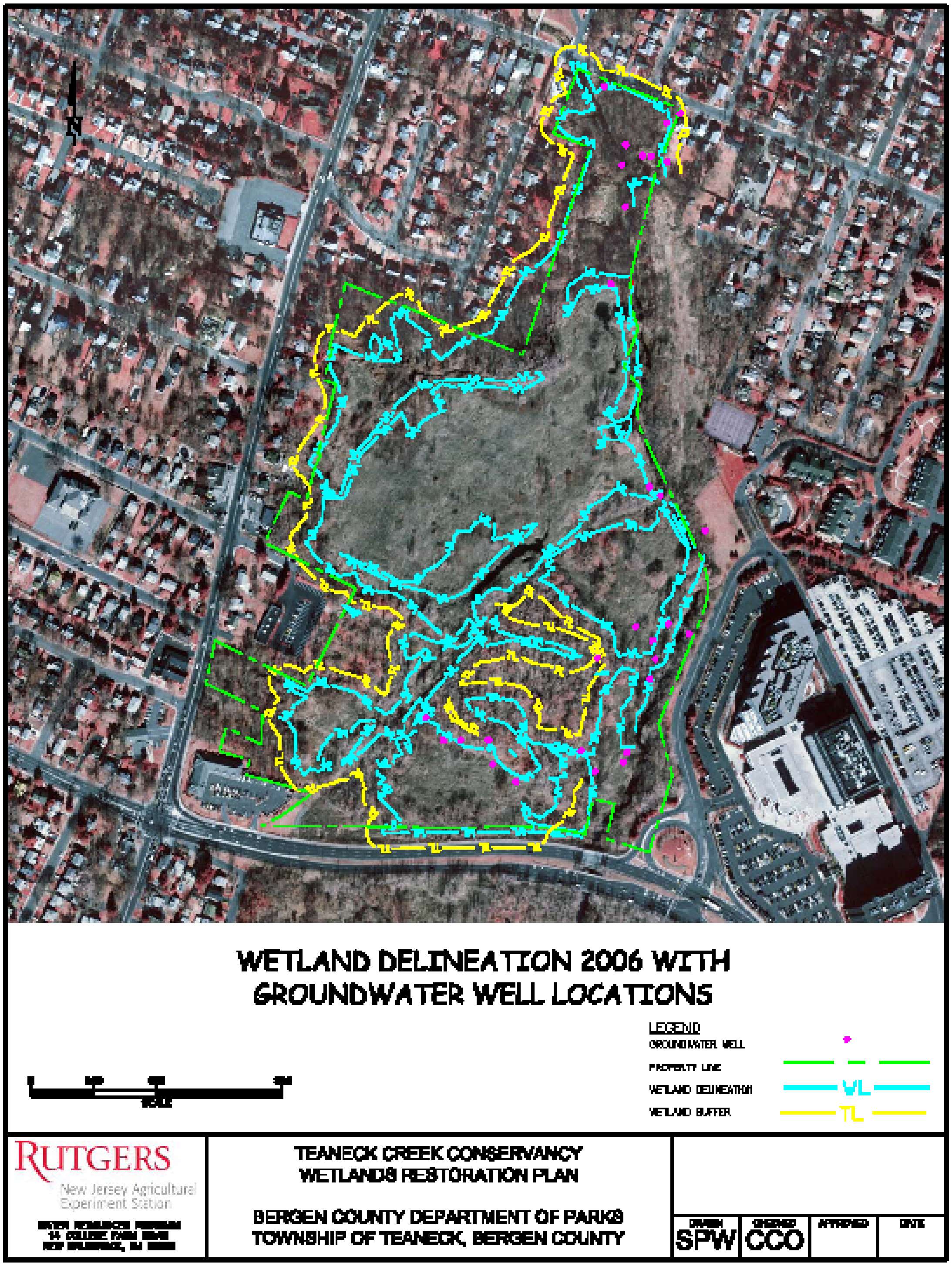
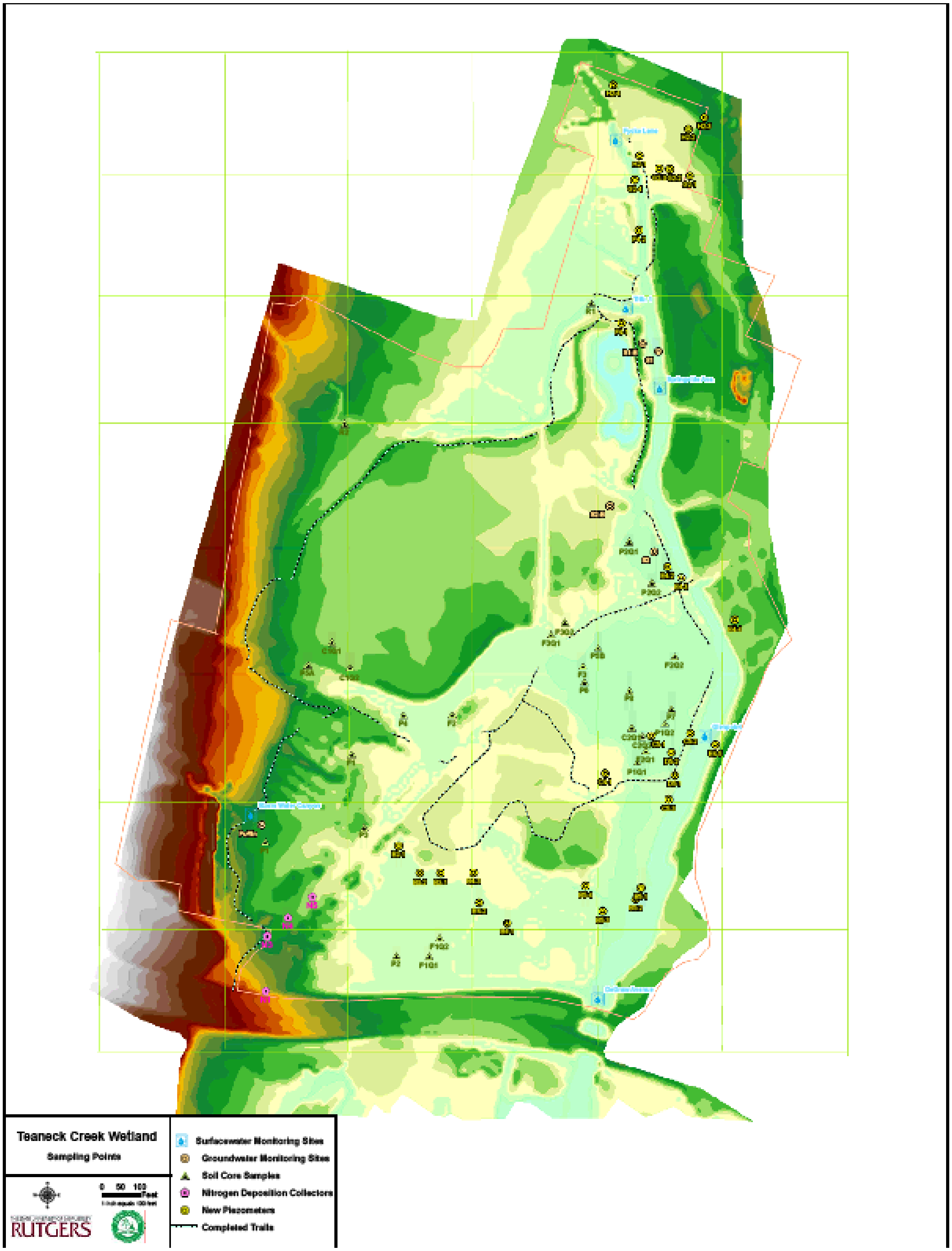


Figure 11. Map of all sampling locations.



Restoration of a Forested Riparian Wetland Ecosystem: Modeling Urban Wetland Hydrology

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Introduction

Wetlands can be highly variable ecosystems, characterized by fluctuating water levels and the prevalence of saturated soil conditions during the growing season. Wetland systems often act as critical sources, sinks, and transformers of anthropogenic and natural materials received from the surrounding watershed (Mitsch & Gosselink 2000). Riparian wetland ecosystems are positioned downstream of headwaters, and typically receive runoff from adjacent watershed land uses (Grayson et al. 1999, Thurston 1999). Due to the high levels of urbanization occurring in the 20th century, many isolated wetlands now occur in urban locations, and the hydrology of these urban wetland systems and their surrounding ecosystems has been radically altered (Ehrenfeld et al. 2003). Attempts at urban restoration activity often include modification of a particular area within a wetland system where adverse impacts have occurred (Lewis 1990). It is critically important to understand the specific hydrology of a given site in order to determine current functional value(s) of the wetland, as well as the hydrologic requirements with respect to restoration goals. The hydrology of the wetland system must also be defined in order to predict post-restoration wetland structure and function(s), a highly complex process due to the ambiguity of classifying potential changes that can occur as a result of both anthropogenic and/or natural processes (Hawk et al. 1999).

A comprehensive water-budget is necessary to characterize the hydrology of an urban wetland system. However, difficulties arise in creating hydrologic simulations over extended time periods and estimating the various components of urban hydrology (Dexler et al. 1999). Although a few water budgets have been created in the attempt to describe wetland hydrology (Konyha et al. 1995, Reinelt & Horner 1995, Hawk et al. 1999, Arnold et al. 2001, Kirk et al. 2004, Zhang & Mitsch 2005), models capable of describing urban wetland processes are virtually non-existent (Drexler et al. 1999, Raisin et al. 1999), and we are aware of only one study (Owen 1995) that has attempted to develop a comprehensive urban water budget. This leaves a large data gap when trying to simulate urban hydrology, especially since current wetland modeling is derived from traditional pond design engineering (Konyha et al. 1995). The lack of reliable data poses a challenge in understanding how urban wetlands interact with adjacent ecosystems and watersheds, and so the development of a hydrologic model that can accurately describe urban wetland processes is a necessary first step in successfully achieving restoration objectives.

The goal of this study was to develop an accurate baseline hydrological model to describe the urban wetlands of Teaneck Creek as they exist currently. Once calibrated to existing conditions, the model can then be used to evaluate various potential hydrological manipulations (e.g., grading, water control structures), providing a critical component in the development of a Restoration Plan for the Teaneck Creek Conservancy (hereafter the Conservancy) site. Secondarily, we hope to develop an Urban Wetland Model that will also provide a framework for a future assessment of the restoration's success, and serve as a basis to predict water quantity characteristics of other urban wetlands. A unique aspect of this model and the subsequent Restoration Plan will be the integration of data related to this system's denitrification potential, its surface and ground water interactions, and atmospheric nitrogen deposition.

Modeling Urban Wetlands

The basic hydrologic parameters of wetland water budgets include surface water influxes, precipitation, groundwater influxes, storage of water, percolation, and evapotranspiration (Owen 1995, Hawk et al. 1999, Reinelt & Horner 1995). There are three approaches used to model wetland hydrology - single event models, stochastic models, and comprehensive water budgets (Koob et al. 1999). The mass balance approach provides a framework to develop a water budget, which seeks to incorporate the dynamic structure and processes that control a wetland's hydrology. Further generalizations or additional parameters, such as a proposed restoration design of the system's hydrology may also be included in a model (Owen 1995, Reinelt & Horner 1995, WRP Techincal Note HY-CP-5.2 1997, Yu & Schwartz 1998, Drexler et al. 1999, Raisin et al. 1999, Kincanon & McAnally 2004, Gobel et al. 2004, Mo et al. 2005, Xiong & Melching 2005, Zhang & Mitsch 2005). The advantage of applying a stochastic model to urban wetlands lies in the incorporation of uncertainty into the model results. This approach contrasts with deterministic models, which produce identical results when provided with constant input parameters. Another alternative is to use a deterministic model with variable inputs to examine a range of conditions, e.g., dry conditions, wet conditions, average conditions.

Surface and groundwater hydrology, in conjunction with soil characteristics, control a wetland hydrology budget. The recharge and discharge of a wetland due to subsurface flow is considered a critical dynamic of the entire system (Mitsch & Gosselink 2000), yet there is insufficient research to confirm and describe these interactions (Siegel 1988), particularly in urban settings. Soil characteristics, the type and permeability of surrounding land use, as well as spatial location will determine ground water characteristics of the wetland (Hawk et al. 1999), increasing the complexity of modeling subsurface flow though the heterogeneous soils found in urban systems (Drexler et al. 1999).

Precipitation is a critical parameter in wetland hydrologic simulations. Surface water inflows in urban wetlands can occur via both stream overbank flow and storm drain inputs to the wetland system. In highly urbanized locations, the input of stormwater runoff into area wetlands is a highly probable event. High impervious cover in urban settings (roofs or road surfaces) increases stormwater runoff velocities, thus altering traditional watershed budgets (Gobel et al. 2004). Evapotranspiration (ET), a combination of evaporation that occurs from plant canopies, soil surfaces, or open water regions, and transpiration, defined as evaporation from the vegetation, is an additional factor contributing to a wetland water balance. ET influences a substantial number of wetland dynamics, including vegetation sustainability, soil systems, and the nutrient and hydrologic budget (Baird et al. 2005).

Teaneck Creek Hydrologic Model

Wetland hydrology is commonly influenced by groundwater (Restrepo et al. 1998, Wilsnack et al. 2001, Krasnostein & Oldham 2004, Baird et al. 2005), yet few groundwater studies have been undertaken on an annual time frame (Bradley 2002). Some wetland systems are dominated by the interactions between ground and surface water, and so these parameters cannot be simulated independently of each other. An individual surface or ground water simulation is insufficient to describe long-term interactions where significant connections exist between these two systems (Said et al. 2005), and so the integration of surface water and ground water models may be required (Perkins & Sophocleous 1999, Said et al. 2005). Groundwater models are predominately founded on physically based concepts of spatially distributed ranges, while surface water models are founded on a more theoretical, lumped parameter modeling approach (Perkins & Sophocleous 2000).

The connection of surface and ground water models can cause numerous problems when modeling an urban wetland system. A major concern involves the heterogeneous nature of the soil, land use, and vegetation layer found in various subbasins of the wetland (Perkins & Sophocleous 2000). Creating smaller individual subbasins creates unwanted complexities when attempting to simulate an entire hydrologic system. In many wetland studies (Grayson et al. 1999, Koob 1999, Owen 1995, Thurston 1999) groundwater interactions with the surface water system are modeled to develop a comprehensive water budget. However, if an urban wetland system is characterized by minimal or non-existent groundwater interactions, the complexities of these models are unnecessary.

In urban wetland systems there often exist subsurface soil layers characterized by low hydraulic conductivity and permeability rates. In such urban systems the impermeability of the soil layer leads to differences in water budget components from those found under non-urban conditions. Groundwater recharge and ET are initially hindered in urban systems, therefore reducing or removing the groundwater component from the hydrologic budget (Reinelt and Horner, 1995). In urban systems where the groundwater component is virtually nonexistent, the most effective modeling approach to simulate hydrologic processes is the application of a nonlinear reservoir method, such as the United States Environmental Protection Agency Stormwater Management Model (SWMM).

SWMM is a comprehensive deterministic model for urban stormwater runoff, with the capability of considering both water quality and quantity during a single event or on a continuous time frame (Huber & Dickinson 1988, Tsihrintzis & Hamid 1998, Bhaduri et al. 2001, Burian et al. 2001, Choi & Ball 2005, Lin et al. 2005, Smith & Banting 2005, Xiong & Melching 2005). SWMM is designed to simulate real time storm events based on spatial and temporal rainfall, evaporation, topography, impervious cover, percolation, depression storage values for impervious and pervious regions, storm drainage attributes such as slope and geometry, Manning's n, and infiltration rates (Burian et al. 2001, Bhaduri et al. 2001, Choi & Ball 2005). Based on these parameters, SWMM will model infiltration and storage and divert the remaining runoff as sheet flow (Burian et al. 2001). SWMM includes four simulation blocks to model urban storm water runoff: RUNOFF, TRANSPORT, EXTRAN, and STORAGE/TREATMENT.

When integrated with a GIS platform SWMM is capable of developing simulations for defined subwatersheds existing within the boundaries of a given system. The watershed boundary is divided into smaller subdivisions, based on land use, soil characteristics, impervious attributes, and topography (Smith & Banting 2005), which allows SWMM to generate runoff hydrographs based on daily rainfall data for each delineated subwatershed (Smith & Banting 2005). An inflow of precipitation data will produce outflows of infiltration, evaporation, and surface runoff. Surface runoff will occur when each subbasin or reservoir reaches maximum storage. The depth of water for each subcatchment will be calculated continuously over the desired time step, through continuous calculations of the water balance. For each subwatershed SWMM can simulate an individual rainfall event or a continuous simulation in time steps of minutes to years based on the desired use.

The non-traditional urban wetland requires non-traditional modeling approaches. The SWMM model exhibits the highest potential to accurately simulate hydrological processes occurring within an urban wetland. The capability of the SWMM model to simulate urban settings can provide a solid framework for developing an efficient water budget for an urban wetland system. Through SWMM, the processes that define urban wetland systems, with limited groundwater influences, may be simulated on a continuous basis, therefore providing a comprehensive description of the role of urban wetlands within the surrounding watersheds, and so we chose SWMM to model the Teaneck Creek wetland hydrology. The approach we chose was to simulate the response of the wetland over a five-year period that included wet, dry, and average meteorological conditions. In this way, we could understand the response of the wetland under a variety of hydrologic regimes.

MATERIALS AND METHODS

Sewer system record survey maps of the Township of Teaneck (1972), 2002 NJDEP Orthoimagery, and 10-meter and 2-foot Digital Elevation Models (DEMs) were obtained to delineate the extent of the sewersheds draining into the wetland using ArcGIS 9.0. The 10-meter DEMs, along with the invert elevations of the catchments to each storm sewer line in the township were analyzed and individual drainage areas were assigned to each basin. A total of 46 sub-sewersheds were delineated within the sewershed draining into the Teaneck Creek Conservancy Wetland (Fig. 1) and the size and slope characteristics of each were determined in ArcGIS.

All 46 sub-sewersheds (subcatchments) were constructed in EPA SWMM 5.0 with their corresponding attributes and dimensions. The attributes of the subcatchments required to run a storm simulation consist of: area, width, % slope, % imperviousness, infiltration method, and the outlet junction. The NRCS TR-55 SCS curve number infiltration method was used, based on the 1/8 acre or less (65% imperviousness) average residential lot size and the particular hydrologic soil group existing in each sub-sewershed (SCS 1986). The hydrologic soil group of each sub-sewershed was provided by the NRCS SSURGO soils data layer imported into

ArcGIS 9.0. Also, it should be noted that soil characteristics of the Conservancy's wetlands have been highly modified by anthropogenic activity during the construction of the New Jersey Turnpike in the 1950's and by current urban conditions. The soils existing in the wetland system are highly heterogeneous and mixed with debris from the surrounding urban system, largely underlain by a low permeability clay layer that limits groundwater interactions.

Once the entire sewershed was defined in SWMM, the six outfalls of the sewer lines and sub-sewersheds were modeled to complete the storm sewer portion of the system. The wetland subcatchments were then created using 2-meter DEMs within the boundary of the Teaneck Creek Conservancy (TCC). The attributes for the subcatchments were measured through ArcGIS 9.0 and imported into SWMM. The routing of water through the wetland from the sewer system to the Teaneck Creek was predicted using the 2-foot GIS contours for the wetland and confirmed by on-site surveys during rainfall events. Six subcatchments were delineated within the TCC, some of which flowed in different directions depending on the water elevations within the basins. This was accomplished in SWMM using weirs and diversion structures and each wetland basin was modeled as a pond with storage defined by the topography. There are six stormwater inflows to the wetland and eight locations where water discharges to the Teaneck Creek and tributaries. Figure 2 is a graphical representation of the predicted surface water routing through the wetland and Figure 3 shows the geographical location of the various wetland basins. The details of the SWMM model are contained in Mak (2007).

Model Calibration

Two rainfall events were recorded at a representative location of the model environment. A pressure transducer and a rain gage were installed at Stormwater Canyon (S-1 in Fig. 2), which receives runoff representative of the other sub-sewersheds within the drainage system and is the primary source of water to the largest area of the wetland that will be restored. The rainfall events were input into SWMM to calibrate the model through a comparison of the predicted flow versus the actual measured flow during these two storm events. The pressure transducer recorded water depth throughout the storm at 4-minute intervals, requiring a rating curve to calculate the actual flow through the canyon. Previous flow measurements recorded at Stormwater Canyon were used to develop the rating curve for the two rainfall events. The recorded rainfall data were input into SWMM with the corresponding dates and time steps of the storm events. The output data from each simulation were then imported into Microsoft Excel for model validation. For the two storm events, two subsets of simulations were run for the model calibration process. The parameters adjusted during the calibration of the model were the curve numbers representing the infiltration routing processes, the % impervious area with no depression storage, and % impervious cover values for each subbasin in the sub-sewershed under review. Plots of observed versus measured flow for each calibration simulation were then analyzed for the validation of the model.

Validation

To validate the model, a numerical integration method (trapezoidal rule) was used to analyze the measured versus predicted values. The total runoff volume for each simulation was calculated using the trapezoidal rule and compared to the measured flows. At the calibration point, the measured versus predicted values for total runoff volume differed by only 2.06% (Mak 2007).

Water Budget Calculations

Once the model was calibrated and validated, it was used to generate annual rainfall simulations to develop a water budget. To simulate an annual rainfall event, 15-minute and hourly precipitation data in DSI-3260 and DS-3240 format, respectively, were imported into SWMM as a .dat file. Due to completeness of the data set and relative proximity, the precipitation records from Newark Airport were used for these annual simulations. Figure 4 shows the overall logic flow of how the model was developed and used to calculate annual water budgets.

The SWMM model was used to predict the volume of water draining into and out of the TCC wetland from the surrounding sewershed. Using this information, a monthly water budget was created for the entire wetland for the years of 2000-2005.

The calculation of the water budget was done in Microsoft Excel using runoff data imported from EPA SWMM 5.0, the New Jersey State Climatologist (http://climate.rutgers.edu/stateclim_v1/monthlydata/index.html), and the National Climatic Data Center (NOAA) (www.ncdc.noaa.gov). The calculation of the water budget follows a mass balance approach provided by Mitsch & Gosselink (2000) and Owen (1995). The general mass balance exists as (change in storage = input – output). The mass balance applied to the wetland is derived from the expression:

Equation 1: Water Budget Equation

$$\Delta S = P + S_i + G_i - AET - I - S_o - G_o \pm T$$

Where:

ΔS = change in storage volume
P = precipitation
S_i = surface water inflow
G_i = ground water inflow
AET = actual evapotranspiration
I = infiltration
S_o = surface water outflow
G_o = ground water outflow
T = tidal flow

For each annual simulation, surface water inflows (Si) and outflows (So) in cubic feet per second (CFS) were imported from EPA SWMM 5.0 and converted into units of acre-feet for the water budget calculations. Hourly precipitation values (DS3240 format) from Newark International Airport (Station #286026) were obtained from the National Climatic Data Center (NOAA) (www.ncdc.noaa.gov) for the Years 2000-2005. The Newark station is located approximately 16 miles from the Conservancy wetlands and contains the most complete hourly rainfall data sets of any station in the vicinity. The precipitation (P) inputs for the wetland itself were calculated by summing the hourly data (in inches) and converting to acre-feet.

Ground water inflows (Gi) were assumed negligible, and were not included in the water budget calculations. Although there is evidence of ground water movement in portions of the wetland, a highly impermeable clay layer exists underneath much of the system, minimizing the influences of groundwater. Multiple monitoring wells were installed within the wetland in an effort to record data for ground water modeling. However, the existence of a dense clay layer under most of the wetland acts as an aquaclude and causes the system to act essentially as a perched bog, with some infiltration into surficial sediments above the clay layer and very slow movement toward the creek. We have observed a few seeps along the Creek bank in several areas that flow for a few days after large rainfalls that support this assessment. These infiltration losses (I) were calculated by SWMM based on the soil characteristics in the wetland basins and converted from inches to units of acre-feet. The total infiltration loss for the entire system was calculated by summing the values for the individual wetland basins for each month during the 6-year simulation period.

Potential evapotranspiration (PET) was calculated on a monthly basis using the Thornthwaite equation (Mitsch & Gosselink 2000):

Equation 2: Potential Evapotranspiration (PET)

$$PET_i = 1.6\left(\frac{10T_i}{I}\right)^a$$

PET_i = PET for month I (mm/mo)

T_i = mean monthly temperature (°C)

I = local heat index, $\sum\left(\frac{T_i}{5}\right)^{1.514}$

A = (0.675 ∗ I^3 – 77.1 ∗I^2 + 17,920 ∗ I + 492,390 ∗10^{-6}

The Thornthwaite method was chosen due to its simplicity and reasonable accuracy (Mitsch & Gosselink 2000). Only air temperature is required to derive values for PET occurring within the wetland. Air temperature data were retrieved from a continuous weather monitoring station located in Lyndhurst, New Jersey, approximately 10 miles from the Conservancy. These data were provided by the Meadowlands Environmental Research Institute (MERI). Data were retrieved from this station because of its close proximity to the project area and the availability of the data. Actual evapotranspiration (AET) values were derived by applying a correction factor to the calculated PET.

All of the model inputs and collected data were imported into Excel to compute the monthly budgets for Years 2000-2005 to simulate the current conditions of the existing wetland. Monthly precipitation totals and simulated runoff totals were combined to represent the total inflow into the system, while actual evapotranspiration, infiltration loss into the wetland, and simulated outflow totals were combined to represent the total outflow of the system.

Results

The change in storage of the system during each month was calculated by subtracting the total outputs from the total inputs of the system. This represents the amount of water that is stored in or removed from the wetland system every month. To calculate the cumulative storage for the wetland system, the change in storage for each month was added to the previous month's cumulative storage, resulting in the cumulative storage plot shown in Figure 5. Table 1 summarizes the monthly and annual precipitation values for the six year period of analysis. Years 2000 (44.45 in) and 2005 (47.78 in) were average years and the amount of water in the wetland at the end of the year was roughly the same as at the beginning. Year 2001 (37.47 in) was the driest year analyzed, especially in the fall, and the wetland ended the year with a deficit of about 70 acre-ft compared to the beginning of the year. This deficit did not fully recover until the end of 2003 (54.77 in), which was the wettest year in the period of record.

The monthly change in storage values were averaged (all Januaries, all Februaries, etc.) over the six-year period of record to generate average monthly storage changes. These are shown in Figure 6, along with the cumulative plot of the average values. On average, the wetland gains water in the spring and fall and loses water in the summer during the growing season. The detailed data used for the calculations of the water budget are included in Mak (2007).

Discussion

A methodology has been developed for analyzing the water budgets of urban wetlands, with particular application to the restoration of the Teaneck Creek

Conservancy wetlands. While the results presented here are for the entire TCC wetland complex, the SWMM model can be used to analyze water budgets for each of the individual wetland basins shown in Figure 3. The model can be used to analyze each wetland basin separately or in combination, to evaluate the effect of various restoration options, such as grading changes or installing water control structures. Additionally, the model can be used in combination with water quality data to analyze nutrient loadings to various areas within the wetland.

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Table 1. Annual precipitation (inches) as measured at Newark Airport.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	2.79	1.51	2.77	3.31	3.89	5.30	7.30	4.57	3.66	0.54	4.08	4.73	44.45
2001	1.45	1.98	4.72	2.29	3.03	7.43	1.76	4.55	5.44	0.82	1.36	2.64	37.47
2002	1.21	0.91	3.99	5.49	5.12	5.36	1.70	3.93	4.79	8.33	5.73	4.00	50.56
2003	3.34	2.66	4.09	2.76	3.45	6.29	2.96	6.72	6.93	5.90	3.94	5.73	54.77
2004	2.10	3.19	3.12	5.04	4.60	2.58	8.39	3.38	8.76	0.96	4.87	3.72	50.71
2005	4.36	2.80	4.84	3.84	1.64	2.28	4.18	0.40	2.61	12.40	4.28	4.15	47.78

Driest year = 2001
Wettest year = 2003
Average years = 2000,
2005

Figure 1. Sewershed System based on the Township of Teaneck Digital Elevation Model (DEM) – 10 meter.

Figure 2. Surface water routing through Teaneck Creek Conservancy wetlands. S = inflows to the Conservancy wetlands; O = outflows from the Conservancy wetlands.

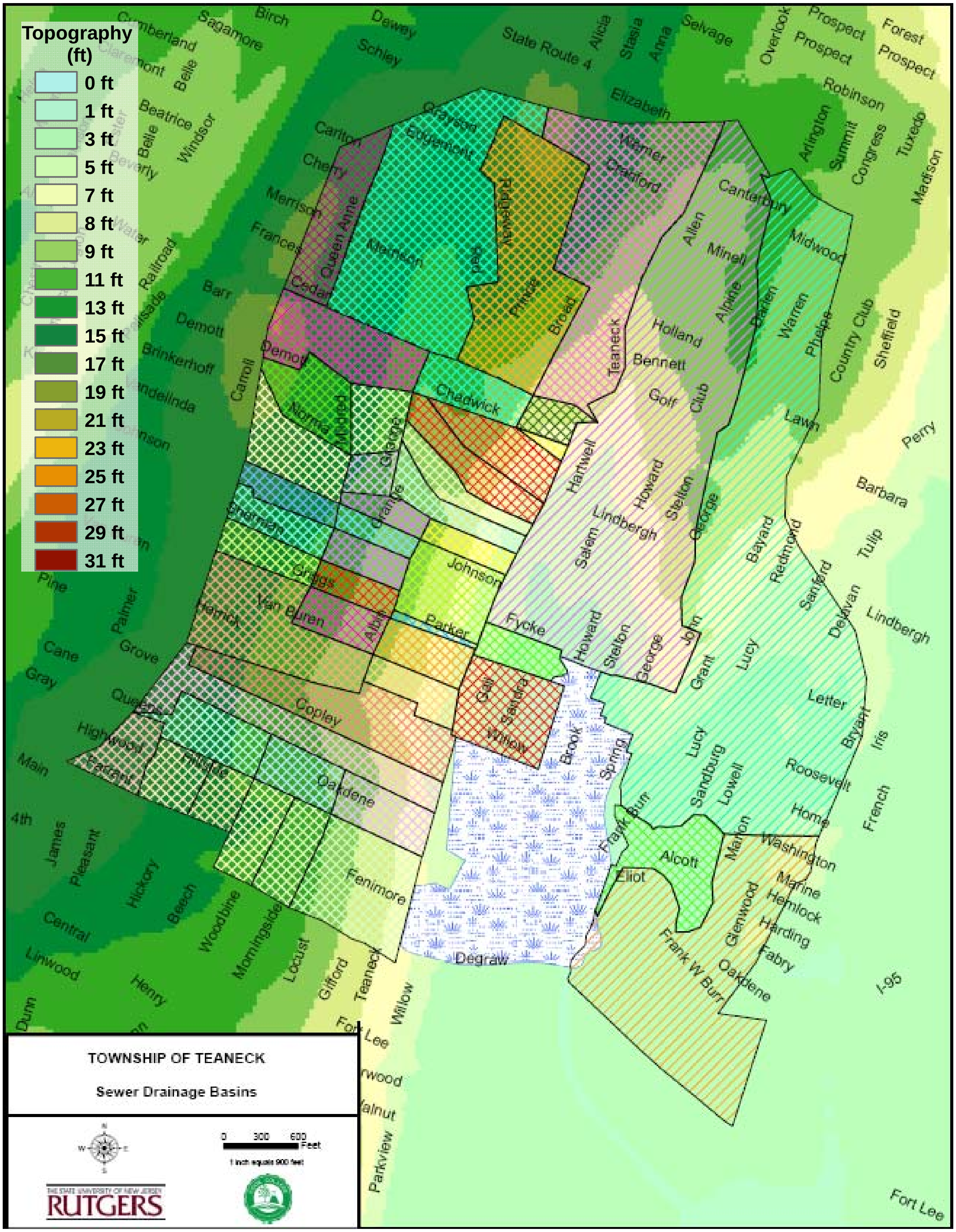
Figure 3. Teaneck Creek Conservancy wetland areas.

Figure 4. Logic flow for model development and water budget calculations.

Figure 5. Cumulative monthly water budget for the period 2000-2005.

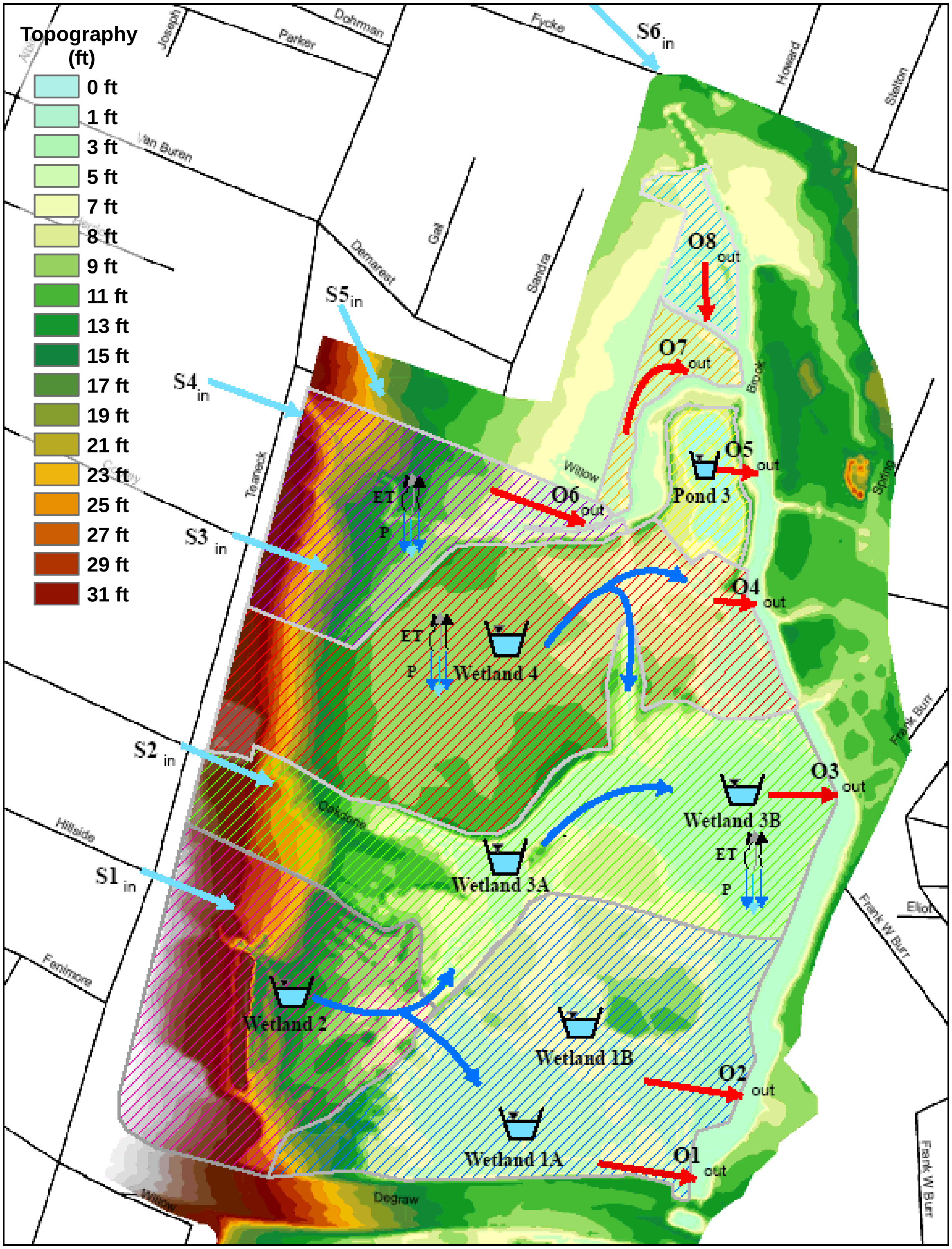
Figure 6. Average monthly Teaneck Creek Conservancy water budget for the period 2000-2005.

Fig. 1.



Topography (ft)
0 ft
1 ft
3 ft
5 ft
7 ft
8 ft
9 ft
11 ft
13 ft
15 ft
17 ft
19 ft
21 ft
23 ft
25 ft
27 ft
29 ft
31 ft
TOWNSHIP OF TEANECK
Sewer Drainage Basins
0 300 600 Feet
1 inch equals 900 feet
RUTGERS

Fig. 2.



Topography (ft)
0 ft
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17 ft
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21 ft
23 ft
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31 ft
S1 in
S2 in
S3 in
S4 in
S5 in
S6 in
O1 out
O2 out
O3 out
O4 out
O5 out
O6 out
O7 out
O8 out
ET
P
Wetland 1A
Wetland 1B
Wetland 2
Wetland 3A
Wetland 3B
Wetland 4
Pond 3
Joseph
Parker
Dohrman
Fycke
Howard
Stelton
Van Buren
Demarest
Gail
Sandra
Teaneck
Willow
Brook
Spring
Frank W Burr
Oakdene
Hillside
Fenimore
Degraw
Eliot

Fig. 3.

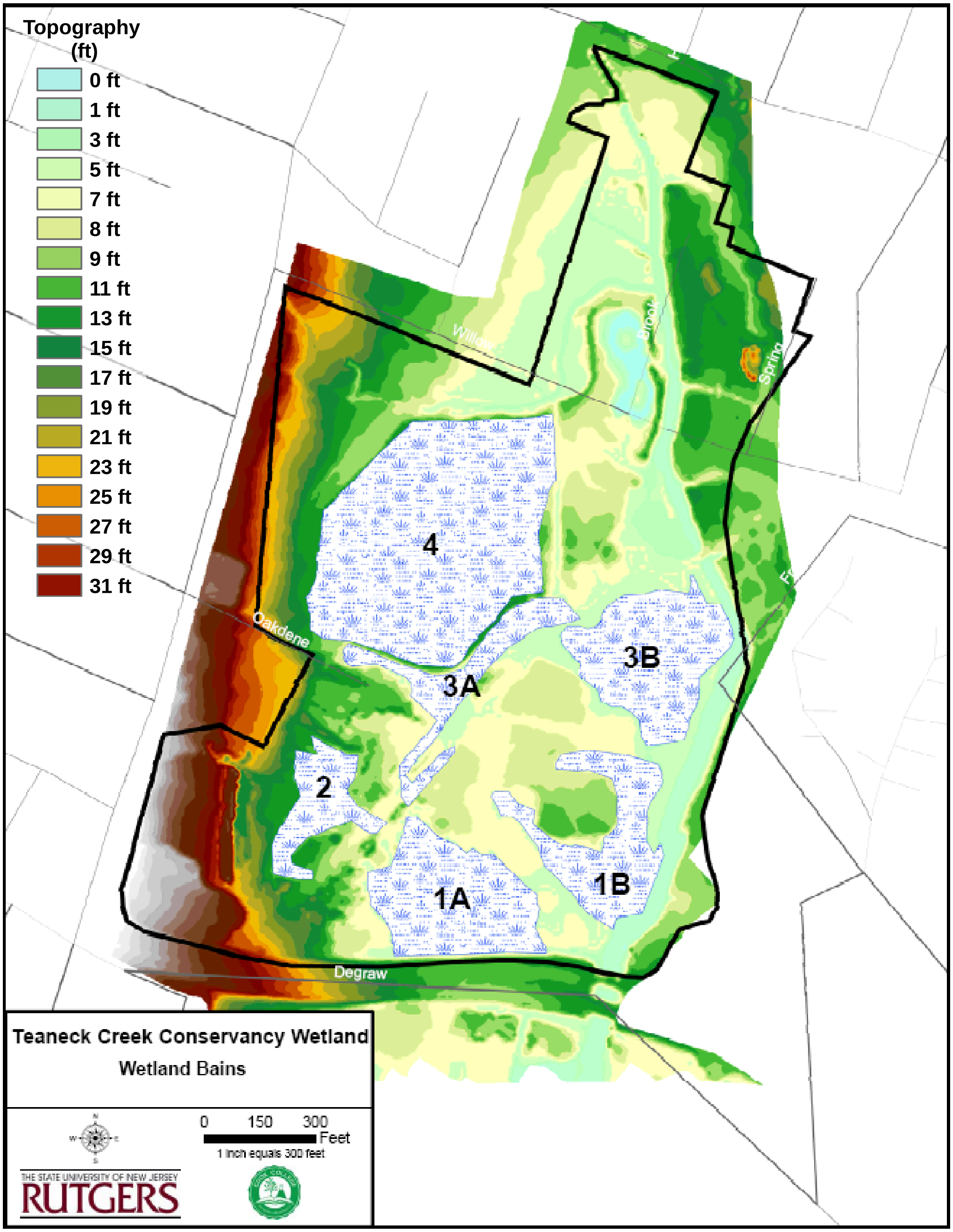
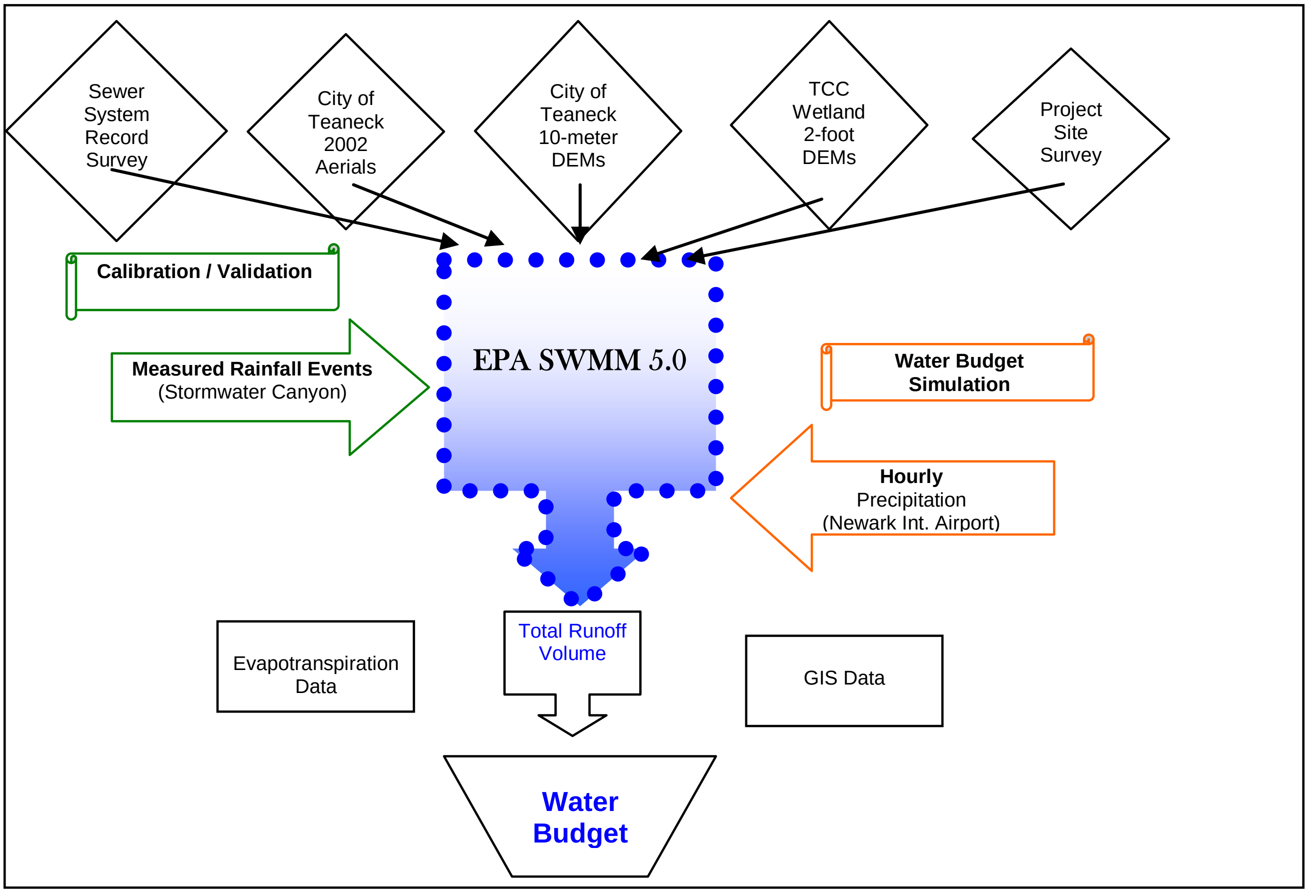
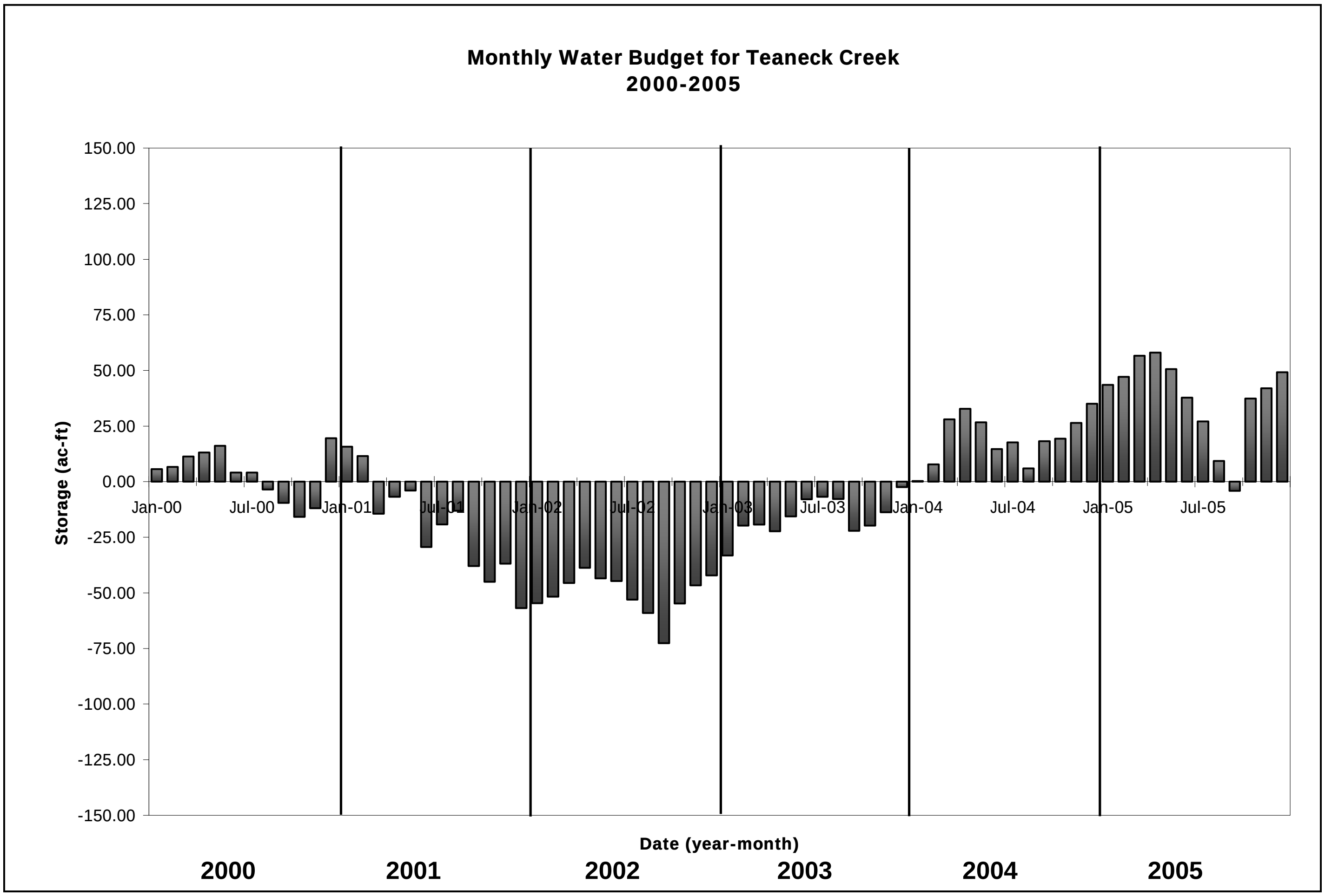

Topography (ft)
0 ft
1 ft
3 ft
5 ft
7 ft
8 ft
9 ft
11 ft
13 ft
15 ft
17 ft
19 ft
21 ft
23 ft
25 ft
27 ft
29 ft
31 ft
Willow
Brook
Spring
Oakdene
4
3A
3B
2
1A
1B
Degraw
Teaneck Creek Conservancy Wetland
Wetland Bains
0 150 300
Feet
1 inch equals 300 feet
THE STATE UNIVERSITY OF NEW JERSEY
RUTGERS

Fig. 4



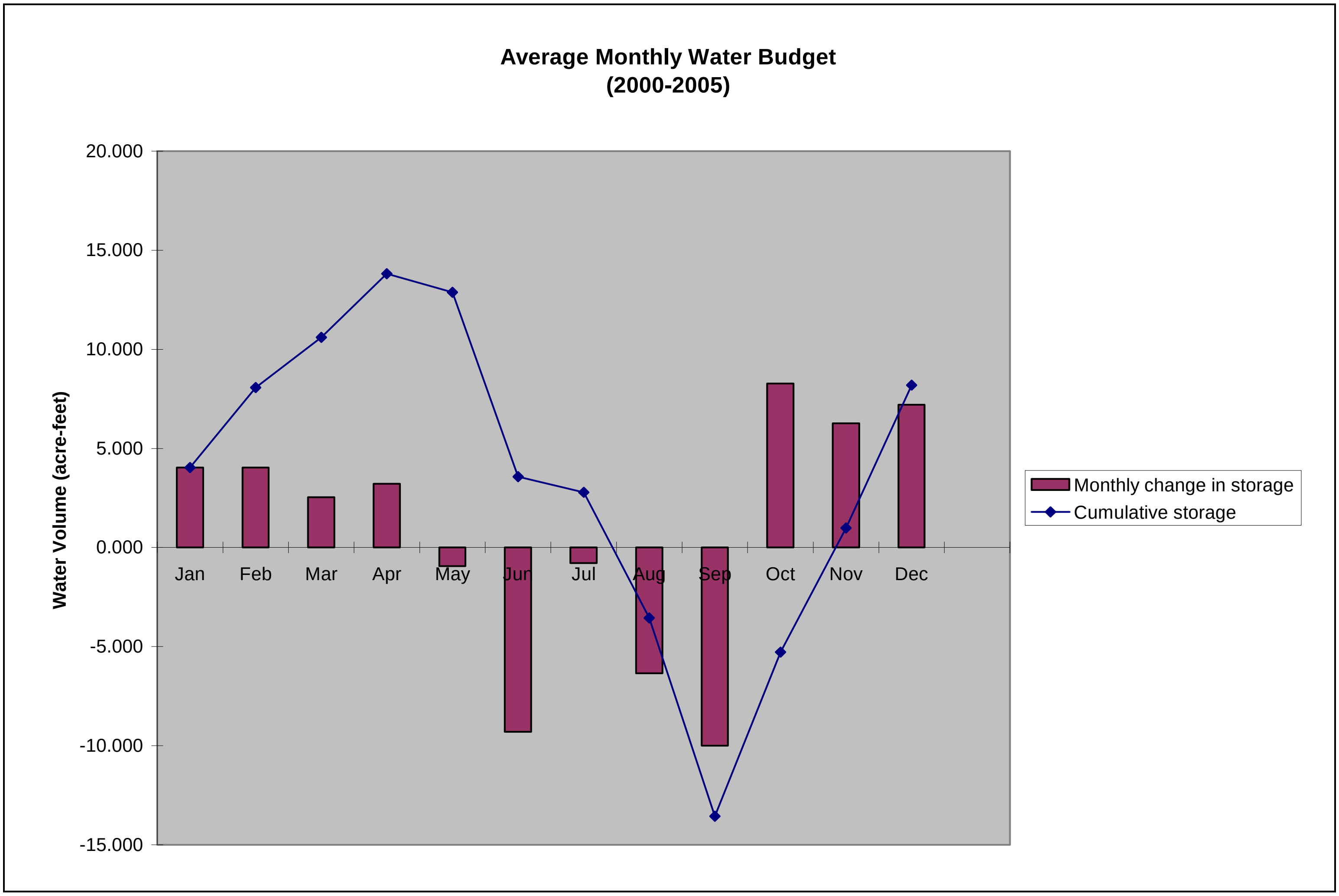
Sewer System Record Survey
City of Teaneck 2002 Aerials
City of Teaneck 10-meter DEMs
TCC Wetland 2-foot DEMs
Project Site Survey
Calibration / Validation
Measured Rainfall Events (Stormwater Canyon)
EPA SWMM 5.0
Water Budget Simulation
Hourly Precipitation (Newark Int. Airport)
Evapotranspiration Data
Total Runoff Volume
GIS Data
Water Budget

Fig. 5



Monthly Water Budget for Teaneck Creek
2000-2005
150.00
125.00
100.00
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
-150.00
Storage (ac-ft)
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
Jul-02
Jan-03
Jul-03
Jan-04
Jul-04
Jan-05
Jul-05
Date (year-month)
2000
2001
2002
2003
2004
2005

Fig. 6.



Average Monthly Water Budget
(2000-2005)
20.000
15.000
10.000
5.000
0.000
-5.000
-10.000
-15.000
Water Volume (acre-feet)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Monthly change in storage
Cumulative storage

Restoration of a Forested Riparian Wetland Ecosystem: A Vegetation Survey of Teaneck Creek Wetlands

By Beth Ravit[1], Linda Rohleder[2], Lea Johnson[2], Joan Ehrenfeld [3], and Peter Kallin[4]

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Abstract

A Conceptual Restoration Plan is being developed for the Teaneck Creek Conservancy wetlands, located in Bergen County, New Jersey's Overpeck Park. Re-establishment of a hydrologic connection between the creek and its interior surface and ground waters, combined with removal of historic fill materials, will result in the rehabilitation of 20 wetland acres on this 46-acre site. A project goal is to establish native plant communities within these rehabilitated wetland areas and to eliminate or control the spread of invasive plants. To determine the location of the existing native vegetation, and to characterize the substrate quality (native hydric soils versus fill materials) and moisture *(*wet versus dry) associated with this plant community, we visually identified and ranked the abundance of the flora on the site. Using the New Jersey Coefficient of Conservatism (NJ CC), we calculated a Floristic Quality Assessment Index (FQAI) for twenty-eight 100m X 100m sampling units. Plant diversity was found to be high (245 species) compared to other NJ urban wetlands, and native species comprised 60% of the total plant species observed. Two-thirds of the total tree and shrub species were native, while only half the vine forb/herb species were native. Introduced species were found to have invaded a minimum of 30% of each sampling unit and a maximum of over 50% in a *Phragmites*-dominated interior area, where plant diversity was the lowest seen on the site. The top ten high FQAI value native species were predominantly wetland plants. A comparison of the FQAI with the soil type and moisture properties indicates that wet soils may be the more important of the two variables in structuring the existing vegetation at this site. The FQAI score identified a high quality wetland area that must be guarded from disturbance during the restoration

activities. The FQAI score, in combination with soil properties and/or moisture content, will be used to inform the decision making process as the Teaneck Creek wetland Conceptual Restoration Plan is developed.

Key Words: Urban, wetland, native, invasive, Floristic Quality Assessment Index, diversity, restoration, hydrology

Introduction

Existing vegetation on the 46-acre Teaneck Creek Conservancy (Fig. 1) wetland site consists of a mixture of native and introduced plant species. Many of the non-native species are aggressively invasive [*Alliaria petiolata* (garlic mustard), *Polygonum cuspidatum* (Japanese knotweed), *Polygonum perfoliatum* (mile-a-minute vine), and *Rosa multiflora* (multiflora rose)], and have formed monospecific expanses in certain areas of the site. Goals for rehabilitation of the site include re-establishing hydrologic connectivity between the creek and its interior surface and ground waters and removal of fill materials, resulting in the re-establishment of 20-acres of wetlands containing vegetation typical of a northern New Jersey (NJ) riparian corridor. Specific goals for the project include protection of existing native plants growing in hydric soils, elimination or containment of the invasive vegetation, and replanting of native wetland flora within the restored wetland areas. Although this is not the usual definition of "restoration," for the sake of simplicity, we will use this term to refer to these project goals.

To characterize existing vegetation on the site, and to aid in developing a sustainable restoration approach, utilizing a Floristic Quality Assessment Index (FQAI) to describe the existing flora (Lopez & Fennessey 2002), we undertook a site vegetation evaluation. The FQAI has been adopted in several other geographic locations for the purposes of wetland assessment (Mushet et al. 2002, Cohen et al. 2004, Bourdaghs et al. 2006, Miller & Waldrop 2006), and is used to characterize the conservation value of multiple locations within a site that potentially may be altered by restoration activities. This methodology assigns a subjective ranking called a "coefficient of conservatism" to each plant species. Species more likely to be found in natural areas are assigned higher numbers, while species commonly found in disturbed areas are given lower numbers (Matthews et al. 2005).

Using the values obtained in the FQAI characterization, the restoration approach will prioritize high FQAI value areas that should remain undisturbed during and following wetland restoration on the site. Low FQAI value areas will be considered as candidates for hydrologic and soil restoration activities followed by subsequent replanting with native species. We also used the FQAI value to test whether a correlation existed between hydrology, soil properties, and the vegetation patterns.

Methods

Field Sampling

In order to obtain a coarse-scale view of the vegetation on the Teaneck Creek Conservancy site at a resolution of 1 hectare, a grid system was established and overlaid on a GIS based map. These 100 m x 100 m sampling units were overlain onto an aerial map of the site (Fig. 2). Sample units were labeled from south to north with alphabetic letters and from west to east with numbers. Each unit was visited at least once during the spring, summer, and fall of the 2006 growing season, beginning in late May and ending in early November. Sampling was performed by making multiple traverses through the sampling unit, identifying, and recording all plant species observed.

As part of this observation, an estimate was made of each plant species' abundance, based on visual cover within the sampling unit, using a subjective five-level scale. The lowest score (1) = "rare" was assigned if the species occurred as a single plant, or only a few individuals, or if the populations were very small and highly localized. A species was scored as (2) = "few" if it occurred in several small populations throughout the unit, or as many isolated individuals that constituted less than 10% of the overall cover. A species was scored as (3) = "occasional" if it contributed approximately 10% to 40% of the total cover, or if it occurred in several substantial populations within the unit. Species that occupied 40-60% of the sampling unit, or that were distributed as individuals throughout the unit in virtually all locations were scored as (4) = "common." Species that constituted > 60% of the total unit cover were scored as (5) = "abundant." The highest abundance level attained by a species throughout all sampling events was retained when data from all site visits was consolidated. All abundance estimates were assigned by L. Rohleder to maintain consistency in the assessment.

After the vegetation in each sampling unit was identified we obtained the New Jersey coefficient of conservation (NJ CC) for each species (Bowman 2006). This coefficient describes the habitat requirements for a particular species, including its sensitivity to disturbance (Matthews et al. 2005). Coefficient values ranged from 0 to 10, and introduced plants are always assigned a 0. The NJ CC for all species within a sample unit was then used to calculate a Floristic Quality Assessment Index (FQAI) for each sampling unit cell.

Soil & Moisture Properties

A wetness rating was assigned to each sampling unit cell by Dr. P. Kallin based on the dominant hydrologic condition(s) observed while doing the site's wetland delineation (Ravit et al. this volume). This characterization was based on the presence of saturated soil, inundation, hydric soil criteria, water table data, and a visual determination as to the proportion of the grid square that met hydric soil criteria [(1) = primarily wet ($\geq$ 60%); (2) = primarily dry ($\leq$ 40%) ; (3) = mixed (40 – 60%)], based on criteria in the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (FMIDJW 1989). Utilizing multiple soil borings in each sampling unit cell, the soil quality was also characterized by Dr. P. Kallin with respect to the type and source of the dominant substrate material(s): (1) = primarily native soil; (2) = primarily dredge fill; (3) = primarily dredge fill with debris; and (4) = mixed. The use of the term "native" describes non-fill substrate that was consistent with the soil survey and exhibited soil horizons and textures indicative of a native glacial soil, and had native vegetation growing in the surrounding area. A visual evaluation of each sampling unit was also conducted.

Statistical Analysis

All analyses of variances (ANOVAs) were conducted using SAS System GLM (SAS Software, Version 9.1). Due to the high level of anthropogenic disturbance on this site, we set the threshold for significant differences between sampling units at the α = 0.10 level. We acknowledge that this choice was somewhat arbitrary, but due to the high degree of heterogeneity on the site, and the fact that there were only 28 sample units, we opted to use a less restrictive alpha test. Due to the coarse scale of the sampling in this study and because the Simpson Diversity Index is weighted toward abundances of the most common species, we used this index to determine plant species diversity (PC-Ord, Version 4). ANOVA was used to test for differences in the diversity scores among the sampling units and two-factorial ANOVAs (Independent Variables = MOISTURE x SOIL, Dependent Variable = FQAI score) were used to test if there was an interaction that affected the FQAI value.

Results

Overall the number of plant species found on the Conservancy site was high compared to other NJ urban wetlands (Ehrenfeld 2005). A total of 245 plant species (please contact author for plant list) were identified within the Teaneck Creek Conservancy, and all species observed have been reported as present in the NY metropolitan region (Clemants & Moore 2003). The number of species within a 100 meter square sample unit ranged from a low of 20 to a high of 83, with a mean per sampling unit of 50 species (Table 1). Of the plants identified, 145 were native species and 98 were species that have been introduced to this area.

Thirty-three species were observed in more than 50% of the sampling unit cells (Table 2). The top 4 most widely distributed species, which are all considered invasive, included *Phragmites australis* (common reed), *Alliaria petiolata* (garlic mustard), *Ampelopsis brevipedunculata* (porcelainberry), and *Rosa multiflora* (multiflora rose), which were found in over 90% of the sampling units. We note that although *Phragmites australis* can be categorized as a native species (Clemants & Moore 2003), there is a genotype which originated outside the U.S. that has invaded and replaced native genotypes throughout eastern coastal marshes (Saltonstall 2002). Although it has not been tested, we are assuming that the plant found on the Conservancy site is this genotype. All the sample units were heavily invaded by non-native species, although the number of widely distributed native species (19) was slightly greater than the number of widely distributed introduced species (13). Across the entire site more than 40% of the species identified were non-native, and five sample units had more than 50% non-native species cover. Trees and shrubs exhibited the highest proportion of native species (approximately two-thirds of the total number identified) versus vines and forbs (approximately half the species were native). The most commonly observed native plants tended to be wetland species, while the highly distributed introduced plants were predominately upland species.

The ratio of native to introduced species per sample unit ranged from 0.7 to 2.4, with a mean of 1.5 (Table 3). This ratio was higher under wet (Fig. 3) versus mixed or dry conditions ($F_{2,25} = 2.46$, $p = 0.1$), suggesting that wetter hydrology may favor native species. The top ten high NJ CC value native plants were *Scirpus expansus* (wood bulrush, OBL), *Viburnum alnifolium* (hobble bush, FAC), *Carya cordiformis* (bitternut hickory, FACU), *Polygonum amphibium* var. emersum (smart weed, OBL), *Allium triccocum* (wild leek, FAC+), *Cardamine bulbosa* (spring cress, OBL), *Tilia Americana* (American linden, FACU), *Veratrum veride* (false hellebore, FACW+), *Quercus bicolor* (swamp white oak, FACW+), *Dioscorea villosa* (wild yam, FAC+). Other than two trees (American linden and bitternut hickory) these species were all obligate or facultative wetland species.

Soil quality was highest in the sampling units at the northern end of the property and in portions of the eastern and western borders (Fig. 4) where the soils were composed of primarily native organic material. The interior of the site was dominated by dredged materials, and the soil adjacent to the southern boundary is unconsolidated fill/debris. However, the soil type was not found to be a significant factor with respect to the number of plant species, the ratio of native to introduced species, or the FQAI score within a sampling unit. A two-factor ANOVA found no interactions between moisture and soil with respect to the tested variables.

The highest quality FQAI sampling units were located at the northeastern portion of the site (Fig. 5), which had the lowest proportion of introduced plant species (30%). The FQAI score ranged from a high of 22.8 in this northeastern corner to a low of 6.3 in the *Phragmites*-dominated interior areas and adjacent to the DeGraw Ave. southern boundary of the property. Diversity (as measured by the Simpson diversity index) was found to be significantly lower ($F_{26,1} = 63.84$, $p = 0.098$) in the *Phragmites*-dominated D3 sampling unit than in the high FQAI G2 and H2 areas (Fig. 6).

Discussion

Although surround by highly urbanized land use, the forested wetlands of the Conservancy contained 245 different plant species. Significant differences were found in the distribution of native versus introduced plant species, and in habitat conservation values across the site. The overall number of native species was 60% of the total species on site, a proportion quite similar to that observed by Clemants & Moore (2003) in their survey of native and nonnative flora in large northern urban areas. We note that in the Conservancy site, the proportion of introduced species is four-fold greater than that reported by Ehrenfeld (2005) in northern NJ forested wetlands. However, because the two studies used different sampling methods, it is possible that the differences in non-native species cover are the result of sampling methodologies.

Differences in habitat value as described by the FQAI appear to be more strongly influenced by hydrology rather than the various soil substrates. The influence of hydrology in determining wetland vegetation is well documented (Toner & Keddy 1997, Magee & Kentula 2005, Dwire et al., 2006 and references therein), and in this study, 9 of the grids with the highest FQAI values were associated with wet or mixed moisture regime versus 3 high FQAI value grids characterized as dry. Conversely, 8 of the highest FQAI value locations were composed of fill or mixed materials, while only 4 high FQAI value locations had native soils. The two highest FQAI values were associated with wet and native soils (locations G2, H2), and these areas must be protected from disturbance during and following the restoration activities. However, it is obvious from our observations that these two variables alone will not guarantee high FQAI scores (locations B5, G1). The results of this study will be used to delineate low FQAI value areas where removal of fill and/or reintroduction of saturated hydrology could produce environmental conditions that would support replanting of native wetland flora (A2, A3, A4, C3, D4, F4). Conversely, areas that have been filled, yet exhibit high FQAI values may be better left as they currently are (B3, B4, C1, C2).

One question left to be decided is how to address relatively large wet areas with low FQAI value (D3, D4, E3) that are currently functioning as a *Phragmites*-dominated detention basin for stormwater storage. Future work will combine the sub-watershed model (see Obropta et al., this volume) with data from the vegetation survey and on-going soil denitrification studies to examine this question.

Acknowledgements

Funding for this work was provided by the New Jersey Wetlands Mitigation Council. We thank the staff of the Teaneck Creek Conservancy for their help and support with field work. We also acknowledge Bill Olson for his help in identifying plant species.

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Table 1. The Effect of moisture and soil properties on the number of species (mean ± standard error), the ratio of native to introduced species, and the FQAI scores in the Teaneck Creek Conservancy site. Intro = Introduced non-native species; FQAI = Floristic Quality Assessment Index.

Moisture	**No. of Species**	**Native:Intro**	**FQAI**
Dry	58 ± 15.5	1.4 ± 0.37	16.0 ± 2.51
Wet	49 ± 21.1	1.7 ± 0.44	15.6 ± 4.43
Mix	46 ± 12.3	1.3 ± 0.39	13.8 ± 3.42
	NS	$F_{2,25} = 2.46$, $p = 0.10$	NS
Soil			
Dredge	45 ± 22.9	1.6 ± 0.43	13.1 ± 5.10
Fill	52 ± 16.0	1.3 ± 0.39	14.7 ± 3.25
Mix	53 ± 22.8	1.6 ± 0.51	15.6 ± 3.03
Native	50 ± 17.1	1.6 ± 0.45	16.9 ± 3.64
	NS	NS	NS

Table 2. The 33 species distributed in 50% or more of the 28 Teaneck Creek Conservancy sampling units surveyed. Wetland plant indicators: OBL = wetland plant (99% of time); FAC = occurs in wetland or upland; FAC W = usually occurs in wetland (67-99% of time); FAC U = occasionally occurs in wetlands (1-33% of time). Number of grids = the number of sampling units where a species was observed.

Scientific Name	Common Name	Wetland Indicator	Growth Habitat	No. of Grids	Percent of Grids
Native					
Acer negundo	Box elder	FAC +	Tree	15	> 50%
Acer rubrum	Red maple	FAC	Tree	22	> 75%
Acer saccharinum	Silver maple	FACW	Tree	21	> 75%
Ageratina altissima	Rough snakeroot	FACU-	Forb/Herb	15	> 50%
Allium vineale	Wild onion	FACU-	Forb/Herb	15	> 50%
Fraxinus pennsylvanica	Green ash	FACW	Tree	14	50%
Geum canadense	White avens	FACU	Forb/Herb	24	> 75%
Impatiens capensis	Jewelweed	FACW	Forb/Herb	25	> 75%
Juglans nigra	Black walnut	FACU	Tree	19	> 50%
Oenothera biennis	Common evening primrose	FACU-	Forb/Herb	14	50%
Parthenocissus quinquefolia	Virginia creeper	FACU	Vine	20	> 50%
Phytolacca americana	Pokeweed	FACU+	Forb/Herb	21	> 75%
Polygonum virginianum	Virginia jumpseed	FAC	Forb/Herb	17	> 50%
Populus deltoides	Eastern cottonwood	FAC	Tree	21	> 75%
Prunus serotina	Black cherry	FACU	Tree	19	> 50%
Salix nigra	Black willow	FACW+	Tree	14	50%
Symplocarpus foetidus	Skunk Cabbage	OBL	Forb/Herb	15	> 50%
Toxicodendron radicans	Poison ivy	FAC	Vine	17	> 50%
Ulmus americana (?)	American elm	FACW-	Tree	21	> 75%
Phragmites australis	Common reed	FACW	Graminoid	26	90%
Introduced					
Acer platanoides	Norway maple		Tree	15	> 50%
Ailanthus altissima	Tree of heaven		Tree	16	> 50%
Alliaria petiolata	Garlic mustard	FACU-	Forb/Herb	26	90%
Ampelopsis brevipedunculata	Porcelainberry		Vine	29	100%
Artemisia vulgaris	Mugwort		Forb/Herb	15	> 50%
Catalpa bignonoides	Southern catalpa	UPL	Tree	15	> 50%
Morus alba	White mulberry	UPL	Tree	16	> 50%
Polygonum cuspidatum	Japanese knotweed	FACU-	Forb/Herb	17	> 50%
Polygonum perfoliatum	Mile-a-minute vine	FAC	Vine	25	> 75%
Robinia pseudoacacia	Black locust	FACU-	Tree	16	> 50%
Rosa multiflora	Multiflora rose	FACU	Shrub	26	90%
Setaria sp.	Foxtail grass		Graminoid	14	50%
Solanum dulcamara	Bittersweet nightshade		Vine	15	> 50%

Table 3. Attributes of the 28 individual sampling unit 100 m by 100 m cells. Diversity scores were computed using the Simpson Diversity Index. Designations for soil properties: 1 = "native;" 2 = "dredge fill;" 3 = "fill + debris;" 4 = "mixed." Designations for soil moisture: 1 = "Dry;" 2 = "Wet;" 3 = "Mixed."

Sampling Grid	Soil	Moisture	No. Species	Native:Intro	FQAI	Diversity
G2	1	2	78	1.79	23.1	0.984
H2	1	2	65	2.42	22.4	0.987
B4	2	3	56	1.95	18.7	0.979
D5	4	2	83	1.68	18.5	0.986
C2	3	1	74	0.90	18.4	0.985
C4	2	1	70	1.69	17.9	0.984
C5	1	2	62	1.82	17.8	0.983
D2	4	2	56	2.11	17.6	0.980
C1	3	1	42	1.21	17.1	0.973
B3	3	2	37	1.64	16.5	0.969
E4	3	2	62	1.48	16.5	0.983
F3	1	2	44	1.10	16.5	0.975
B2	3	3	52	0.73	15.9	0.978
E2	2	2	62	1.95	15.8	0.982
F4	1	3	43	1.39	15.6	0.975
F2	1	3	36	1.25	15.0	0.970
C3	3	3	67	1.23	14.8	0.984
B5	1	2	58	1.23	14.7	0.980
E1	4	2	31	1.82	14.2	0.963
A1	3	1	65	1.83	13.4	0.983
G1	1	2	22	2.14	13.4	0.950
B1	1	1	42	1.47	13.2	0.973
A2	4	2	40	0.90	12.0	0.972
A4	3	3	39	1.60	11.9	0.972
D4	2	3	46	1.09	10.9	0.976
D3	2	2	14	1.80	8.5	0.916
A3	3	3	28	0.87	7.8	0.960
E3	2	2	20	1.00	6.6	0.942

Figure 1. A map of New Jersey showing the location of the Teaneck Creek Conservancy restoration site.

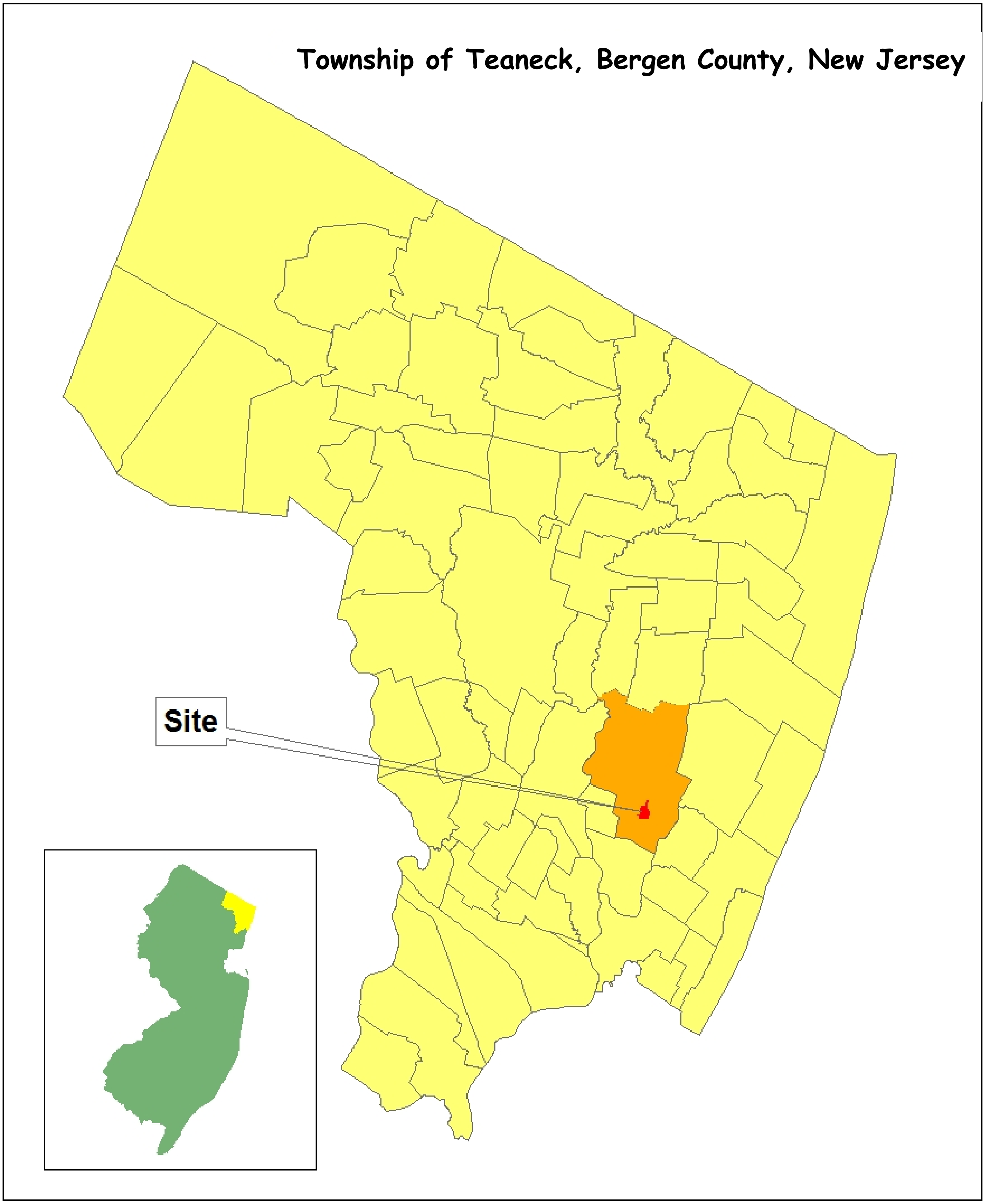


Figure 2. Teaneck Creek Conservancy (site outlined in blue) aerial map overlain with 100 m x 100 m sampling unit cells. Map Courtesy of Bergen County.

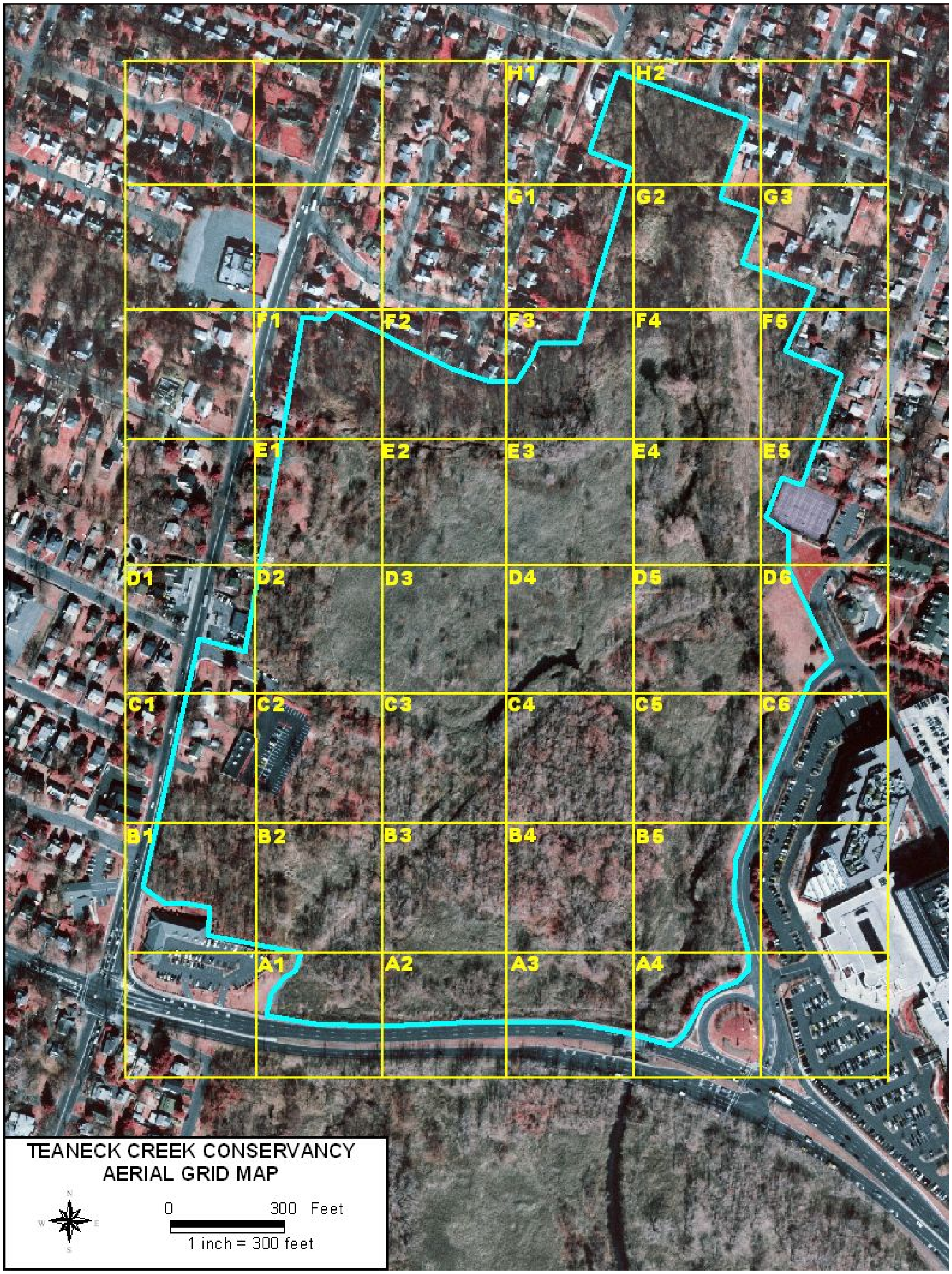


Figure 3. Dominant soil moisture property of each Teaneck Creek 100 m x 100 m sampling unit.

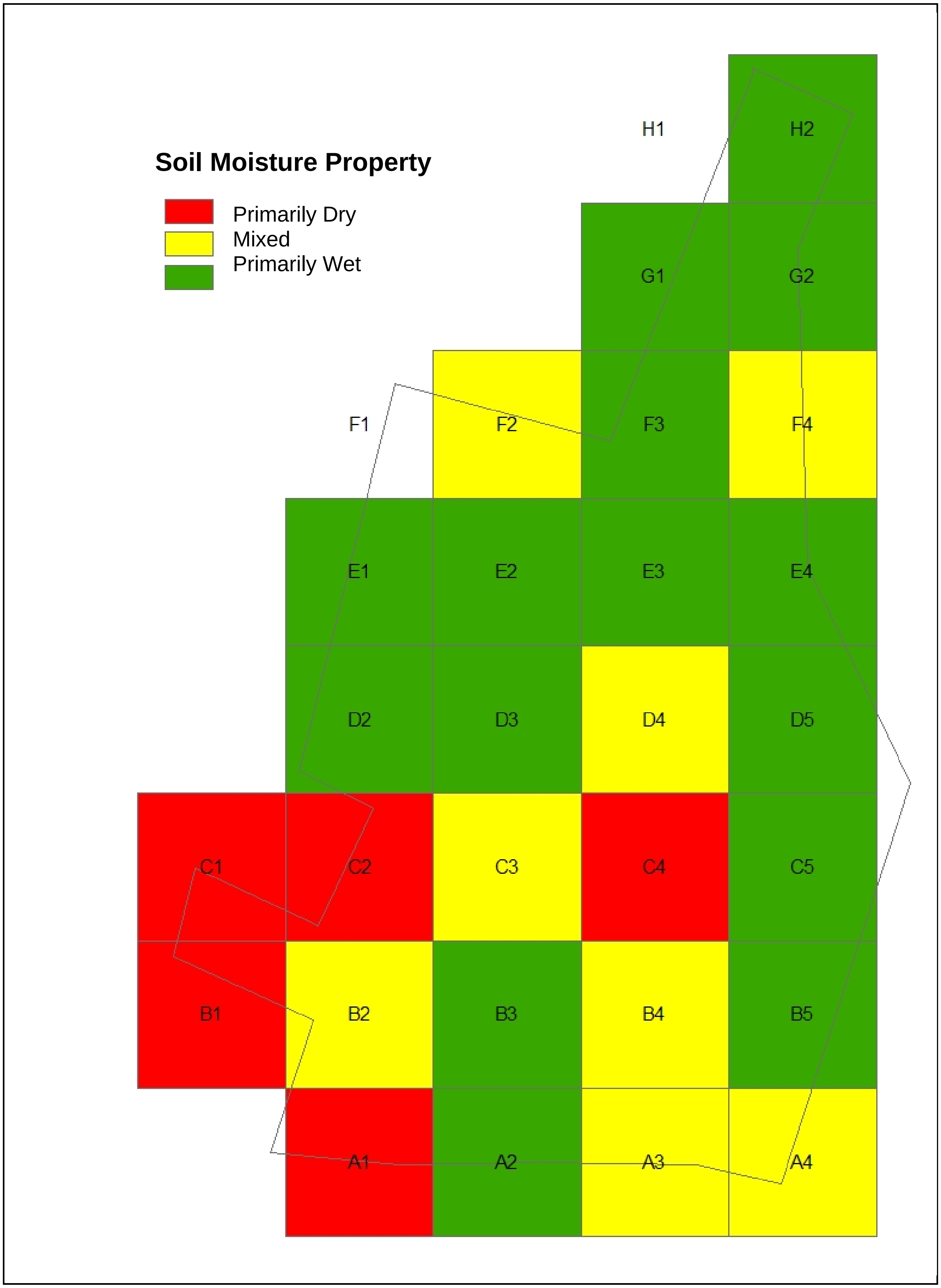


Figure 4. Dominant soil properties of each 100 m x 100 m Teaneck Creek sampling unit.

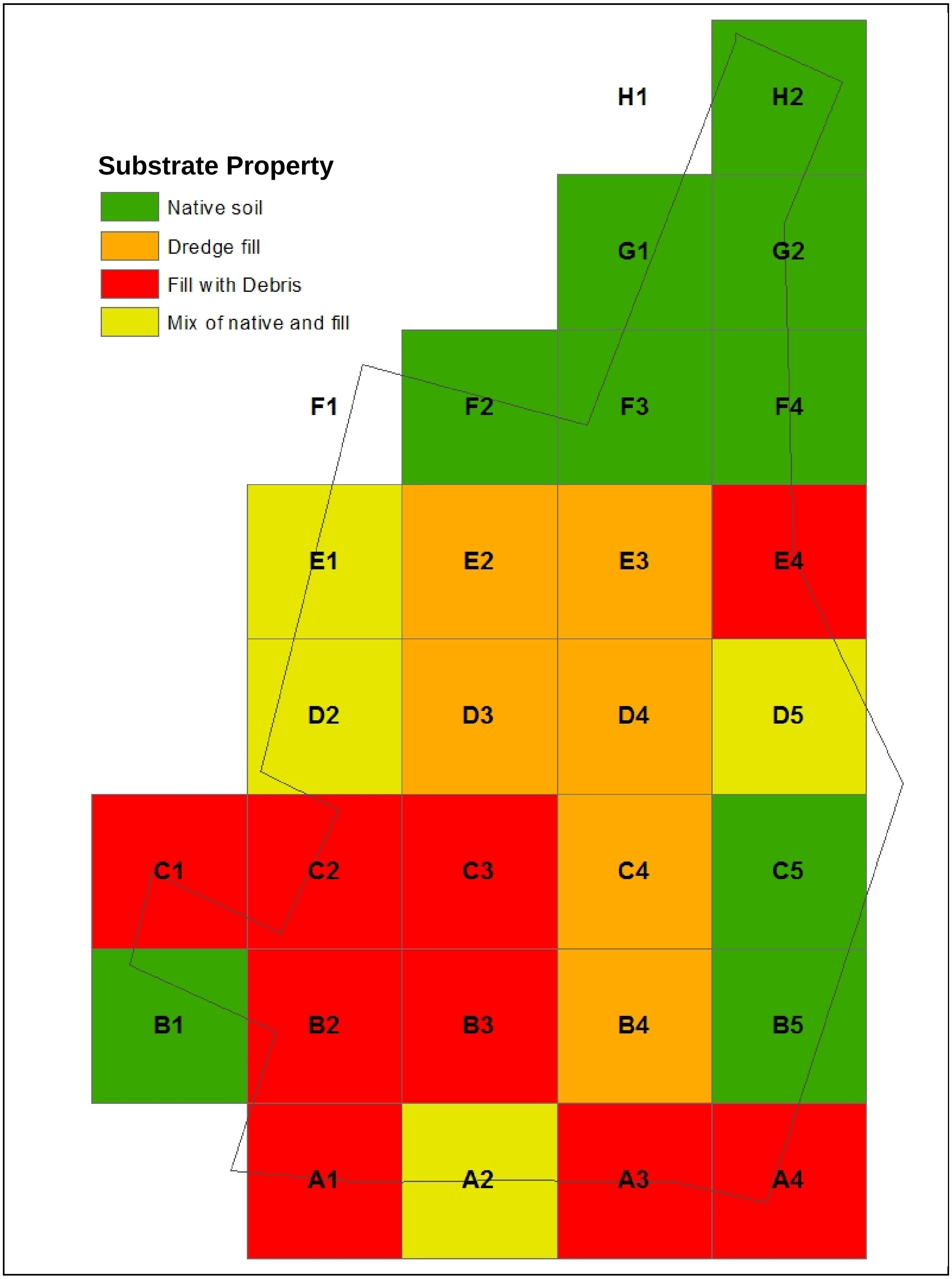


Figure 5. Floristic quality of each 100 m x 100 m Teaneck Creek sampling unit.

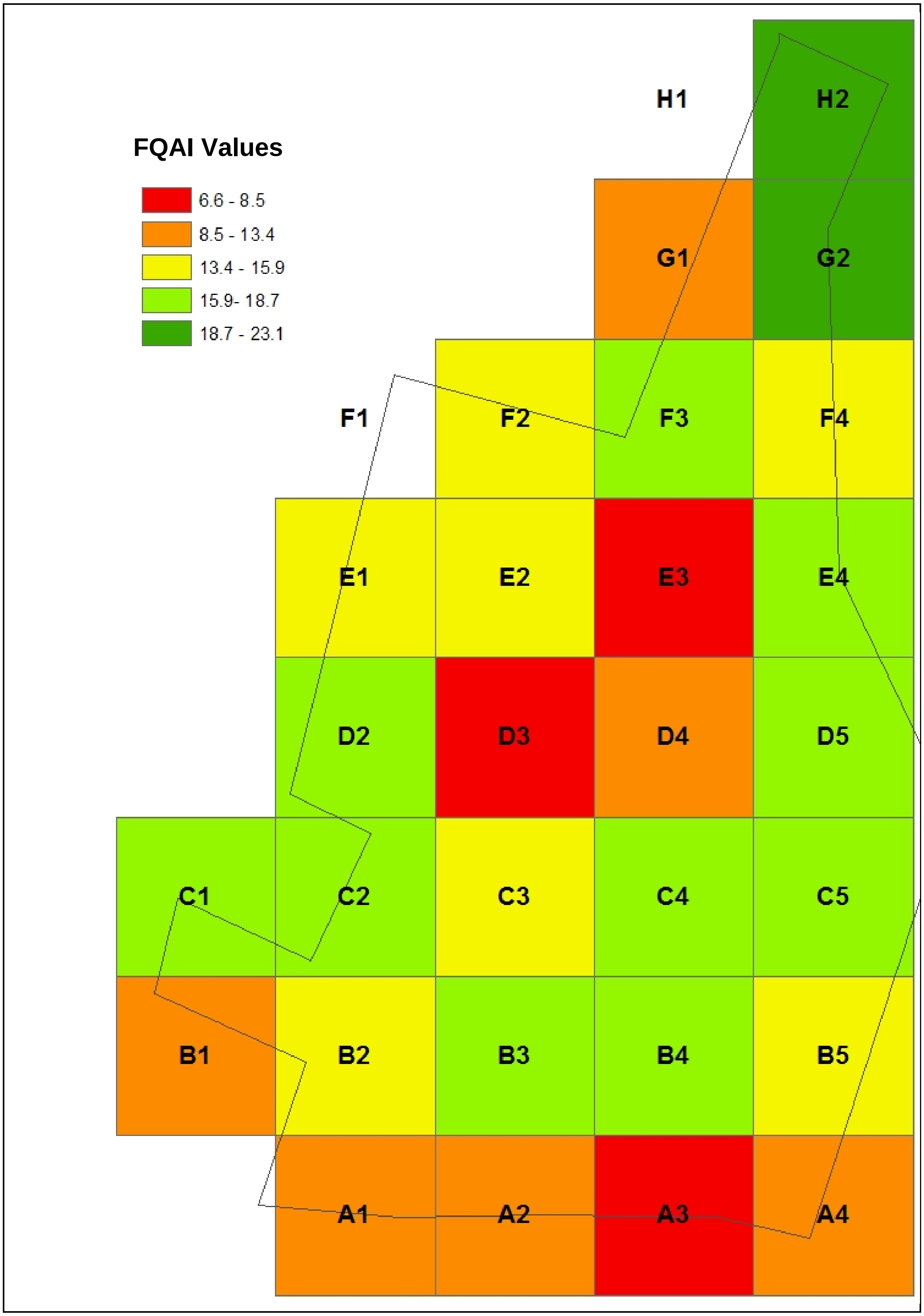
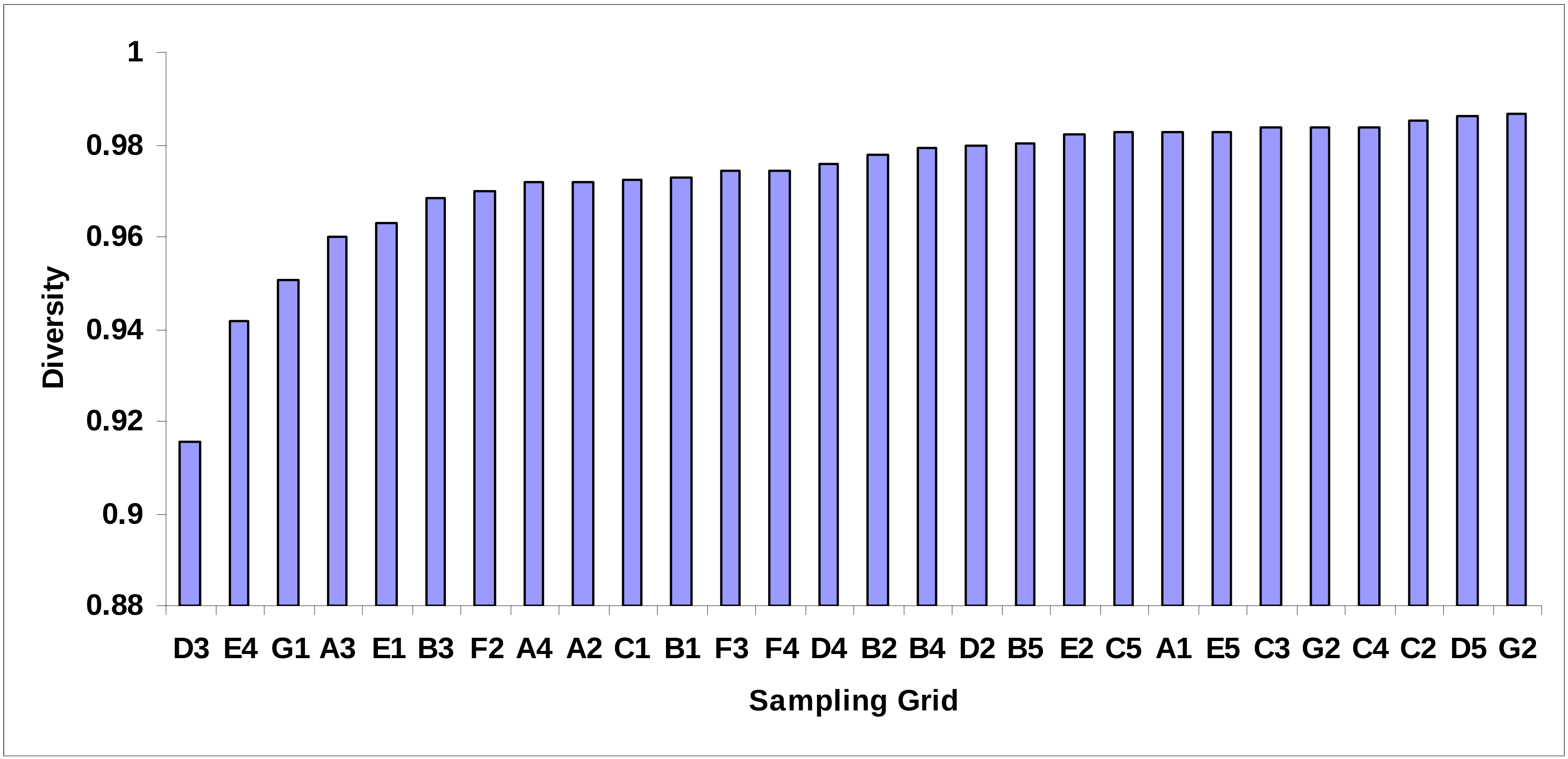


Figure 6. Plant species diversity score for each 100 m x 100 m Teaneck Creek sampling unit as measured by the Simpson Diversity Index.



Implementing Restoration Projects Upstream of Teaneck Creek Conservancy

Jeremiah D. Bergstrom [1], Peter Kallin[2], and Christopher Obropta[3]
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ABSTRACT

The Teaneck Creek Conservancy, in partnership with the Bergen County Department of Parks, is working to restore a passive recreation wetland in the heart of highly urbanized northern New Jersey. This 20-acre wetland restoration/enhancement will occur on an ecologically degraded 46-acre property situated in the Township of Teaneck. The non-profit Teaneck Creek Conservancy has raised the funds necessary to investigate environmental conditions of the site, and based on these site conditions, to develop a long-term habitat restoration plan for managing and improving the extensive wetlands complex on the property. During initial site investigations scientists identified several off-site situations that were negatively affecting the health and diversity of the wetland and riparian habitats in the Teaneck Creek Conservancy. Significant off-site influences include high nitrogen inputs and non-point source pollution generated by a local hospital, and the extensive presence of invasive species, dominated by Japanese knotweed (*Polygonum cuspidatum*), along the upstream banks of the Teaneck Creek. This upstream source of high nitrogen loadings and seeds of invasive species continues to threaten efforts to achieve a successful and sustainable long-term wetlands restoration on the Teaneck Creek Conservancy site.

To address the high nitrogen inputs the restoration team has partnered with Holy Name Hospital, which is situated at the headwaters of the Teaneck Creek. The hospital is currently routing parking area runoff directly into the Teaneck Creek. During winter months the hospital uses urea to de-ice their parking structure, causing high loadings of ammonia to flow directly into Teaneck Creek. The Conservancy restoration team has engineered plans for installing a rain garden to treat runoff from the hospital parking lots prior to this surface water reaching Teaneck Creek. To address the downstream spread of invasive species, the restoration team formed a partnership with the Teaneck Board of Education to address the invasive species that are located directly downstream of the hospital and adjacent to the northern entrance to the Teaneck Creek

Conservancy site. Working with the restoration project partners, the Teaneck Board of Education has developed plans and submitted permit applications to the New Jersey Department of Environmental Protection. The planned upstream restoration project will address existing erosion and stormwater impacts on the school property, implement an invasive species management program in partnership with the U.S. Fish and Wildlife Service to control the Japanese knotweed, and re-establishing a native riparian vegetative buffer along the entire length of Teaneck Creek on the school property. These examples of the formation of critical alliances to deal with upstream factors illustrate the type of approach required to develop successful and sustainable long-term ecological restorations in urban areas.

INTRODUCTION

Upstream Urban Conditions

A key factor that increases the difficulty in achieving successful and sustainable urban wetland restoration is the influence of off-site environmental conditions (see Ravit et al. this volume). Upstream properties outside the control of the restoration project partners can negatively affect the success of a restoration by contributing contaminated runoff or invasive seed sources. During the wetlands research and site investigations at the Teaneck Creek Conservancy (hereafter the Conservancy), we identified several off-site locations that were negatively impacting the health and diversity of the wetland and riparian habitats in the restoration site.

Teaneck Creek Headwaters

The headwaters of the Teaneck Creek are located on property owned by Holy Name Hospital, which is immediately upstream of the Thomas Jefferson Middle School and the Conservancy restoration site. The hospital holds an NJDEP permit allowing the discharge of 100,000 gal day^{-1} of groundwater, which is pumped from the hospital basement into the Teaneck Creek (see Arnold, this issue). This high quality discharge originates in a small garden and tumbles through a series of rocky pools towards Teaneck Road approximately 300 feet south of the hospital. Two additional pipes from the hospital property discharge into Teaneck Creek before it reaches a culvert located under Teaneck Road and leading to the Thomas Jefferson Middle School property. The first pipe drains heated water from an onsite sterilization facility and the second pipe contains stormwater runoff from the hospital parking deck and parking lots. There is a visible change in water quality in the stream where this nonpoint source (NPS) pollution enters the creek. In addition to these two pollution sources, runoff from slightly over an acre of parking lots flows southward, where it runs along a curb to a catch basin in the southwest corner of the parking lot (Fig. 1). At this catch basin the runoff enters a pipe and is immediately discharged into Teaneck Creek prior to the creek entering the Teaneck Road culvert. This water carries whatever pollutants (suspended solids, oil, grease, metals) that are washed from the parking lot's asphalt surface.

During a community outreach event the local hospital (Holy Name) staff contacted the Conservancy to see if there was anything the hospital could do to help with the wetlands restoration project. After discussions with the wetlands restoration scientists, it was determined that the best contribution the hospital could make would be to construct a rain garden on their property to treat runoff from the parking lot. The Rutgers Water Resources Program (www.water.rutgers.edu) engineered an appropriate rain garden design to address the hospital parking area drainage patterns (Figs. 2, 3).

The proposed rain garden design routes runoff from the parking lot through a set of curb cuts into a series of bioretention cells, which are incorporated into the landscaping between the hospital parking lot and Teaneck Road. The cells are designed to hold and infiltrate the NJDEP designated 1.25-inch Water Quality Storm. The cells are connected by grass swales that allow excess runoff from larger storms to be routed to the existing catch basin, bypassing the bioretention cells, which minimizes erosion and damage to the rain garden system. This approach to stormwater management is designed to provide treatment for the runoff from approximately 90% of all precipitation events, significantly reducing suspended solids, oil, and grease runoff into Teaneck Creek. The rain garden is scheduled for construction in the fall of 2007.

Teaneck Creek Upstream Conditions

The headwater flows originating at Holy Name Hospital combine in the storm sewer system (total watershed drainage area of almost 300 acres), and then discharge through a 7.5' x 5.0' elliptical concrete pipe onto the property of the Thomas Jefferson Middle School. The Teaneck Creek flows through the school property for approximately 900 feet before entering a culvert located underneath Fycke Lane that discharges into the northern entrance of the

Conservancy. The upstream section of the stream consists of an open channel with extensive eroding bank areas (Fig. 4). High velocities discharging from the culvert outfall pipe into the stream have undermined the stream banks and caused a portion of the side bank to collapse into the stream bed, causing serious safety and liability concerns. The downstream section of the stream on school property has sloping banks, which are shallow enough to minimize erosion. However, as the stream abruptly turns near Fycke Lane before discharging into the Conservancy its slope changes and the velocity along the bank increases, causing erosion near the twin box culverts exiting the school property (Fig. 5). Due to the extensive presence of the invasive Japanese knotweed (*Polygonum cuspidatum*) plant, the stream bank areas and soils have become highly erodible. During heavy rainfall events, the Japanese knotweed is continually spread downstream from the school site into the forested wetlands and stream corridors of the Conservancy.

Teaneck Creek Invasive Control

One of the most significant off-site influences was the extensive invasive species colonization, dominated by Japanese knotweed, along Teaneck Creek at the Thomas Jefferson Middle School property immediately upstream of the restoration site (Fig. 6). This upstream source of seed and stems continues to threaten the project partners' efforts to manage Japanese knotweed and other invasive species in the riparian and wetlands areas of the site. Once this source of invasive vegetation was identified, team members approached the Teaneck Board of Education and formed a partnership to repair the Teaneck Creek as it flows through school property.

As the site exists today, high stream flows are causing the substantial stream bank erosion in the Teaneck Creek reach adjacent to the school. This erosion creates hazardous conditions on the school property due to the presence of steep, unstable stream banks. To remedy this problem, the Teaneck Board of Education is proposing to complete a stabilization and restoration project, whose goals include moderating high stream flows, stabilizing the stream banks and channel, and reestablishing a native riparian buffer. Working in conjunction with the Conservancy project partners, the Teaneck Board of Education has submitted permit applications to the New Jersey Department of Environmental Protection (hereafter NJDEP). The proposed school property restoration plan will address existing stream bank erosion and stormwater impacts, implement an invasive species management program in partnership with the U.S. Fish and Wildlife Service to control the Japanese knotweed, and commit to re-establishing a native riparian vegetative buffer along the entire length of Teaneck Creek where it flows through the Thomas Jefferson Middle School property. The Conservancy partners are working closely with the Teaneck Board of Education to provide Best Management Practices (BMPs) that will reduce ongoing maintenance, improve school safety and liability issues, while improving and enhancing this valuable ecological resource.

In evaluating stream bank stabilization and restoration options on the school property, the engineering team prepared hydrologic and hydraulic calculations to determine stream flows and velocities during storm events. Using the hydrologic soil group, land use and impervious cover percentages, the analysis calculated a composite curve number of 82 for the nearly 300-acre drainage area (Table 1). As part of the design of the stabilization and restoration plan, we also calculated the flow and frequencies associated with various storms events that would potentially affect Teaneck Creek (Table 2). The first phase of this project will stabilize approximately 200 linear feet of stream channel immediately downstream of the existing 7.5 ft by 5 ft reinforced concrete pipe outlet discharging onto the school property. This 200-foot segment is currently experiencing extreme erosion and sedimentation due to the pipe discharge. The project proposes re-grading and stabilization of the stream banks with cobble, natural ‘rip-rap’ stone, installation of live staking, and extensive planting of native riparian shrubs and trees. In addition, a stabilized outlet and boulder rock-vanes are proposed to reduce velocities and redirect flows away from the side banks and towards the center of the stream. All proposed stream channel modifications have been designed to achieve no net fill within the stream channel and floodplain (Fig. 7).

The second phase of the project is restoration and stabilization of stream banks along an additional 600 linear feet of stream (Fig. 8). Work in this section will include removal of a pedestrian bridge crossing the stream, regrading of stream banks to a 3:1 slope, and construction of a 4-foot-wide safety shelf. The regrading activities will remove the invasive Japanese knotweed and establish native riparian vegetation. Plantings and stabilization efforts will be enhanced with the installation of coconut fiber logs and boulders, and the use of erosion control mat or turf reinforced mat.

URBAN RESTORATION PARTNERSHIPS

When working in urban regions, wetland habitat restoration efforts need to go beyond the borders of the specific project site to evaluate potential affects coming from upstream and other off-site sources. Without investigating off-site areas, unpredictable and unexpected conditions related to stream flows, stormwater drainage, landscape management, and maintenance can significantly influence the success of a restoration effort. A key step in successfully building support for projects in urban settings is to identify key property owners, managers and information sources to establish strategic partnerships beyond the borders of the project site. Through informal and public meetings, local education outreach efforts, and working with citizen volunteers, scientists and engineers can obtain valuable insights and information. By partnering with community leaders and neighboring property owners, scientists and engineers share knowledge and build trust, which can lead to additional projects and ecological improvements beyond the original target restoration site, helping to ensure the success of the restoration effort.

Acknowledgements

Funding support for the Teaneck Creek studies has been provided by the New Jersey Wetlands Mitigation Council. We thank the staff of the Rutgers Cooperative Extension Water Services group for their contributions to this project, and we gratefully acknowledge the support of Holy Name Hospital, the Teaneck Board of Education, and the Thomas Jefferson Middle School, Teaneck, NJ.

Table 1. Teaneck Creek Watershed Landuse Characterization.

Sub Area	Area (sq. feet)	Soil Group	Land Use (Zoning Name)	Max. Imp. Cover (%)	Pervious Cover (%)	Runoff Curve Number (From%)	(CN*Area)
1	41.75	B	RS - Residential Single Family	40%	60%	72	3,014
2	118.59	B	RS - Residential Single Family	40%	60%	72	8,562
3	25.89	B	RS - Residential Single Family	40%	60%	72	1,869
4	0.53	B	B2 – Business District Office	65%	35%	83	44
5	20.98	B	B2 – Business District Office	65%	35%	83	1,740
6	77.00	B	P - Public Land District	70%	30%	85	6,553
7	24.18	B	P - Public Land District	70%	30%	85	2,058
8	1,303,760.87	B	RS - Residential Single Family	40%	60%	72	94,131,535
9	647,571.81	B	RS - Residential Single Family	40%	60%	72	46,754,685
10	0.90	B	RS - Residential Single Family	40%	60%	72	65
11	153,304.24	B	H - Hospital	70%	30%	85	13,046,191
12	1,502,052.57	B	RS - Residential Single Family	40%	60%	72	108,448,196
13	1,777.53	B	B2 – Business District Office	65%	35%	83	147,446
14	7,264.05	B	B2 – Business District Office	65%	35%	83	602,553
15	960.29	B	B2 – Business District Office	65%	35%	83	79,656
16	86,986.89	B	B2 – Business District Office	65%	35%	83	7,215,563
17	0.01	B	B2 – Business District Office	65%	35%	83	1
18	25,364.95	B	B2 – Business District Office	65%	35%	83	2,104,023
19	21,122.57	B	P - Public Land District	70%	30%	85	1,797,531
20	4,567.64	B	P - Public Land District	70%	30%	85	388,706
21	13,919.72	B	B1 – Business District Retail	90%	10%	94	1,304,278
22	4,251.43	B	B2 – Business District Office	65%	35%	83	352,656
23	1,408.19	B	P - Public Land District	70%	30%	85	119,837
24	70,476.04	B	RS - Residential Single Family	40%	60%	72	5,088,370
25	2,050.77	B	B2 – Business District Office	65%	35%	83	170,111
26	892,710.16	C	RS - Residential Single Family	40%	60%	84	74,630,569
27	3,395,934.33	C	RS - Residential Single Family	40%	60%	84	283,900,110
28	630,625.42	C	H - Hospital	70%	30%	91	57,260,788
29	1,311,170.55	C	RS - Residential Single Family	40%	60%	84	109,613,858
30	761,314.97	C	B2 – Business District Office	65%	35%	90	68,213,821
31	327,562.85	C	B2 – Business District Office	65%	35%	90	29,349,631
32	256,631.90	C	B2 – Business District Office	65%	35%	90	22,994,218
33	151,630.16	C	P - Public Land District	70%	30%	91	13,768,019
34	109,661.46	C	B1 - Business Retail	90%	10%	96	10,483,636
35	132,762.54	C	B1 - Business Retail	90%	10%	96	12,692,099
36	89,402.10	C	P - Public Land District	70%	30%	91	8,117,711
37	467,967.51	C	P - Public Land District	70%	30%	91	42,491,450
38	145,945.07	C	RS - Residential Single Family	40%	60%	84	12,201,008
39	26.49	C	RS - Residential Single Family	40%	60%	84	2,215
40	159,632.15	C	H - Hospital	70%	30%	91	14,494,599
41	1.76	C	RS - Residential Single Family	40%	60%	84	147
42	54,099.53	C	B2 – Business District Office	65%	35%	90	4,847,318
Total Area	**12,734,228.34**					**82**	**1,046,836,438**

Note: Data Sources NJDEP Land Use Land Cover 2002, Teaneck Township Zoning, and SSURGO Hydrologic Soils Classification, Bergen County. B soils have a moderate infiltration rate; C soils have a slow infiltration rate).

Table 2. Teaneck Creek Storm Event Associated Flow Rates.

Event Frequency	Flow Rate (cfs)
2-year	95.93
10-year	309.78
25-year	482.96
50-year	601.97
100-year	734.81

Note: Event frequencies required by NJDEP permitting process. Rainfall totals used to calculate stream flows are NRCS rainfall estimates.

Figure 1. Holy Name Hospital Rain Garden Conceptual Design Plan and parking lot drainage area.

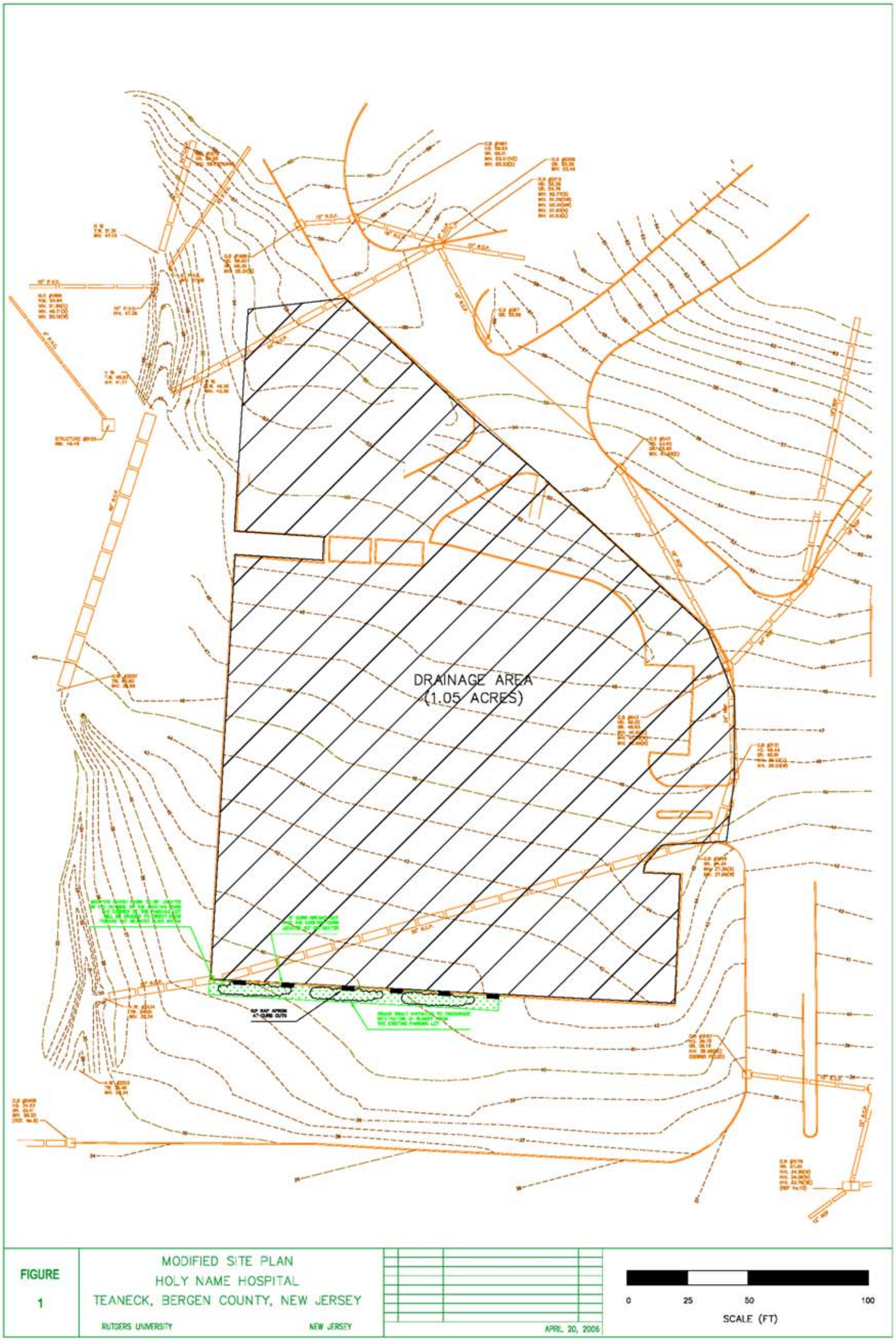


Figure 2. Holy Name Hospital Rain Garden Conceptual Details.

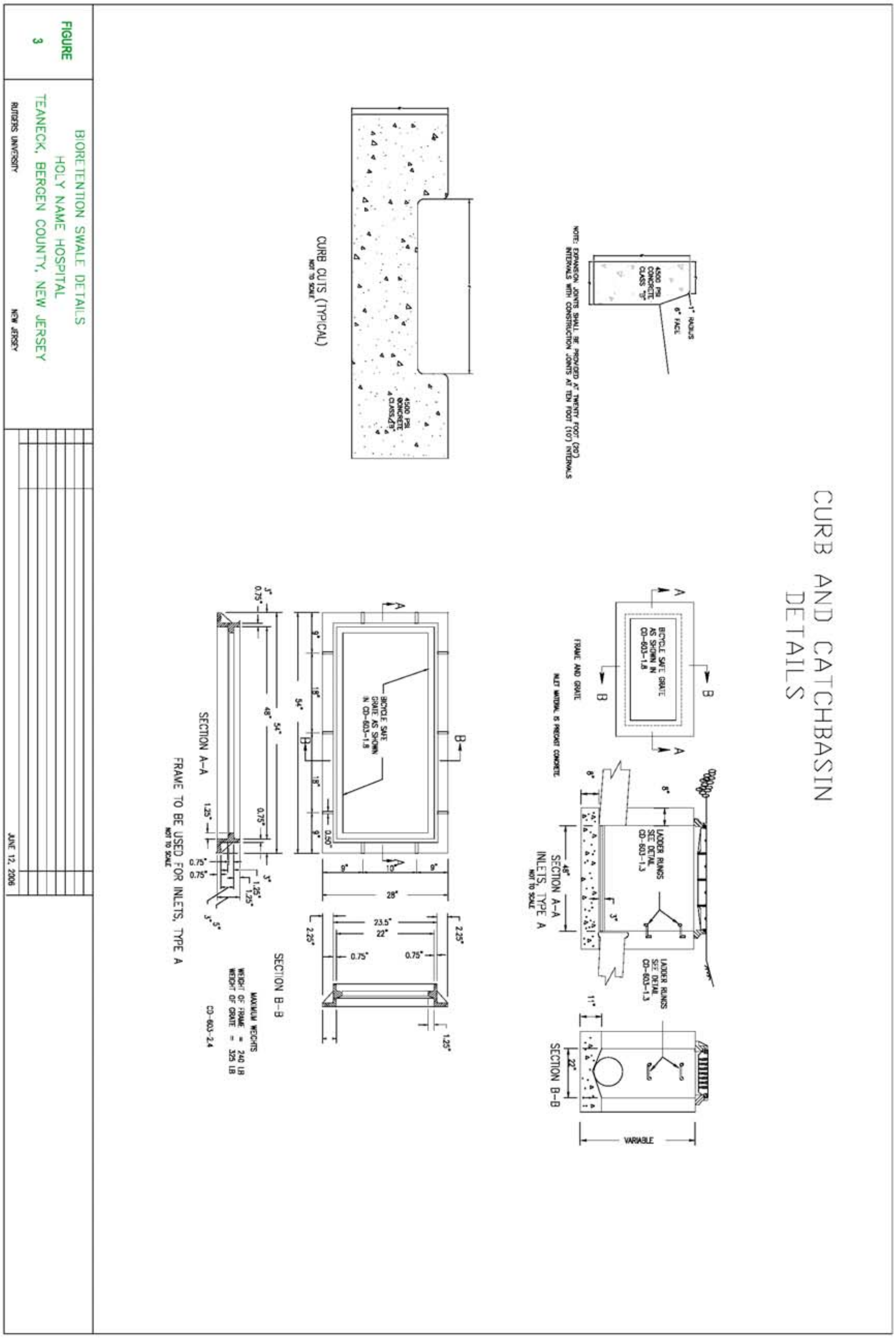


Figure 3. Holy Name Hospital Rain Garden Conceptual Profile.

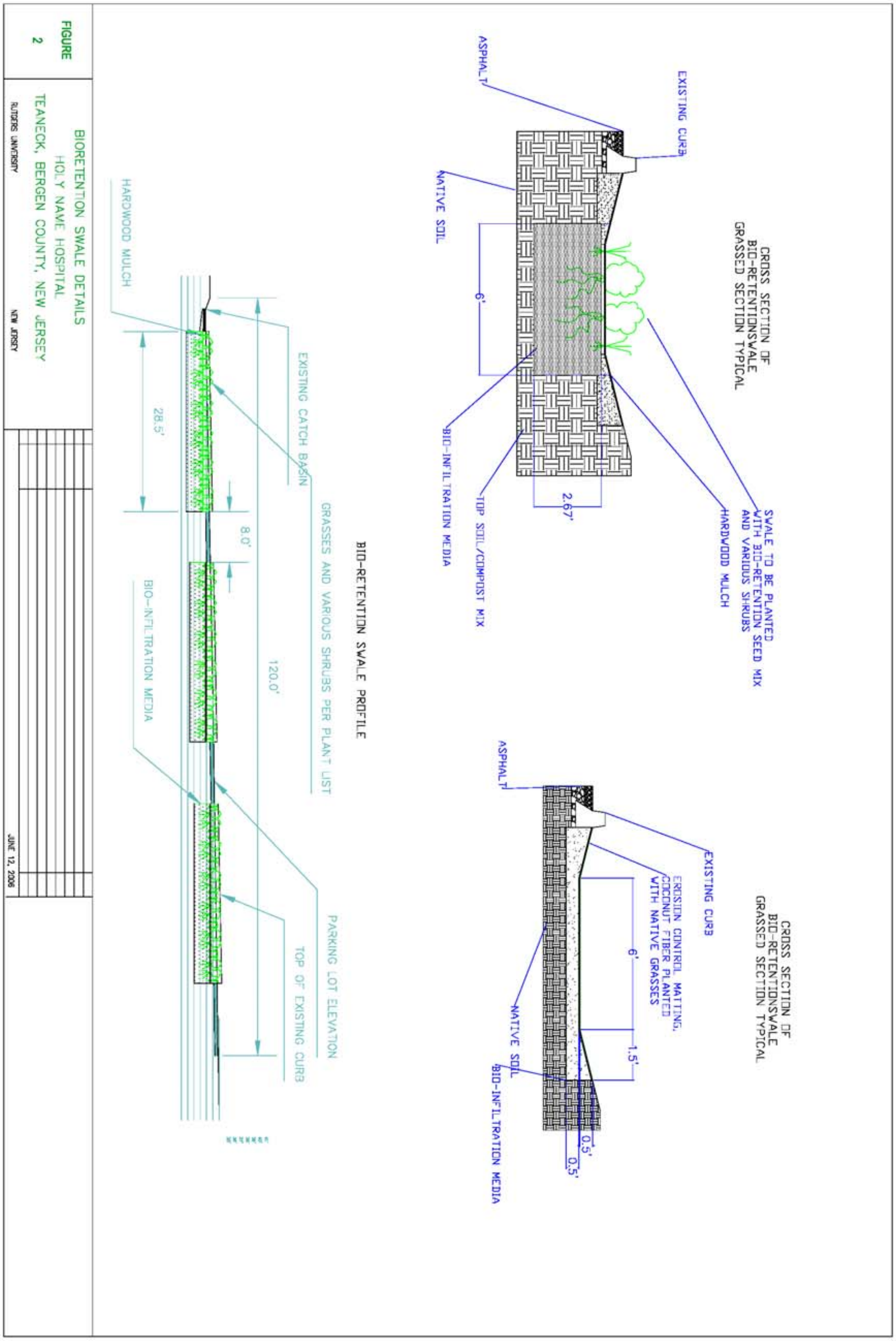


Figure 4. Erosion downstream of discharge pipe at Thomas Jefferson Middle School.

Figure 5. Teaneck Creek near Fycke Lane at Thomas Jefferson Middle School.

Figure 6. Japanese knotweed (*Polygonum cuspidatum*) colonization along Teaneck Creek on Thomas Jefferson Middle School property.

Figure 7. Outlet Stabilization Plan at Thomas Jefferson Middle School.

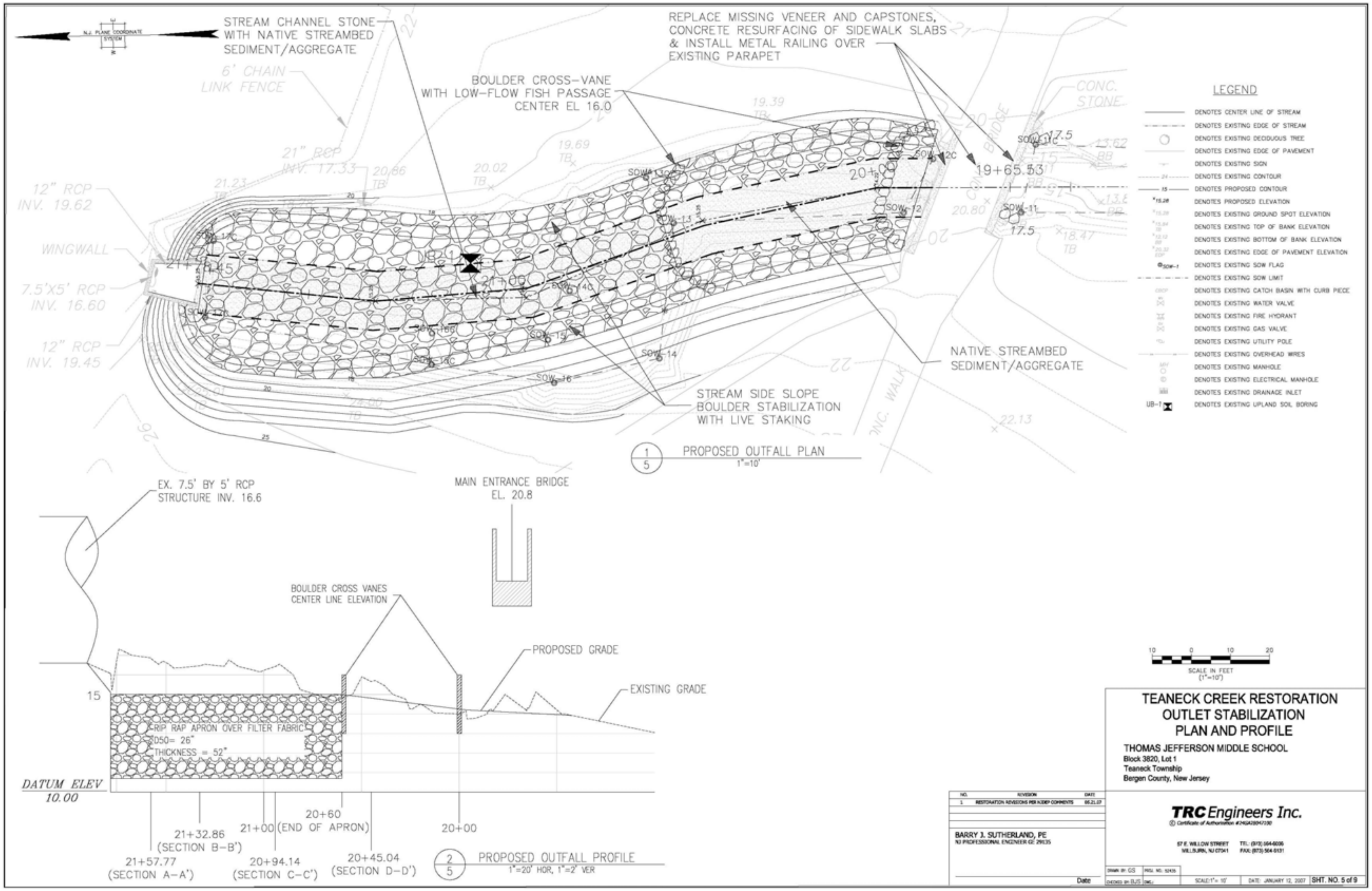
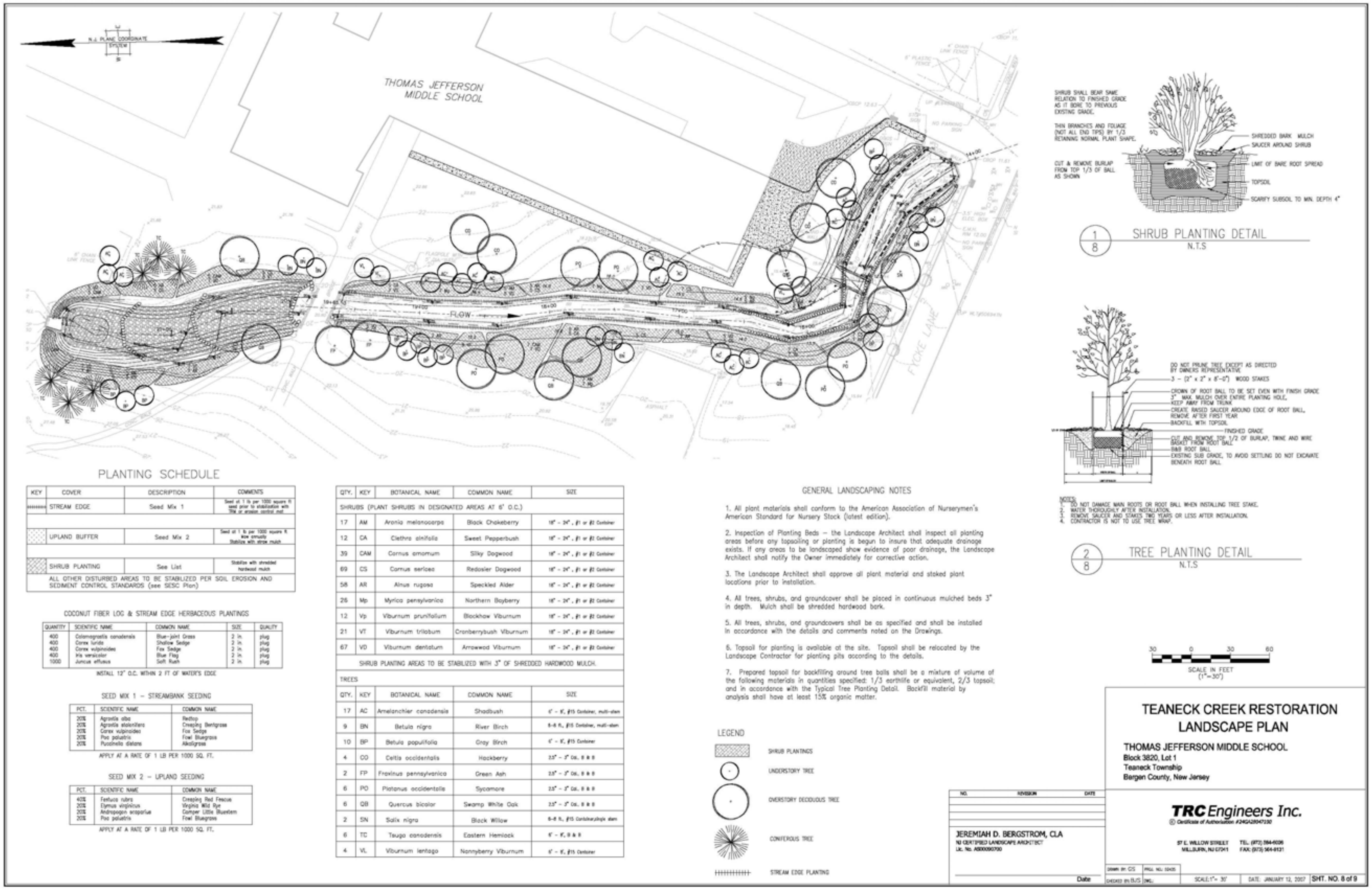


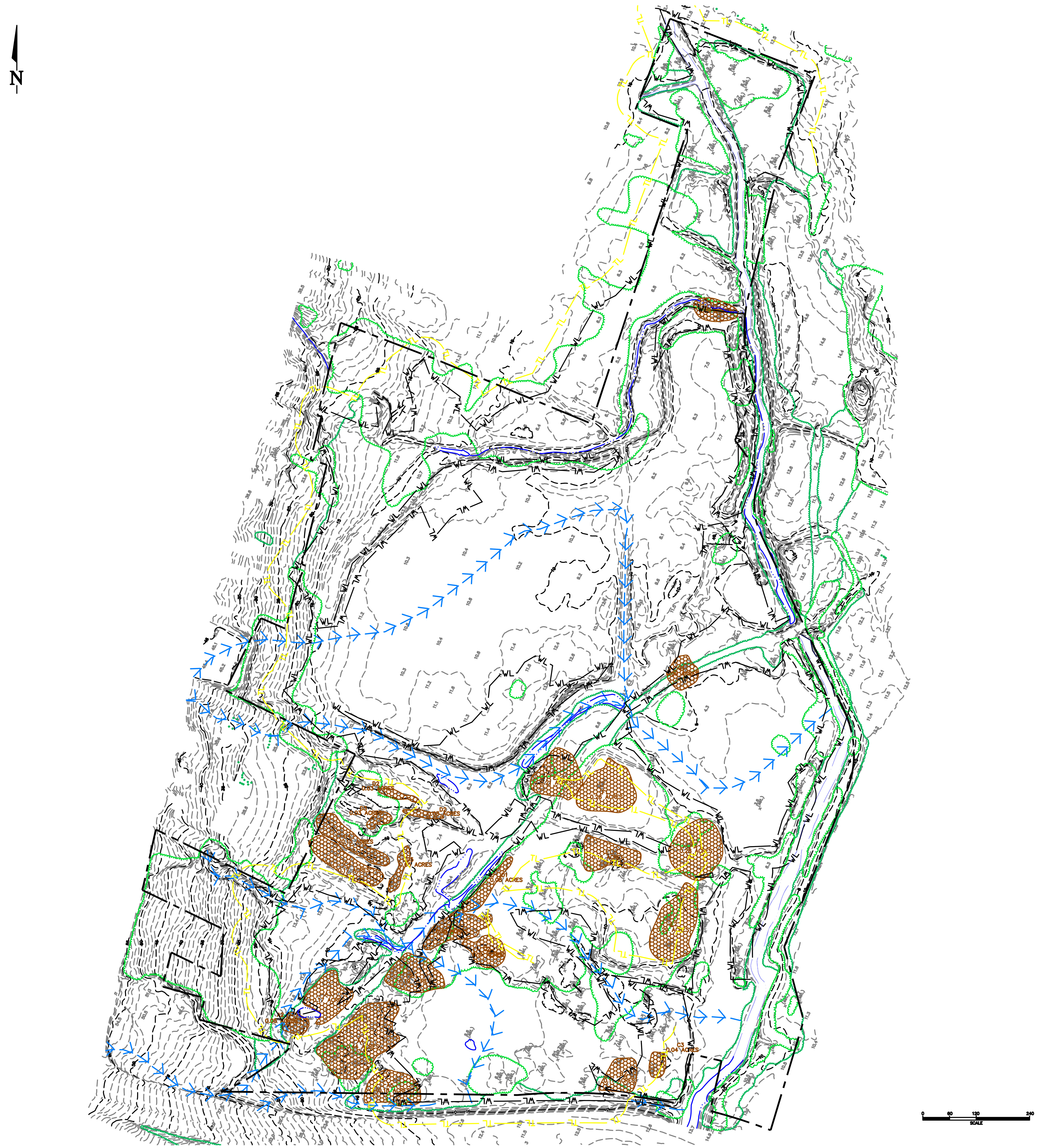
Figure 8. Restoration Plan at Thomas Jefferson Middle School.



Rutgers
New Jersey Agricultural Experiment Station

APPENDIX 2

Conceptual Restoration Plans prepared by Rutgers University

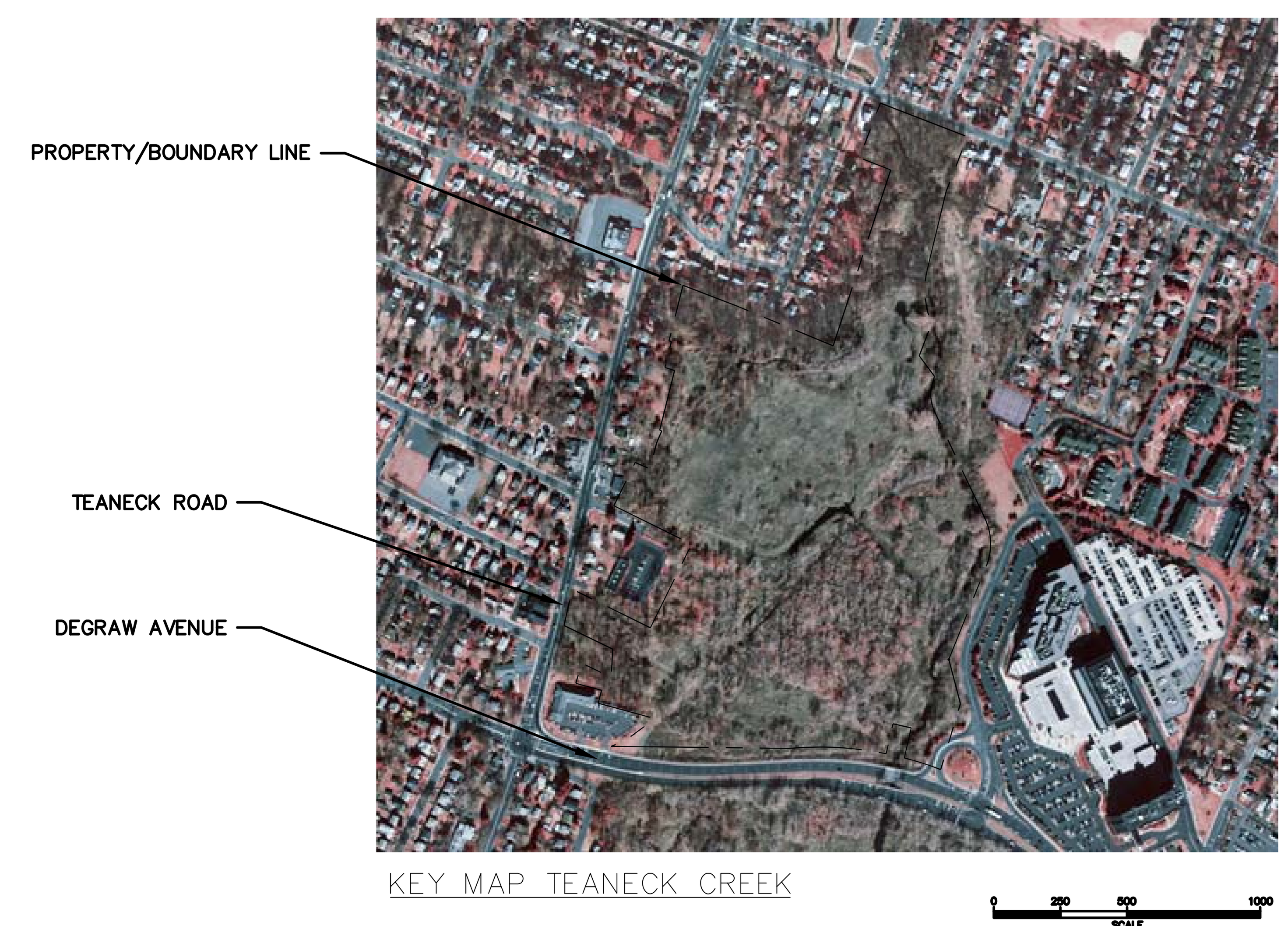


NOTES:

1. THE RESTORATION AND CREATION OF ADDITIONAL WETLAND WILL BE CONCENTRATED ON THE SOUTHERN AREA OF THE SITE. DUE TO ACCESS LIMITATIONS AND LOCATION OF THE DEBRIS, WHICH MUST BE REMOVED, RCE DETERMINED THAT THE SOUTHERN AREA OF THE SITE WOULD PROVIDE THE MOST EFFICIENT METHOD TO REMOVE DEBRIS AND INCREASE WETLAND AND SURFACE STORAGE.

2. THE NORTHERN AREA OF THE SITE WILL INCLUDE INVASIVE SPECIES MANAGEMENT AND REVEGETATION PLANS.

3. RUTGERS UNIVERSITY HAS COMPLETED SEVERAL STUDIES OF THE TEANECK CREEK WETLANDS FOCUSING ON THE HYDROLOGY, SOIL TYPES AND HEALTH AND DIVERSITY OF THE PLANT LIFE. THESE STUDIES HAVE BEEN INSTRUMENTAL IN DETERMINING THE BEST METHODS AND STRATEGIES AND WHERE BEST TO IMPLEMENT WETLAND ENHANCEMENT AND RESTORATION AT THE SITE.



KEY MAP TEANECK CREEK

LEGEND

- EXISTING MINOR CONTOURS
- EXISTING MAJOR CONTOURS
- PROPERTY LINE
- STREAM
- RUNOFF FLOW PATH
- DEBRIS PILES
- WETLAND 2006 DELINEATION (WL)
- WETLAND 2006 BUFFER (TL)

CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532

DESIGNED	CHECKED	APPROVED	DATE
SPW	PLK		AUG 2007

TEANECK CREEK CONSERVANCY
WETLANDS RESTORATION PLAN

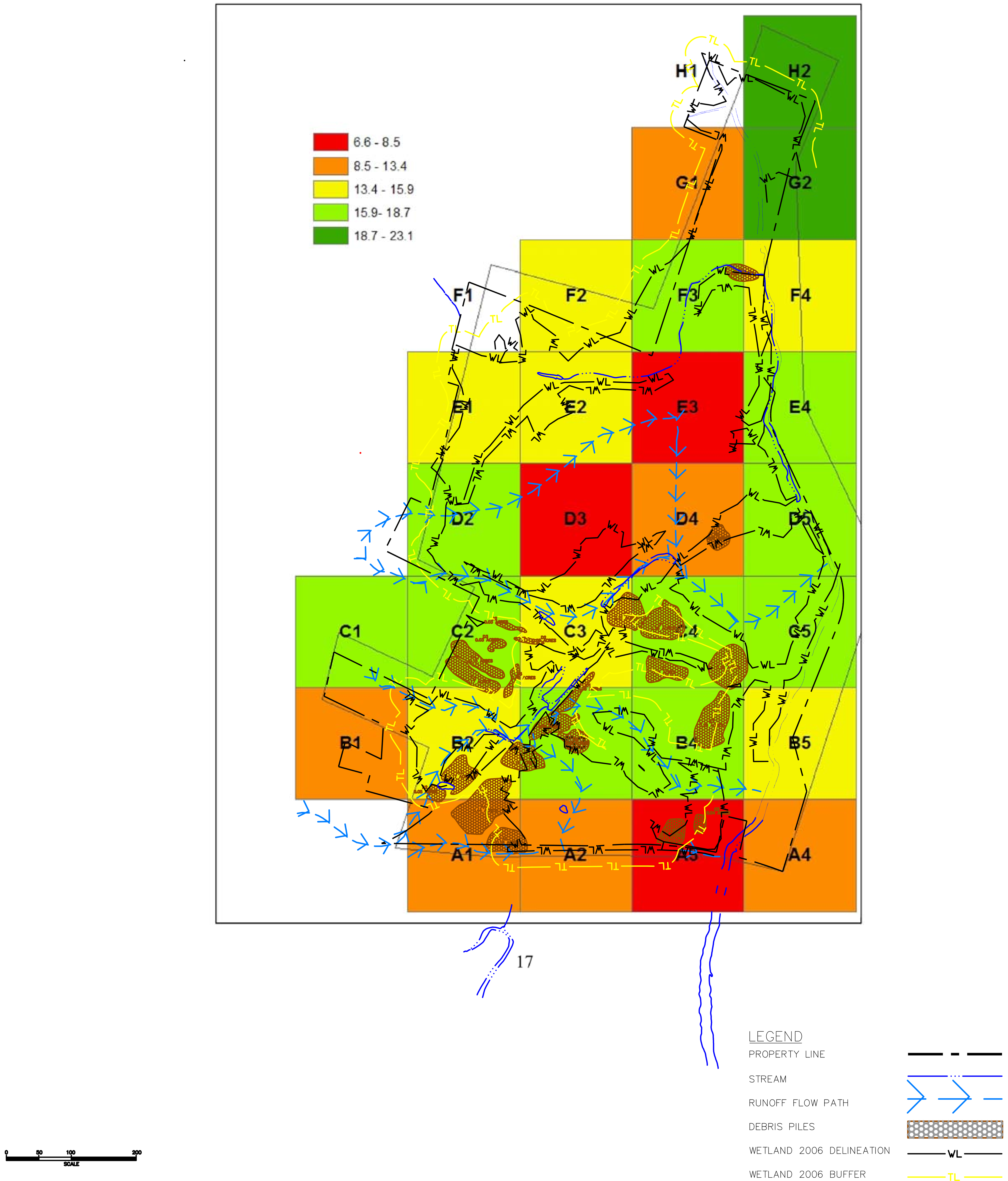
BERGEN COUNTY DEPARTMENT OF PARKS
TOWNSHIP OF TEANECK, BERGEN COUNTY

RUTGERS COOPERATIVE EXTENSION
WATER RESOURCES PROGRAM
14 COLLEGE FARM ROAD
NEW BRUNSWICK, NJ 08901
WWW.WATER.RUTGERS.EDU

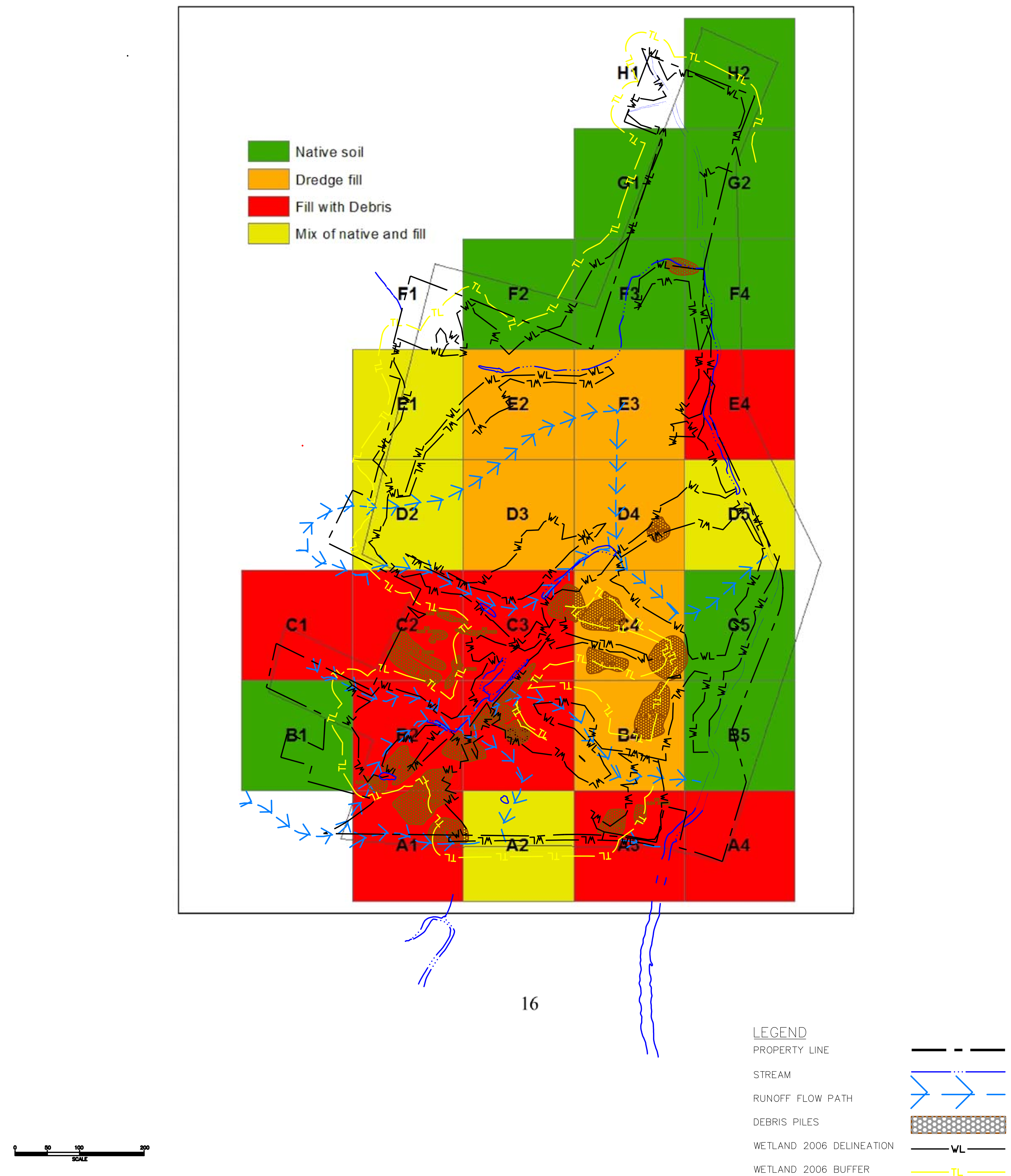
RUTGERS
New Jersey Agricultural Experiment Station

JOB | SHEET # | B/O | TOTAL

FLORISTIC QUALITY OF EACH 100 M X 100 M TEANECK CREEK SAMPLING UNIT



SOIL QUALITY OF EACH 100 M X 100 M TEANECK CREEK SAMPLING UNIT



CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532

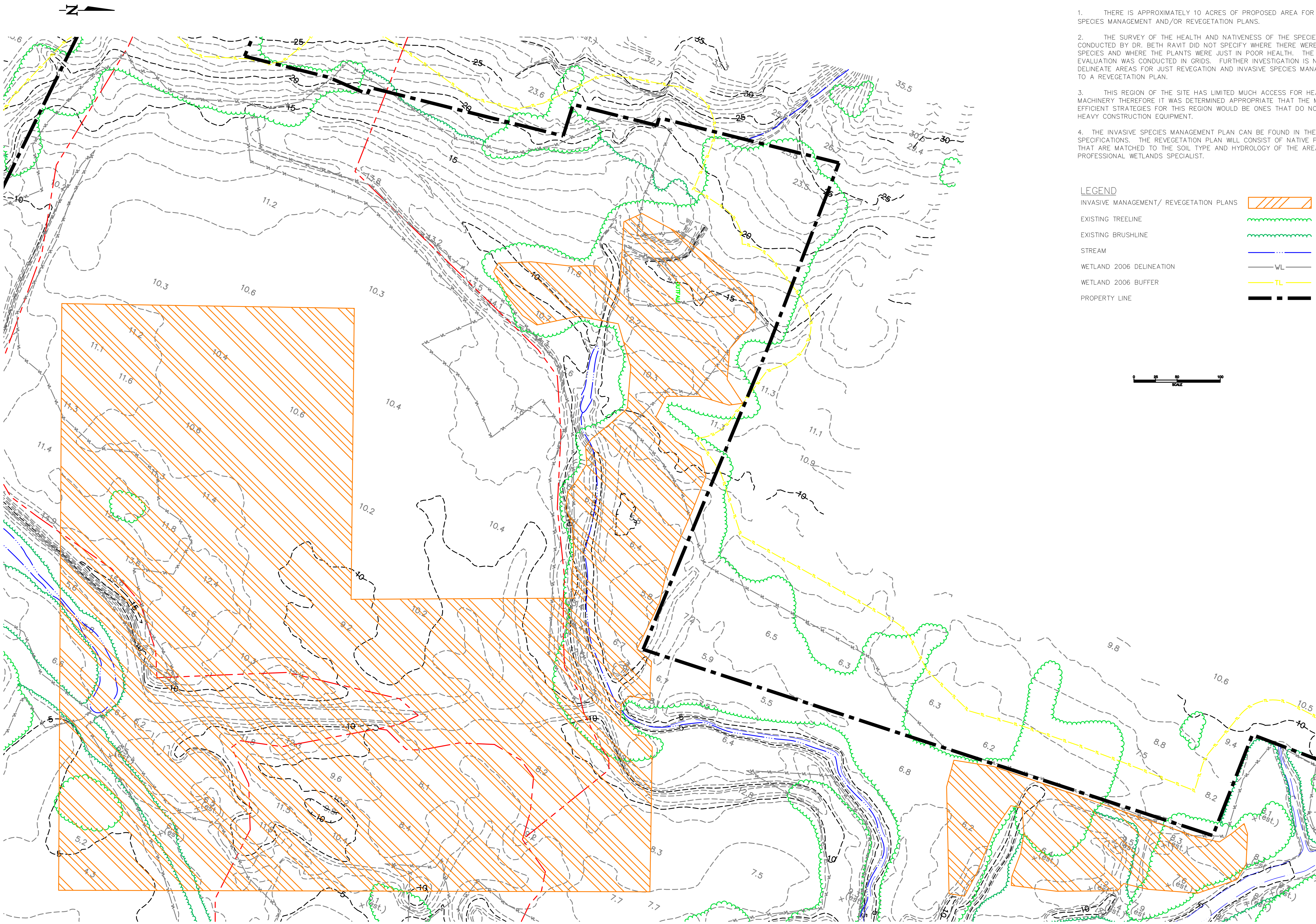
TEANECK CREEK CONSERVANCY
WETLANDS RESTORATION PLAN

BERGEN COUNTY DEPARTMENT OF PARKS
TOWNSHIP OF TEANECK, BERGEN COUNTY

RUTGERS COOPERATIVE EXTENSION
WATER RESOURCES PROGRAM
14 COLLEGE FARM ROAD
NEW BRUNSWICK, NJ 08901
WWW.WATER.RUTGERS.EDU

RUTGERS
New Jersey Agricultural Experiment Station

DESIGNED SPW | CHECKED PLK | APPROVED | DATE AUG 2007



NOTES:

1. THERE IS APPROXIMATELY 10 ACRES OF PROPOSED AREA FOR INVASIVE SPECIES MANAGEMENT AND/OR REVEGETATION PLANS.

2. THE SURVEY OF THE HEALTH AND NATIVENESS OF THE SPECIES CONDUCTED BY DR. BETH RAVIT DID NOT SPECIFY WHERE THERE WERE INVASIVE SPECIES AND WHERE THE PLANTS WERE JUST IN POOR HEALTH. THE EVALUATION WAS CONDUCTED IN GRIDS. FURTHER INVESTIGATION IS NEEDED TO DELINEATE AREAS FOR JUST REVEGATION AND INVASIVE SPECIES MANAGEMENT TO A REVEGETATION PLAN.

3. THIS REGION OF THE SITE HAS LIMITED MUCH ACCESS FOR HEAVY MACHINERY THEREFORE IT WAS DETERMINED APPROPRIATE THAT THE MOST EFFICIENT STRATEGIES FOR THIS REGION WOULD BE ONES THAT DO NOT REQUIRE HEAVY CONSTRUCTION EQUIPMENT.

4. THE INVASIVE SPECIES MANAGEMENT PLAN CAN BE FOUND IN THE SPECIFICATIONS. THE REVEGETATION PLAN WILL CONSIST OF NATIVE PLANTS THAT ARE MATCHED TO THE SOIL TYPE AND HYDROLOGY OF THE AREA BY A PROFESSIONAL WETLANDS SPECIALIST.

LEGEND

- INVASIVE MANAGEMENT/ REVEGETATION PLANS
- EXISTING TREELINE
- EXISTING BRUSHLINE
- STREAM
- WETLAND 2006 DELINEATION (WL)
- WETLAND 2006 BUFFER (TL)
- PROPERTY LINE

CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532

DATE

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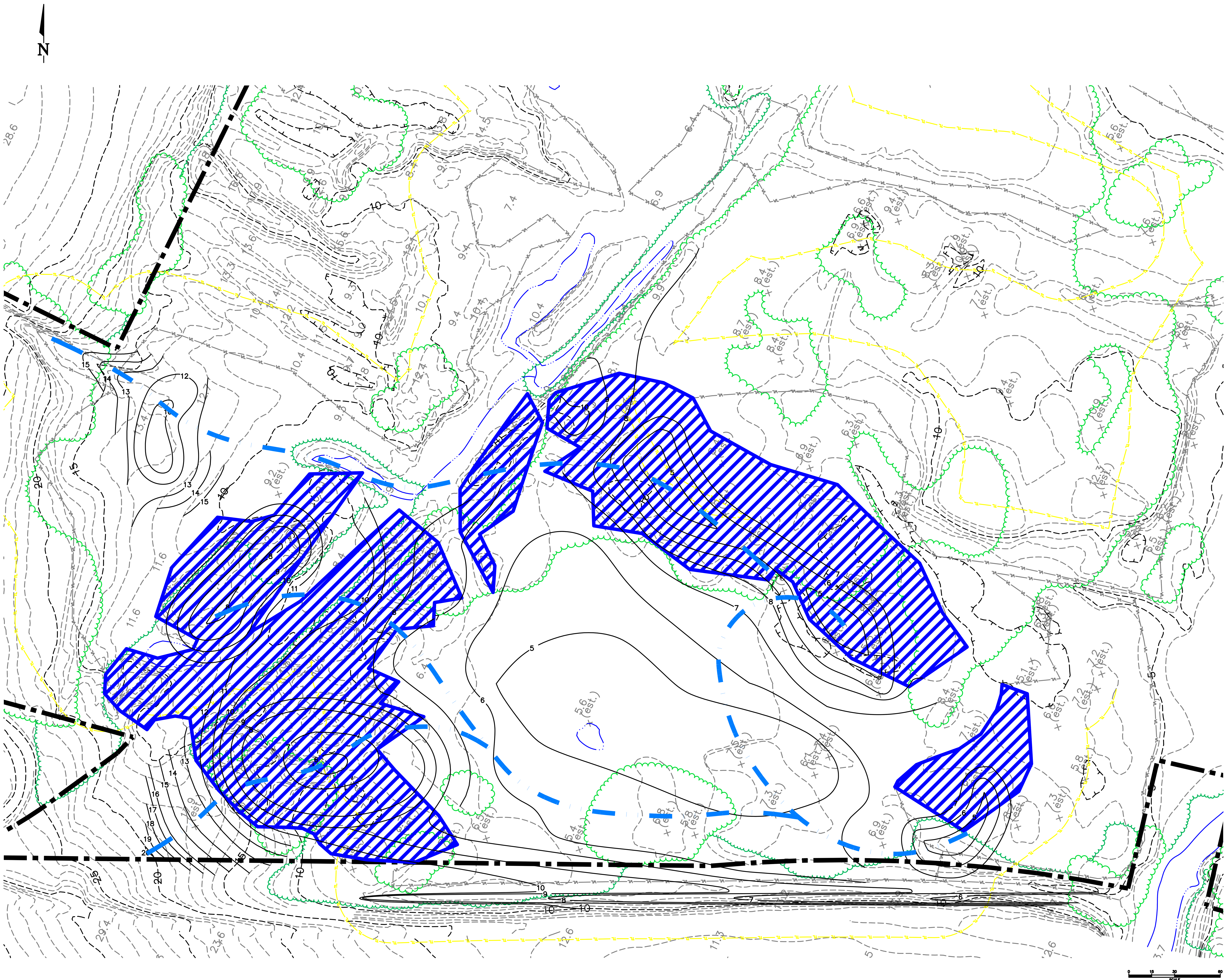

NOTES:

1. THE PROPOSED PLAN INCREASES EMERGENT WETLAND AREA BY 2.5 ACRES.

2. THE PROPOSED CONTOURS DEMONSTRATE NEW ECOSYSTEMS CREATED IN THE EXISTING WETLAND THAT WILL DIVERSIFY THE HABITATS AT THE SITE.

LEGEND

- PROPOSED EXPANSION OF WETLANDS
- EXISTING TREELINE
- EXISTING BRUSHLINE
- STREAM
- PROPOSED CONTOUR
- PROPOSED FLOWPATH

CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532

DESIGNED	CHECKED	APPROVED	DATE
SPW	PLK		AUG 2007

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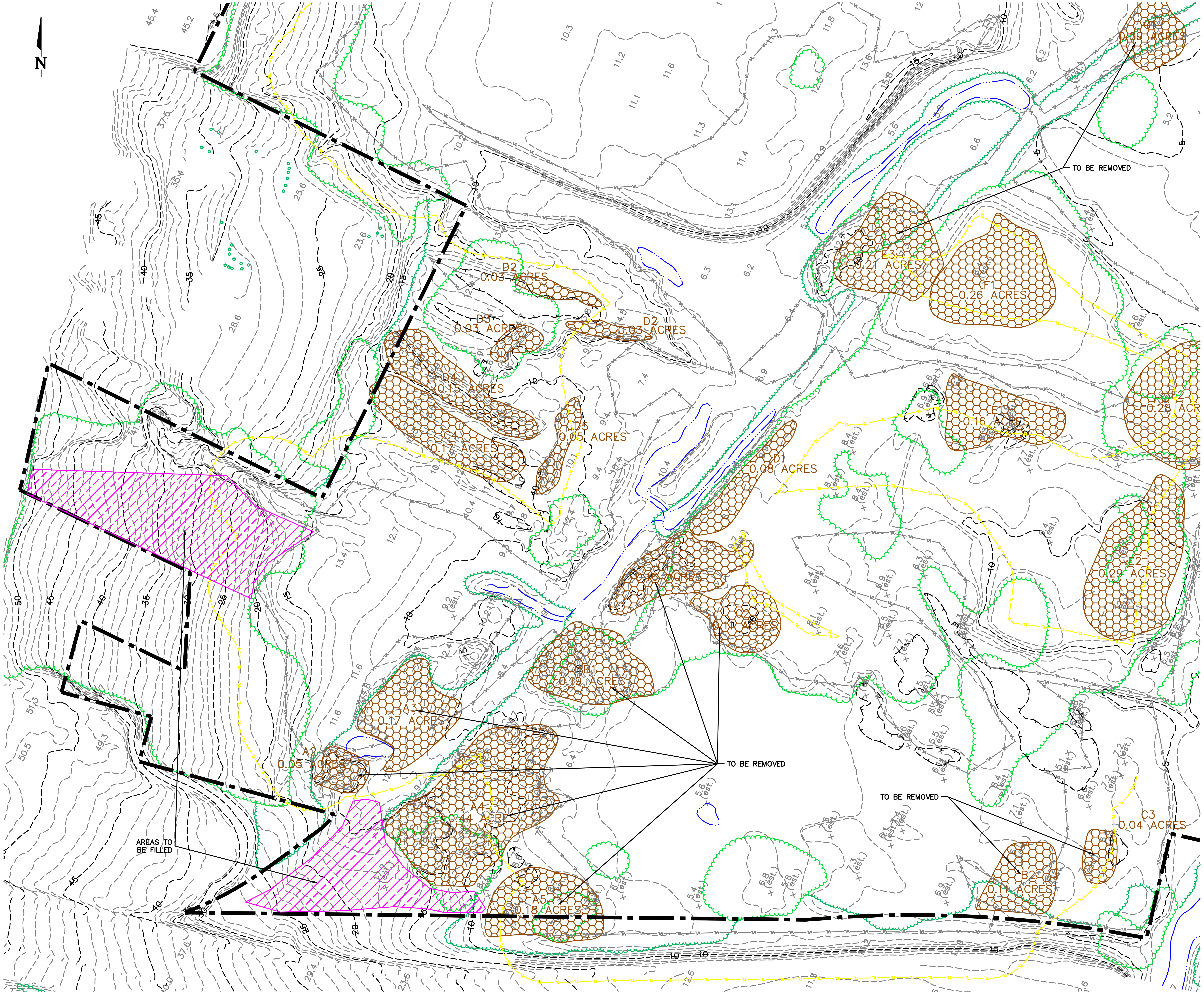

NOTES:

1. THE FOLLOWING DEBRIS PILES LISTED MUST BE REMOVED FROM THE SITE: A2, A3, A4, A5, B1, B2, C1, C2, C3, E3 AND G1.

2. THE TOTAL VOLUME REMOVED FROM THE SITE FOR THE DEBRIS PILES IS APROXIMATELY 14,500 CUBIC FEET.

3. ADDITIONAL REGRADING WILL BE REQUIRED AT THE SITE TO INCREASE THE AMOUNT OF WETLAND. THIS ADDITIONAL SOIL WILL BE RELOCATED TO THE AREAS INDICATED ON THE MAP. THESE AREAS WERE CHOSEN USING THE VEGETATION AND SOIL SURVEY. THESE AREAS WERE FOUND TO BE IN POOR CONDITION SOIL AND VEGETATION WISE. IT IS ALSO RECOMMENDED THAT THE ADDITIONAL FILL SOIL BE USED TO COVER THE REMAINING DEBRIS PILES AS PER NJDEP PERMIT REQUIREMENTS.

4. THE PURPOSE OF THIS PROJECT IS TO ENHANCE THE ECOSYSTEM OF TEANECK CREEK AND CREATE ADDITIONAL WETLANDS. REGRADING OF THE SITE WILL BE REQUIRED TO REMOVE DEBRIS PILES. THERE IS AN EXPECTED EXCESS OF SOIL FROM THE REGRADING AND REMOVAL PROCESS. DEPOSITING EXCESS SOIL WILL HAVE A NEGATIVE IMPACT ON QUALITY HABITAT AREAS. DEPOSITION/FILL AREAS WERE CHOSEN DUE TO POOR SOIL AND VEGETATION CONDITION. THE PLAN AVOIDS THE RISK OF DAMAGING ANY AREAS OF TEANECK CREEK THAT ARE IN GOOD CONDITION.

5. ANY AREA THAT HAS BEEN DISTRUBED BY THE RESTORATION PROCESS WILL BE REVEGETATED TO ENSURE THAT NATIVE SPECIES REESTABLISH.

6. ALL DEPOSITION ON SITE WILL OCCUR OUTSIDE OF AREAS DELINEATED AS WETLANDS FROM THE 2007 DELINEATION COMPLETED BY DR. PETER KALLIN.

LEGEND

EXISTING MINOR CONTOURS
EXISTING MAJOR CONTOURS
PROPOSED RELOACTED DEBRIS PILES
EXISTING TREELINE
EXISTING BRUSHLINE
STREAM
DEBRIS PILES
WETLAND 2006 DELINEATION
WETLAND 2006 BUFFER

0 30 60 120
SCALE

CHRISTOPHER C. OBROPTA, Ph.D., P.E.
PROFESSIONAL ENGINEER - NJ LICENSE # 37532

DATE

DESIGNED	CHECKED	APPROVED	DATE
SPW	PLK		AUG 2007

TEANECK CREEK CONSERVANCY
WETLANDS RESTORATION PLAN

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TOWNSHIP OF TEANECK, BERGEN COUNTY

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New Jersey Agricultural Experiment Station

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SHEET #
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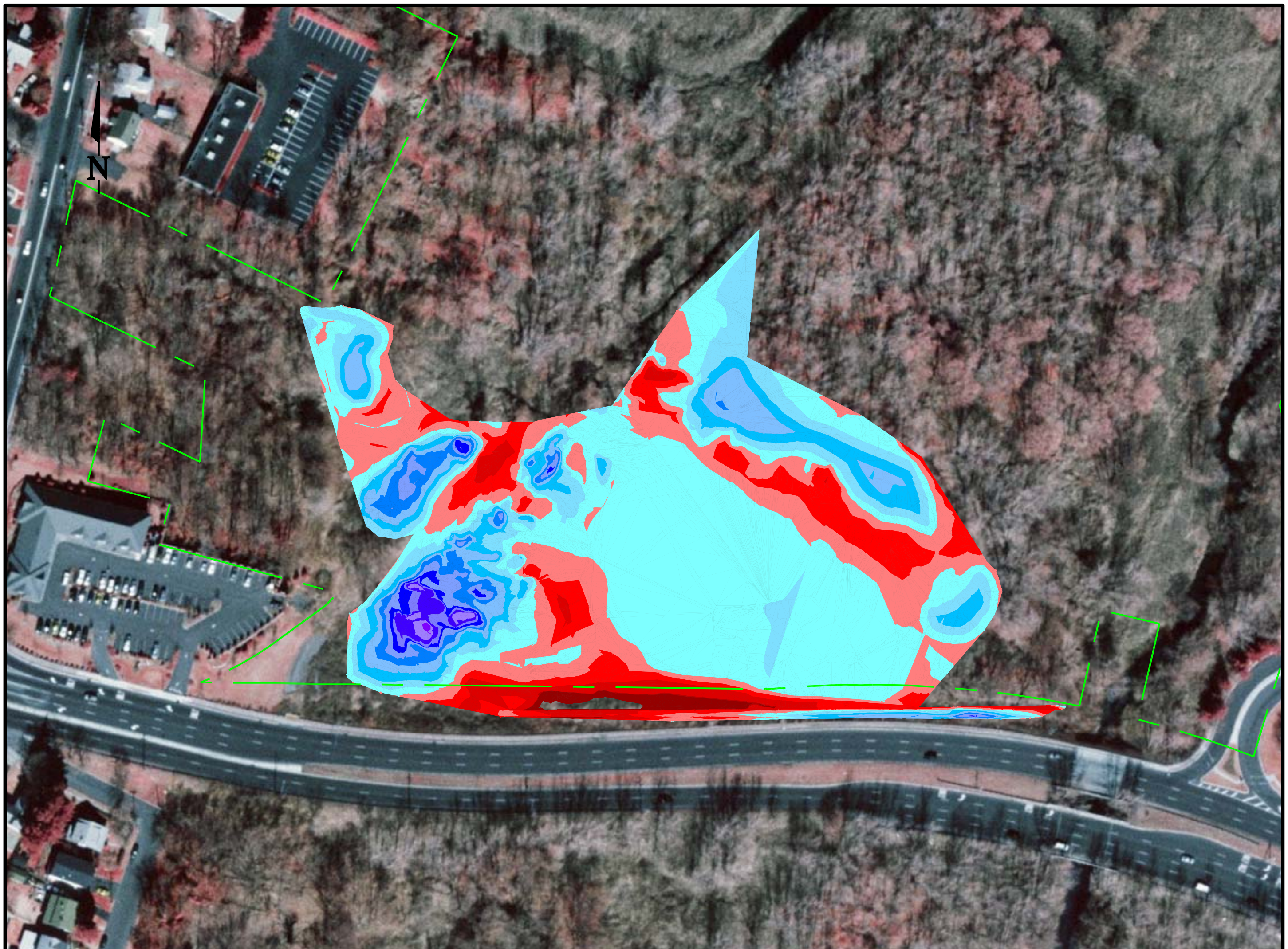
TOTAL
DATE
REVISION



CUT FILL CALCULATIONS FOR TEANECK CREEK

APPROXIMATELY 6,000 CUBIC YARDS

THE FIGURE REPRESENTS WHERE THE CUT AND FILL WILL TAKE PLACE. BLUE REPRESENTS CUTS AND RED REPRESENTS FILLS. THE DEEPER THE COLOR DEEPER THE CUT OR HIGHER THE FILL.

THE DEEPEST CUT IS 4 FEET. THE HIGHEST FILL IS 11 FEET.

0 100 200 400
SCALE

LEGEND
PROPERTY LINE

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TOWNSHIP OF TEANECK, BERGEN COUNTY

DRAWN	CHECKED	APPROVED	DATE
SPW	CCO		

Rutgers
New Jersey Agricultural Experiment Station

APPENDIX 3

Bergen County Freeholder Resolution No. 1550, Wetlands Research and Restoration Design Plan, October 17, 2007

MEMORANDUM

Board of Chosen Freeholders
County of Bergen
One Bergen County Plaza • 5th Floor
Hackensack, N.J. 07601-7076
(201) 336-6200 • Fax (201) 336-6290

Date: October 18, 2007

To County Counsel

From: Valerie Coniglio, Clerk to the Board

Subject: Wetlands Research and Restoration Design Plan

We are enclosing certified copy of resolution #1550 adopted by the Board on October 17, 2007, endorsing the above plan.

VC/af
Enc.

C: Parks
NJ Wetlands Mitigation Council
Teaneck Creek Conservancy
Cooperative Outreach and Extension,
School of Environmental and
Biological Sciences, Rutgers University

2007
BERGEN COUNTY BOARD OF CHOSEN FREEHOLDERS RESOLUTION

MEMBERS	AYE	NAY	ABSTAIN	ABSENT
CALABRESE	✓			
CARROLL	✓			
GANZ	✓			
MCPHERSON	✓			
O'BRIEN	✓			
WAGNER	✓			
PADILLA CHAIRMAN	✓			
TOTALS	7	—	—	—

Resolution No. 1550

Date: October 17, 2007

Page 1 of 6

Subject: Teaneck Creek Conservancy NJ Wetlands Mitigation Council

Purpose: Endorse Wetlands Research & Restoration Design Plan

Account No.

Contract No.

Dollar Amount:

Prepared By: BB/ak

Offered by: Padilla

Seconded by: Carroll

Approved by:

Certified as a true copy of a Resolution adopted by the Board of Chosen Freeholders on above date at a Regular Meeting by: Valerie Coniglio

Valerie Coniglio, Clerk, Board of Chosen Freeholders, Bergen County, New Jersey

WHEREAS, the Teaneck Creek Conservancy, a not-for-profit organization has a long – term license from the County of Bergen to advance the cause of nature study, site specific interpretive art, and the restoration of the natural flora in Area I of the Overpeck County Park, Township of Teaneck; and

WHEREAS, to fulfill a mandate of the County license, the Conservancy and Rutgers University, in partnership with the County applied for a $300,000.00 grant from the NJ Wetlands Mitigation Council, via Resolution # 146, February 16, 2005, for planning and site specific research and investigation to advance the preparation of permits for the restoration and

1510-2

enhancements of wetlands, native plants, public stewardship opportunities, and a long-term management plan that will guide land use, landscaping, maintenance practices and other aspects of park use; and

WHEREAS, the goals of the research project are to restore and enhance 20 acres of fully functioning wetlands on the site and to replace invasive plant species with native vegetation appropriate for this riparian wetland system; and

WHEREAS, the Rutgers University environmental research scientists conducted research at the site from 2005 to 2007 to support the preparation of plans and permit applications for wetlands restoration that will be implemented on the site as soon as permits are approved and required implementation funding has been secured; and

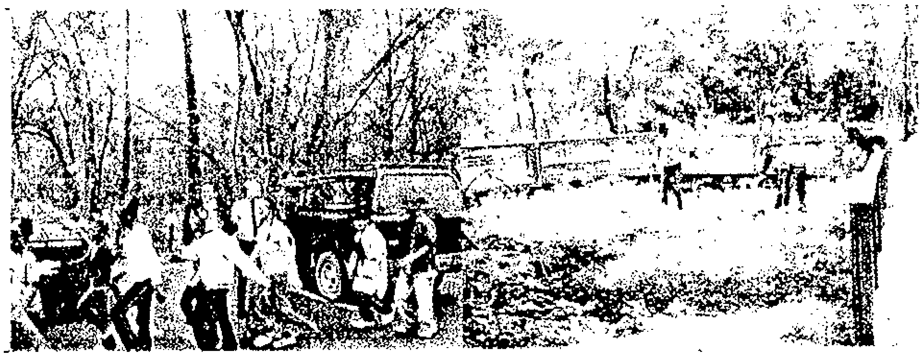
WHEREAS, said wetlands scientific research served as the basis of the preparation of the report entitled "Teaneck Creek Wetland Restoration Project", dated September 2007, by Rutgers University and TRC Environmental Corp., copy of executive summary is attached hereto; and,

NOW THEREFORE, BE IT RESOLVED, upon the recommendation of Bruce Bonaventuro, Director, Department of Parks, the County of Bergen endorses the aforementioned Plan and submission of same to the NJ Wetlands Mitigation Council and the NJ Department of Environmental Protection's Land Use Regulation Program for regulatory permits; and

BE IT FURTHER RESOLVED, that the County Executive be and is hereby authorized to execute any necessary documents in support of this wetlands restoration plan.

BE IT FURTHER RESOLVED, copy of this resolution shall be forwarded to the New Jersey Wetlands Mitigation Council, Bergen County Department of Parks, the Teaneck Creek Conservancy and the Cooperative Outreach and Extension, School of Environmental and Biological Sciences, Rutgers University.

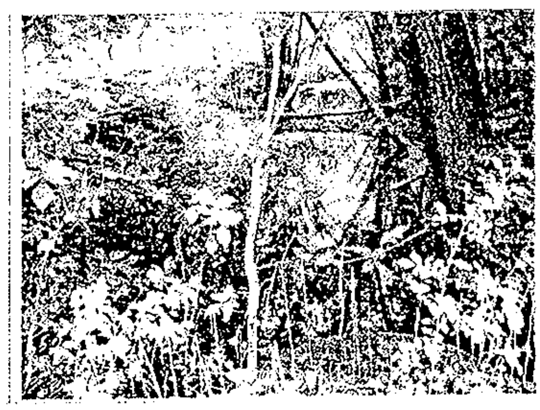
1550-3



TEANECK CREEK WETLAND RESTORATION PROJECT

REPORT PREPARED BY
RUTGERS UNIVERSITY
TRC OMNI ENVIRONMENT CORP.

SEPTEMBER 2007
CONFIDENTIAL



1510-4

This report was prepared by:

Department of Environmental Sciences
School of Environmental & Biological Sciences (SEBS)
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Christopher Obropta, PhD
Beth Ravit, PhD
Peter Kallin, PhD
Michael Mak
Linda Rohleder
Lea Johnson
Sean Walsh

TRC Environmental Corporation
Jeremiah Bergstrom, CLA, ASLA
Kristine Yates

US Geological Survey
Eric Vowinkle

Rutgers Environmental Research Clinic would like to give special thanks to the following individuals for their support and assistance in collection of the research data contained in this report.
Teaneck Creek Conservancy

Gladys & Perry Rosenstein
Mary Arnold
Rita Suri

US Geological Survey
Mike Deluca
Bonnie Gray

Rutgers University
Greg Rusciano

1560-5

I. Executive Summary

The Teaneck Creek Conservancy wetlands are located in the Overpeck County Park, surrounded by a highly urbanized Bergen County landscape. Degradation of the wetlands has occurred for the last two centuries due to human activities, and the hydrology and vegetation of the site today is highly disturbed. To open this portion of the park to the public, the Conservancy has installed a new 1.5 mile trail system. Scientific studies have been undertaken to describe the site's current baseline conditions. This work is now informing the design of the conceptual restoration plan for the site. Specific goals of the project are to restore/enhance 20 acres of fully functioning wetlands on the site and to replace invasive plant species with native vegetation appropriate for this riparian wetland system.

The project team, lead by Rutgers University and TRC Omni Environmental Corp., has been collecting data for the last three years in an effort to characterize existing conditions. The hydrologic studies provided data that has been incorporated into the UESPA Surface Water Management Model (SWMM) to develop a water budget for the site and to describe water movement into and through the site. An important fact that has emerged from this work is the recognition that a hydrologic connection between Teaneck Creek and the site's surface and ground waters does not currently exist due to the presence of clay-fill material berms adjacent to the creek. Soils have been characterized as native, dredge-clay, or unconsolidated fill and the location of these various soil types has been mapped. Plant species have been identified and maps developed showing the location of desirable native species versus areas that are highly invaded.

Based on the data obtained from this research conceptual restoration design plans have been produced. The goal of the design is to protect high quality native areas remaining on the TCC site, to restore new wetland areas through the removal of fill materials and lowering surface elevations, and to reestablish the hydrologic connection between the Teaneck Creek and the interior wetlands and ground waters. The debris removal plan has been designed to accomplish these objectives with as little disturbance

to the site as possible, especially in areas where desirable vegetation is well established. The TCC has been divided into four restoration zones, and specific objectives for each zone have been defined. The greatest area of disturbance during restoration work will occur in the highly disturbed southern portion of the TCC adjacent to DeGraw Avenue.

Due to the presence on the site of highly invasive plant species an ongoing maintenance program involving both TCC and Bergen County must be initiated. It is of vital importance to establish a "No Invasive" buffer area around the undisturbed native vegetation in the northeastern corner of the site adjacent to Fycke Lane. Identification and removal of new invasive species must be undertaken by TCC volunteers, and Bergen County needs to be responsible for mowing the trail grass buffers during and after the growing season. These activities are critical to protect the newly planted areas that have already been restored/enhanced, and to be ready to handle ongoing maintenance issues once the restoration commences.

Costs for the restoration (not including debris removal or remediation activities) are estimated to be $1,245,000. Various funding sources are available to support this restoration work, and when the conceptual plan has been approved by TCC, Bergen County, the NJWMC, and the NJDEP Land Use Division grants to the appropriate funders will be submitted.