GUIDELINES FOR URBAN FOREST RESTORATION

NYC Parks

NEW YORK CITY DEPARTMENT OF PARKS & RECREATION

http://www.nyc.gov/parks

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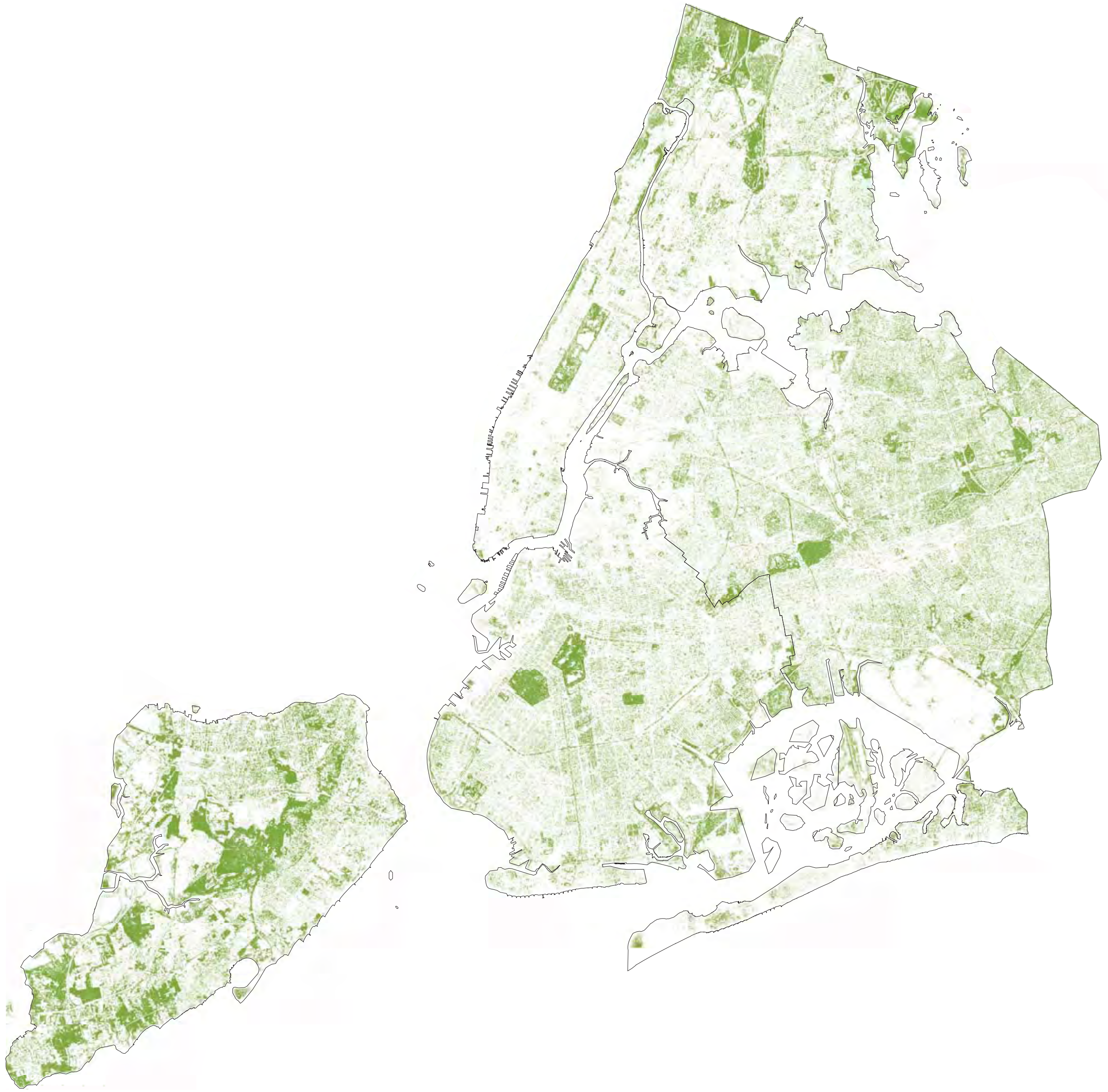

New York City Tree Canopy Map, 2010 GIS data

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PART ONE:

BACKGROUND AND CONTEXT

UFEP planting on Staten Island.

CHAPTER 1: FOREST RESTORATION IN NEW YORK CITY

INTRODUCTION

Guidelines is a compendium of the theories and practices developed, implemented, and tested during thirty years of natural area restoration by the New York City Department of Parks & Recreation's (NYC Parks) Natural Resources Group (NRG). The book includes an overview of the ecological and restoration principles behind NRG's approach to forest restoration, as well as a step-by-step guide to building sustainable urban forests. Though this information is presented through the lens of NRG's experience in New York City, the challenges confronting its efforts to establish healthy forests here are found in most dense urban areas: a legacy of encroachment upon and neglect of natural areas, fragmentation, and the rampant spread of invasive plant species. Just as most local governments share these challenges, many also share New York's commitment to creating a sustainable and ecologically robust urban environment. Forest restoration is a crucial step towards achieving that end.

NRG, one of the nation's first publicly funded urban natural resources conservation units, was founded in 1984 to conserve, restore, and manage New York City's natural areas. Prior to the 1980s, NYC Parks considered the thousands of acres of undeveloped land under its jurisdiction as terra incognita, unknown lands. A prescient NYC Parks commissioner, Henry Stern, questioned the character of these vast areas - roughly half the Department's portfolio at the time, comprising nearly 8,000 acres - that lacked clearly defined uses. To understand the current condition, as well as the potential value, function, and management needs of these natural areas, he established NRG and recruited a team of advisors from the fields of forestry; geography; agronomy; and wetland, wildlife, and plant community ecology.

Once NRG and its advisors began considering restoration strategies for this land, they quickly discovered that their experience with rural and wilderness areas had not fully prepared them for the complexities of urban wilds, where countless practical and ecological constraints hamstring conventional restoration practices. Over time, in the process of restoring more than 1,600 acres of natural areas, including 1,400 acres of forest, NRG has developed, borrowed, and shared new restoration techniques with a broad range of practitioners across the country. Key documents related to improving the practice of urban ecological restoration have emerged from this fruitful communication. Publications such as the Nature Conservancy's Element Stewardship Abstracts, the Society of Ecological Restoration's Management and Restoration Notes, Leslie Sauer's Once and Future Forest (1998), and an assorted collection of conference and seminar papers have become cherished volumes in a slim canon of authoritative literature in the field. NRG itself has published nearly 70 works, including articles, guides, summary reports, ecological assessments, and management plans. Until now, however, no single document has captured the full breadth of NRG's forest restoration knowledge and experience.

New York City Mayor Michael Bloomberg's 2007 MillionTreesNYC reforestation initiative, with its goal of planting and caring for one million trees in New York's five boroughs by 2017, brought about a tremendous and instantaneous expansion of NRG's forest restoration efforts. The desire to present NRG's knowledge and best practices in one volume quickly became an imperative. Guidelines is the result of the collective efforts of innumerable professionals, both in growing NRG's knowledge base since its founding and in distilling that information here, into a usable book which will enable practitioners everywhere to apply NRG's expertise to their own urban forest restoration projects.

Guidelines focuses on forests in New York City, which is located in the northeast of the US and straddles the boundary between southern New England and the northern Mid-Atlantic regions. The basic strategies presented here, however, apply to urban natural area restoration projects in any location, and many of the methods for site selection, site preparation, invasive species removal, and monitoring are equally useful in the restoration of wetlands and other ecosystems as well.

MillionTreesNYC Rockaways Planting.


Forests of Alley Pond Park in Queens shown capturing stormwater and replenishing the water table. (photo by Mike Feller)

WHY RESTORE URBAN FORESTS?

Urban forests are a critical part of the city's green infrastructure, providing an array of ecological services and opportunities for recreation. Healthy forest ecosystems can cool peak summer temperatures, absorb and filter storm water, absorb air pollution, release oxygen, store carbon in vegetation and soils, and support biodiversity, as well as allow city residents respite from the frenzy of urban living. Degraded forests exhibit diminished capacity for providing these functions. Over the past hundred years, wetlands have been turned into airports, native ecosystems have been invaded by exotic plants and animals, and forests have been replaced with parking lots, roads, and high-rise buildings. The fragmentation and isolation of our remaining native forests has made them less resilient and increased their exposure to the ongoing and ever-increasing pressures that come with climate change and urban population growth.

Native urban forest does still exist, and can be protected, restored, and expanded through thoughtful and persistent management. While these forests will never be returned to their primeval state, significant measures can be taken to retain ecological function, and to steward them for future generations. Invasive species, or non-native species that smother, crowd out, consume, or strangle existing vegetation, are one of the biggest challenges to the structure and function of New York City forests (see Chapter 2 for more details). Protection from further development and other damaging human use, control of invasive species, encouraging and planting native species, and continued research and adaptive management of our forests is essential to their, and our, continued good health.

- Offset Climate Change: Forests transform carbon dioxide into wood, leaves, and soils, and release oxygen into the air. Carbon dioxide is a "greenhouse gas" that exacerbates global warming. New York City's trees and forests store 1.35 million tons of carbon each year, thereby reducing heating and cooling costs by a value of approximately $11.2 million annually (Nowak et al., 2007).

- Absorption of Storm Water Runoff: Forest vegetation helps to retain and build healthy soils thereby reducing stormwater runoff, erosion,and downstream sedimentation. This also reduces flooding and property damage and keeps excess water out of already over-burdened sewer systems (Sanders, 1984).

- Provision of Shade and Reduction of Urban Heat Island Effect (UHI): Trees reduce outdoor temperatures through transpiration and reduce interior temperatures by providing buildings with shade, thereby lowering energy consumption by air conditioning. Provision of shade and UHI reduction are particularly important in cities in which buildings and pavements absorb heat by day and re-radiate that heat at night, a phenomenon that increases ambient temperatures by an average of seven degrees Fahrenheit. Such rises in temperature increase health risks to urban populations, raise electricity consumption, and cause further stress to ecological systems (Nowak et al., 2007).

- Improved Air Quality: Trees filter air by removing dust and other harmful pollutants, such as nitrous oxide and ozone, which can cause respiratory illness (Nowak et al., 2006). Through leaf uptake, trees in New York City remove approximately 2,202 metric tons of air pollutants each year. This air filtering generates an annual savings of $10.6 million, based on estimated national median externality costs associated with pollutants (Nowak et al., 2007).

- Improved Biodiversity: Biodiversity refers to the diversity of life in all its forms and at all levels of organization. Diversity is a key indicator of ecosystem health and durability, and thereby directly impacts the benefits, resources, and goods - collectively known as 'ecosystem services' - that natural areas can provide (Tyrrell et al., 2010).

- Increased Value of Neighborhoods: Locations adjacent to or in the proximity of well-managed forested areas benefit from improved property values, neighborhood perception, community pride, and overall well-being (Crompton, 2000; Harnick et al., 2009).

- Improved Public Health: Reductions in psychological stress and increases in physical activity have been linked to the proximity of urban trees and forests (Dwyer et al., 1992; Harnick et al., 2009).

THE HISTORY OF NRG AND FOREST MANAGEMENT IN NEW YORK CITY

Early Work: Inventory and Management Plans

Tasked with evaluating the existing conditions of New York City's undeveloped public lands, NRG and its advisors completed fine-scale inventories that would eventually cover 7,000 acres of natural areas. These inventories included vegetation, wildlife, soil, evidence of human disturbance and, in many cases, hydrologic surveys. An abbreviated version of this process was used to assess properties for potential acquisition as well.

The vegetation survey method employed by NRG to create its inventory was Plant Formation Entitation, originally devised by Mueller-Dombois and Ellenburg in the early 1970's and adapted for use in New York City by NRG in 1984. In this process, discrete vegetation communities or "entities" are identified, described, and mapped. Surveyors divide each natural area into units (as small as 1/10 of an acre) based on the dominant plant cover, and document current uses, evidence of environmental disturbance, and site history for each unit. Using aerial photography and field reconnaissance, similar vegetation types (e.g. Oak/Hickory Forest, ornamental trees, or a pioneering stand of sassafras) can be differentiated and delineated.

Figure 1.1: Vegetation Types in Van Cortlandt Park, 1988

Blue Heron Park is one of the ecological gems discovered on Staten Island. (photo by Mike Feller)

Within the natural areas it inventoried, NRG found meadows containing some of the highest concentrations of rare plants in the state of New York, salt marshes large enough to support rare breeding populations of sharp-tailed and seaside sparrow (*Ammodramus caudacutus* and *maritimus*) and clapper rail (*Rallus longirostris*), and mature forests in which scarlet tanagers bred among cathedral-like tree canopies. New York City's setting at the convergence of northern and southern hardiness zones, and within three physiographic provinces (Coastal Plain, Piedmont, and Appalachian) accounts for the presence of an astounding wealth of plant species. The quality, integrity, and diversity of some of the City's natural areas startled even the NRG team. Seeing the tall tulip trees (*Liriodendron tulipifera*) ascending above spicebush (*Lindera benzoin*) and flowering dogwood (*Cornus florida*) in The Clove in Manhattan's Inwood Hill Park, Yale professor of silviculture Dr. David Smith commented that the park "… has stands of trees that rival the famous old growth in the Smokey Mountain National Park." (personal communication, 1998).

Dumping of vehicles in natural areas in La Tourette Park in 1992.

UFEP inventories documented vinelands covering many areas of Pelham Bay Park in the Bronx.

Unfortunately, NRG's inventory and assessment did not only reveal pristine, ideal habitat. It also uncovered landscapes filled with detritus such as burned-out, rusting car chassis and incinerator ash dumps. In areas where fires or wind throws had created light-filled gaps, invasive species such as Norway maples (*Acer platanoides*) formed canopies so dense that they suppressed all ground cover vegetation, resulting in erosion and the down-slope migration of soil. Teams observed aggressive invasive vines such as porcelainberry (*Ampelopsis brevipedunculata*), Oriental bittersweet (*Celastrus orbiculatus*), and Japanese honeysuckle (*Lonicera japonica*) rising in walls and waves to smother native trees and shrubs at park edges and in canopy gaps created by paths and trails. NRG discovered that arson was rampant and that vandalism, the riding of dirt bikes, and other off-trail park usage was contributing significantly to the degradation of natural areas. As the inventories continued, it became clear that NRG was an eyewitness to the steady and, in some cases, rapid unraveling of New York City's ecosystems.

These findings led NRG to create park management plans that focused on mitigating negative influences. The plans outlined procedures to: remove invasive species; seal off parks from cars and dirt bikes; implement erosion control and slope stabilization measures; and encourage reliance on natural regeneration, with specific planting recommendations for the most degraded areas.

As the new management strategies were put in place, NRG's ongoing observations yielded some significant discoveries. It found that a closed canopy in the core of the forest patch was essential for holding many destructive invasive plants at bay. Previously, because forest margins are visible and easily accessible, restoration professionals assumed that working from the outside in would be efficient and productive, and that establishing a strong perimeter would lead to a stable center. Experience proved, however, that restored margins saw continued stress and active disturbance, which meant heavy ongoing maintenance. Focusing first on controlling invasive plants and closing canopy gaps in the core of the forest helped to strengthen the core forest structure more quickly and was a quicker, more cost-efficient, effective and long-lasting approach. This conclusion has become a guiding principle in NRG's urban forest restoration practice.

Early Projects and Initiatives

Following its early inventory and restoration work, NRG began to receive funding from both public and private sources for a wide range of restoration projects. Funding is a critical component of every initiative: the interests and goals of the funding source often drive a project's focus, and the level of funding directly determines the strategies for implementation and the extensiveness of the work. The diversity of its funding sources, and thus, project types, has allowed for the continual development of NRG's practice and expertise.

In 1991 the City Parks Foundation received a grant from the Lila Wallace/Reader's Digest Fund to establish the Urban Forest and Education Program (UFEP) in cooperation with NRG. UFEP was funded to support the management of upland forests as complete ecosystems. Between 1991 and 1996, UFEP teams planted more than 150,000 trees, intensively managed more than 600 acres of New York City forestland for elimination of invasive plants, and protected approximately 4,000 acres of parkland from further degradation through the installation of twenty miles of perimeter protection. This major project provided NRG with the opportunity to explore multiple forest restoration strategies and monitor their success rates.

UFEP planting of canopy gaps in Alley Pond Park in 1994.

Starting in 1997, the State of New York Department of Environmental Conservation (NYSDEC) began issuing grants for environmental restoration and land acquisition through the 1996 Clean Water/Clean Air Bond Act. NRG received Bond Act funding to restore saltwater and freshwater wetlands in 12 natural areas. Bond Act funding was discontinued in 2008.

In locations where forests bordered on wetlands, Bond Act projects addressed upland as well as tidal habitats. This funding allowed NRG to build on the initial efforts of UFEP, and care for trees planted through that program until they achieved a closed canopy. Comparing sites that received this extended maintenance with those that did not confirmed NRG's theory that semi-annual clipping of vines and other weeds increases the probability that new plantings will survive and flourish. The Bond Act projects also provided NRG the opportunity to plant thousands of herbaceous plugs within many of the UFEP sites and to assess the impacts of various invasive removal techniques over time. Additionally, for five years after the completion of Bond Act projects, NRG monitored wildlife (invertebrates, fish, birds, reptiles, and amphibians) as indicators of successful water quality improvement. Through this work, for example, NRG collected evidence that forest-interior species of birds such as the wood thrush are more abundant during breeding season in native forest than in forest heavily-invaded by exotic plants (Pehek, unpublished data).

In 2001, NRG started the Forever Wild program to protect the most ecologically valuable land within New York City's five boroughs. The Forever Wild program was created both to protect remaining ecological gems within the urban matrix, and to educate New Yorkers about the value of the wilderness in their communal backyard. The Forever Wild program established 48 nature preserves across the city (shown in Figure 1.2: Forever Wild Nature Preserves), covering more than 8,700 acres of ecologically valuable forests, wetlands, and meadows. Since 2008, eleven additional Forever Wild preserves have been designated bringing the total number of preserves to 59. Updates on the Forever Wild preserves can be found on the NYC Parks web site.

Figure 1.2: Forever Wild Nature Preserves of New York City, 2007

Forever Wild Sites

Site	Acres	Habitat Information: Forest	Habitat Information: Wetland – Fresh	Habitat Information: Wetland – Salt	Habitat Information: Meadow	Services: Hiking Trail	Services: Ranger Tours	Services: Visitor Center	Services: Rest Rooms
The Bronx									
1. Bronx Park Preserve	35	•	•			•	• ‿		•
2. North Brother Island	20	•					*		
3. Pelham Bay Park - Hunter Island Marine Sanctuary	138	•		•		•	•		
4. Pelham Bay - Thomas Pell Wildlife Refuge	371	•		•		•	•		
5. Pelham Bay Park Preserve	883	•	•	•	•	•	• ‿	•	•
6. Riverdale Park/Raoul Wallenberg Forest Preserve	112	•				•	•		•
7. Seton Falls Park Preserve	36	•	•			•	•		•
8. Van Cortlandt Park Preserve	573	•	•		•	•	•	•	•
Brooklyn									
9. Four Sparrow Marsh Preserve	67			•			• ‿		
10. Fresh Creek Park Preserve	92			•					
11. Marine Park Preserve	530			•	•	•	• ‿	•	•
12. Paerdegat Basin Park Preserve	161			•	•		‿		
13. Prospect Park Preserve	208	•	•			•	• ‿	•	•
Manhattan									
14. Central Park - The North Woods	34	•				•	•	•	•
15. Central Park - The Ramble	37	•				•	•	•	
16. Central Park - Hallett Nature Sanctuary	4	•				•	•		
17. Inwood Hill Park - Shorakapok Preserve	136	•		•		•	• ‿	•	•
Queens									
18. Alley Pond Park Preserve	549	•	•	•		•	•	•	•
19. Arverne Shorebird Preserve	84								
20. Cunningham Park Preserve	243	•	•			•	•		•
21. Dubos Point Wildlife Sanctuary	33			•					
22. Willow Lake Preserve	106		•						
23. Forest Park Preserve	274	•	•			•	•	•	•
24. Idlewild Park Preserve	242		•	•	•				
25. Udalls Park Preserve	31	•	•	•		•			
26. Spring Creek Park Preserve	75			•					
Staten Island									
27. Arden Heights Woods Preserve	185	•	•			•			
28. Bloomingdale Park Preserve	110	•	•			•			
29. Blue Heron Park Preserve	169	•	•	•	•	•	• ‿	•	•
30. Clove Lakes Park Preserve	131	•	•	•	•	•	• ‿	•	•
31. Conference House Park Preserve	105	•	•			•	•	•	•
32. Deer Park Preserve	40	•				•			
33. Elbs Pond Park Preserve	39		•		•	•	•		
34. Evergreen Park Preserve	22	•				•			•
35. Fairview Park Preserve	22	•	•						
36. High Rock Park Preserve	90	•	•	•	•	•	•	•	•
37. Isle of Meadows Preserve	100			•	•				
38. Islington Park Preserve	22	•	•			•			
39. Lemon Creek Park Preserve	16	•	•			•	• ‿		
40. Long Pond Park Preserve	115	•	•			•			
41. Pralls Island Preserve	74	•		•					
42. Reeds Basket Willow Swamp	49	•	•						
43. Saw Mill Creek Marsh Preserve	117			•			• ‿		
44. Shooters Island Preserve	26								
45. W.T. Davis Wildlife Refuge	428	•	•	•		•	•	•	•
46. Staten Island Greenbelt Preserve	1,352	•	•	•	•	•	•	•	•
47. Sweet Bay Magnolia Preserve	241	•	•		•				
48. Wolfe's Pond Park Preserve	207	•	•			•	• ‿		•
Total	**8734**								

* tours led by NYC Audubon Society ‿ canoe tours

MillionTreesNYC, and the Natural Areas Conservancy

MillionTreesNYC, announced on Earth Day in 2007, is one of the 127 initiatives comprising PlaNYC, New York City's long-term sustainability plan. The program provided a large infusion of funding to NRG to hire full-time staff to battle invasive plants, revitalize the soil, and restore multi-story forests to health and vibrancy. All facets of the urban forest, including street trees, landscape trees, trees on private property, and trees in natural areas, are part of MillionTreesNYC, representing an unprecedented commitment to restoring forest communities throughout the city.

As of 2013, NRG has planted about 375,000 trees in more than 80 parks and public properties under the auspices of MillionTreesNYC, which has supported the installation of more than 750,000 total trees thus far. NRG has also performed invasive species control across 1,163 acres as part of the program. While incorporating the many lessons learned from its prior work into MillionTreesNYC, NRG also continues to adapt its practices in response to the specific needs of this large-scale effort. For example, to reduce the staff time spent controlling invasives during the establishment period, it is assessing the efficacy of significantly increasing the time dedicated to managing invasives in advance of planting a site. NRG is also weighing the advantages of removing invasive species from a large buffer area around sites rather than planting up to the edge of the area where invasive species have been controlled.

The work of NRG under UFEP became a national model for urban conservation. New York City was among the first cities of its size to inventory and restore forests on a large scale. The MillionTreesNYC campaign elevated public awareness about the value of trees and forests, through community engagement, research, and strategic communications. In 2012, NYC Parks took another important step as a leader in urban conservation by forming the Natural Areas Conservancy (NAC), a private organization dedicated to expanding the agency's efforts to restore New York City's natural areas. The inaugural project of the NAC is a citywide ecological assessment. This assessment builds on the work of entitation, using quantitative metrics to measure the health, species richness, and regeneration of all of New York City's forests. This data will inform the long-term planning, budgeting, and practice of forest management in the City.

Before Restoration: Beginning site preparation at Fort Totten in spring 2009. Porcelainberry and Oriental bittersweet vines dominated the site and had to be treated for two growing seasons before the area was ready to plant. (photo by Michael Morris)

After Planting: Fort Totten restoration two years after planting (four years after the site preparation began). (photo by Michael Morris)

PROSPECT PARK RAVINE RESTORATION

In 1994, a comprehensive thirty-year natural area restoration management plan was written for Prospect Park, a 585 acre park in central Brooklyn. The primary goals of the plan included the closure of forest gaps, the remediation of compacted and eroded soils, the removal and management of invasive species, the restoration of forest structure, and the education of the public to promote stewardship. The Ravine Projects that grew out of this plan resulted in the planting of more than 250,000 native plants from local genetic stock on 26 acres of the park's natural areas. The Prospect Park Alliance, a public/private partnership that manages the park, established a natural resources crew which was initially privately funded and, subsequently, has been supported through an endowment.

The Ravine Project's crew implemented the restoration plan successfully and, over time, canopy light gaps closed, erosion was controlled, and an understory with healthy soils was established. Some of the more long-term ecological goals, such as increased biodiversity, sustainability, and regeneration continue to be monitored by the Prospect Park Alliance today.

The Prospect Park Ravine in Summer 2012 after over 15 years of restoration work by Prospect Park Alliance. (photo by John Jordan)

Conclusion

While NRG's on-the-ground work starts with the site and is limited by city borders, it nonetheless has a significant impact throughout the Northeast and Mid-Atlantic. Communication across regions is essential in order to establish larger forest patches and corridors with a diverse range of species and genetic material. In the face of climate change, it is this diversity that will ensure that our forests, and our cities, are robust. NRG is proud to be among the restoration organizations across the country committed to incorporating large-scale thinking into its daily site-scale work.

The public's past indifference towards our cities' natural areas led directly to their degradation. Yet today, city-dwellers are more committed to environmental protection than ever before. NYC Parks now recognize that forests are essential green infrastructure, as important as our roads and sewers; infrastructure that serves not only birds and insects, but humans as well, with innumerable health and environmental benefits. We also recognize that urban forests provide social values as well including places to relax, observe, and find peace. Around the world, city leaders are questioning their forests' capacity to withstand the ongoing pressures of urbanization. Now is the time to protect the valuable urban ecosystems we still have and redouble our efforts to build upon them. We hope that Guidelines will aid forest restoration projects across the country by bringing clarity and rigor to the complex work of restoration.

The chapter that follows describes the ecological underpinnings of NRG's approach to forest restoration and introduces the New York City context in which NRG has developed its practice. The four subsequent chapters are intended to guide the reader through the restoration process, from the earliest stages of project planning through the final steps of post-installation management and monitoring. Chapter 3 covers the complex task of evaluating and ultimately selecting optimal sites for forest restoration. Chapter 4 outlines the work of planning and designing sites, providing guidance on critical project elements, such as developing appropriate planting plans. Finally, Chapters 5 & 6 cover the many technical issues related to performing the physical restoration work on the site, including the various processes for controlling invasive plant species. Chapter 6 also provides information on adaptive management and the incorporation of research into restoration work.

CASE STUDY: Long-Term Forest Restoration at Alley Pond Park

Pro ect Duration 1987 - present

Site Location Alley Pond Park, Queens, NY

Size and land type acre municipal park

Forest Type Invasive-dominated, kettle ponds, abandoned farmland.

Soil Type Glacial till and fill


An example of fire evidence at Alley Pond Park in 1992. (photo by UFEP)

Pre-Restoration Site Conditions

Alley Pond Park, the second largest park in Queens, contains one of the only glacial kettle moraine ecosystems left in New York City and hosts freshwater and saltwater wetlands, tidal flats, meadows, forests, and abundant wildlife. Its forests, among the oldest in the region, contain enormous ecological complexity, in large part due to kettle ponds formed during glacial retreat. The tulip trees, oaks, and beeches in Alley Pond Park's forest are among the largest in New York City and Long Island.

In 1987, NRG conducted an ecological assessment of the vegetation and analyzed the public uses of Alley Pond Park. Along with the rich habitat found in some areas, the assessment revealed many problems including frequent arson, dumping, abandoned vehicles, rampant creation of "desire lines," and widespread invasion by non-native plant species, with Oriental bittersweet (*Celastrus orbiculatus*) and multiflora rose (*Rosa multiflora*) predominating. Destabilized slopes around the kettle ponds caused by invasive plant encroachment and off-trail mountain bike and ATV usage had led to sedimentation and increased loading of nutrients into the ponds. Through this assessment, NRG created a management plan which prioritized the planting of native forest communities and the installation of fencing, perimeter protection, and erosion control structures.

Restoration Goals

- Preserve and protect city-owned forests by reducing dumping and arson in natural areas
- Remove invasive plants and restore native forests
- Engage volunteers in restoration and stewardship of forests to increase the restoration impact
- Reduce erosion and sedimentation of kettle ponds to improve water quality and protect sensitive habitat

Methodology and Results

Total Trees Planted: 58,000 trees and shrubs
Total Acres Restored: More than 100 acres

In 1991, the Urban Forest and Education Program (UFEP), with NYC Parks and its partners, began implementing intensive forest restoration and protection work in Alley Pond Park. Areas dominated primarily by invasive species were treated with herbicide at a rate of almost three acres per year and subsequently planted with native trees. Staff removed many abandoned cars and, with various barriers, secured virtually the entire park from unauthorized vehicle entry. The exclusion of vehicles significantly reduced the incidence of fires, which allowed for regeneration of fire-suppressed trees.

The UFEP restoration plantings included large eastern white pine plantations and several acres of new hardwood forest. NRG did not plant shrubs or herbs during this time. In total, the UFEP program restored approximately 31 acres of the park's forest and planted over 14,000 trees with the help of community volunteers.

From 1999 to 2003, NRG restored three kettle ponds that flow into Alley Pond and Little Neck Bay, with funding from the Clean Water/Clean Air Bond Act through the New York State Department of Environmental Conservation (NYSDEC). Using multiple techniques, restoration teams removed invasive plant species from the upland areas around the kettle ponds. Teams treated eroded slopes and trails with geotextiles and other methods to reduce and redirect the flow of surface runoff and reduce erosion. Staff and volunteers planted native trees and shrubs as well as herbaceous plants to stabilize the soil. Turtle Pond, the largest and most heavily trafficked of the three kettle ponds, was encircled with a cedar-log fence to reduce pedestrian and mountain bike traffic. Over the course of this project, NRG oversaw the installation of a total of 18,025 square feet of erosion control fabric in a six-acre area and more than 19,000 trees and shrubs and 28,000 herbaceous plants across 32 acres. Today, these ponds support wetlands filled with native and exotic emergent plants and shrubs and diverse wildlife, including spotted salamanders, Fowler's toads, mallards, wood ducks, and other native fauna.

NRG staff applying herbicide to invasive plants in 2000.

Photo of volunteers planting trees in restoration areas in Alley Pond Park in 1994.

Following completion of the Bond Act project, NRG continued forest restoration work in Alley Pond Park with its own funding and staff. From 2004 to 2007, NRG planted 21 acres with over 9,000 native trees and shrubs. To increase capacity, educate the public, and improve stewardship, NRG established a partnership with a nearby high school under which staff taught students about forest restoration and stewardship techniques while the students participated in planting events. The Alley Pond Environmental Center (APEC), a non-profit environmental organization, has also partnered with NRG to help organize volunteer planting events, stewardship, and educational outings within the park.

At the start of the MillionTreesNYC initiative in 2007, NRG performed new site assessments throughout the park that identified additional areas choked by invasive plants such as porcelainberry and phragmites. Between 2007 and 2010, crews controlled invasive plants and, with the help of volunteers, planted more than 16,000 trees and shrubs across 17 acres.

Lessons Learned

Through over 20 years of forest restoration work at Alley Pond Park, NRG learned the following lessons:

1. Exclusion of vehicles significantly reduced the incidence of fires and dumping, which allowed for regeneration of forests.

2. Removing invasive plants, stabilizing slopes with geotextiles, and planting shrubs and herbs along with trees helped to reduce erosion and protect sensitive kettle ponds.

3. Working with multiple stakeholders and volunteers helped to increase the capacity of NRG to conduct restorations and provide stewardship to planted areas.

MillionTreesNYC planting at Alley Pond Park in April 2013. (photo by Daniel Avila)

Figure 1.3: Alley Pond Park: Forest Restoration Planting Areas, 1991-2010

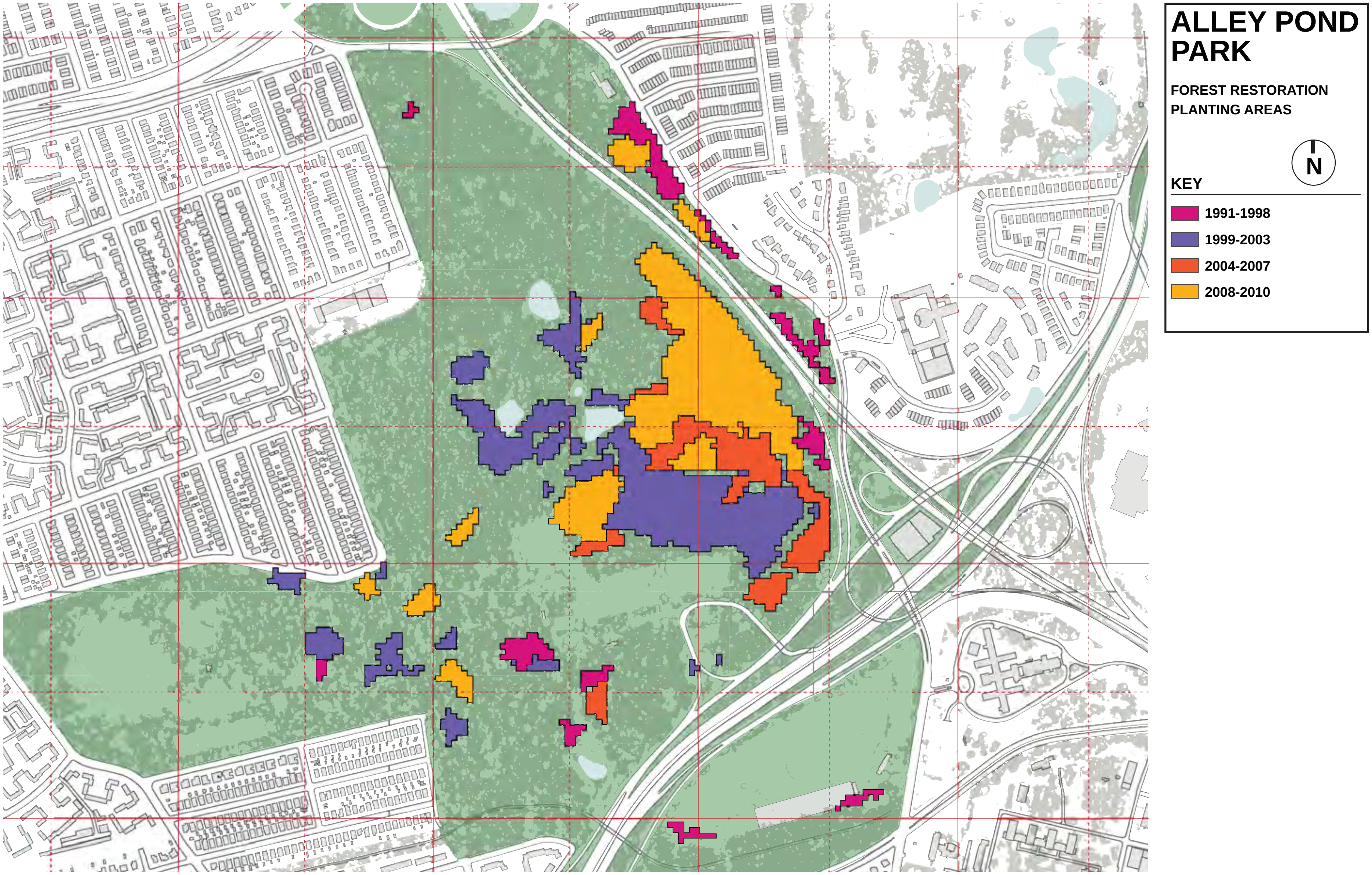
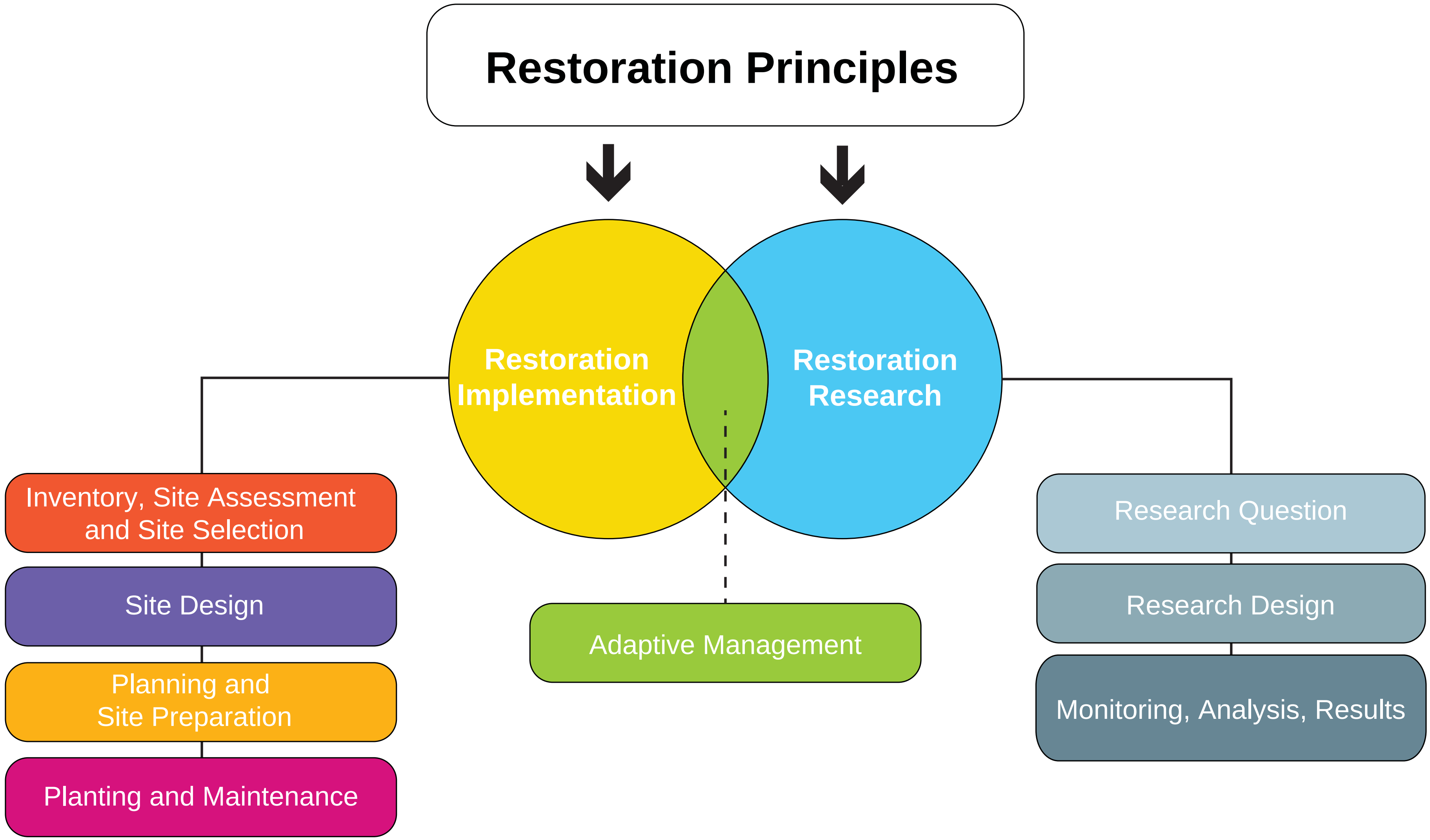


Figure 2.1: Role of Restoration Principles



Restoration principles guide both restoration implementation and research questions. Adaptive management is the process by which research and analysis can inform restoration practice and is discussed further in Chapter 6.

CHAPTER 2: THE URBAN FOREST: RESTORING STRUCTURE AND ECOSYSTEM FUNCTION TO NATURAL AREAS

Urban forests are mosaics of street trees, ornamental woodlands and gardens, disturbed and fragmented sites dominated by invasive plants, and remnants of intact native forests, all under the jurisdiction of a patchwork of public and private property owners. The primary goal of urban forest restoration is to return forest structure, processes, and composition to woodlands and forested areas to within a natural range, and thereby create self-sustaining ecosystems.

While at the fore of the relatively new field of urban restoration ecology, NRG's work is grounded in a deep understanding of established ecological principles. To better explain the best practices for restoring and creating healthy urban forests that will be discussed in the chapters that follow, we will first review the workings of the balanced ecological system that we are trying to realize. This chapter offers an introduction to the basics of forest and landscape ecology, as well as key restoration concepts.

Inwood Hill Park in early spring shows the multi-story structure of a healthy forest. (photo by Mike Feller)

VERTICAL DIVERSITY: MULTI-STORIED FOREST STRUCTURE AND ITS FUNCTION

Multi-storied forests are communities of plants dominated by trees in the canopy layer, with three additional layers below: the mid-story, the understory and the forest floor, all of which are crucial to the ecological function and sustainability of the forest system. The mid-story is comprised of slow-growing and shade tolerant trees that are poised to take the place of the canopy as it ages. The understory is made up of small trees and shrubs. The forest floor is comprised of small plants such as grasses, ferns and wildflowers. This layer also includes soil, decomposing organic matter, and an invertebrate and fungal community that supports and sustains the trees, shrubs, and herbs. Each strata provides a niche for forest fauna. Oven birds nest and feed on the ground; cardinals and wood thrushes nest and forage in the understory; and wood peewee and great-crested flycatchers are canopy denizens. There are crickets and katydids that are segregated to particular forest layer habitats. Chipmunks, common moles, and short-tailed shrew inhabit the forest floor, while southern flying squirrel dwell in the canopy.

Within and moving through these three primary layers are several key elements of the urban forest: climate, wildlife, and people. Regional macroclimates and local microclimates influence the dynamics of forests and play important roles in determining their biological potential. For example, temperature, wind, and topography all affect the availability of water within forests. The wildlife of the urban forest includes birds, reptiles, amphibians, mammals, and arthropods. These animals can be categorized as primary consumers that eat plants, secondary consumers that eat primary consumers, or decomposers that return nutrients and organic matter to the soil. Finally, people are a critical part of any urban ecosystem and can either help or hinder the restoration of urban forests. Vandalism, mountain biking, foraging, arson, and dumping are among the common human activities that undermine forest integrity.

Figure 2.2: Forest Structure

The different layers of the forest are constantly interacting with various biotic and environmental elements.

The plants found in the four layers described previously work in concert to form the multi-storied vertical structure of a healthy northeastern deciduous forest. Plants influence the environment around them in numerous ways. With their form and structure, they provide shade and buffer wind, which, along with the process of transpiration, mitigates air and soil temperature extremes and increases relative humidity. Plant leaves, stems, and trunks trap wind-blown soil and plant and microbe propagules. Plant growth produces an increase in the organic carbon and nutrient content of soil, as well as its water-holding capacity (Whisenant, 1999). These processes, by which existing plants help to support their own growth and that of new plant material, are part of what ecologists refer to as “facilitation” (Bertness and Callaway, 1994; Bruno et al., 2003).

Shrubs and herbaceous material also provide distinct benefits. Shrubs can serve as sinks for seeds, and promote seedling recruitment by attracting perching birds that disperse seeds. Seed germination and development is then aided by the shade cast by the shrubs and the organic matter that accumulates at their bases. When an open, exposed field becomes a forest, the shade provided by quick-growing shrubs helps keep invasive species in check, allowing for the establishment of desirable tree species.

Herbaceous cover provides the crucial function of stabilizing soil and preventing erosion. Herbs also help retain soil moisture and nutrients and ameliorate air and soil temperature extremes, which eases stress on seeds and seedlings in early successional sites. In their study on the effect of ground cover on tree seedlings, Maguire and Forman (1983) concluded that: “…the herb stratum cannot be regarded as a separate and independent component of the forest ecosystem. Not only do the herb species affect the composition and spatial pattern of tree seedlings, but the canopy trees also affect herb patterns. Viewed in total, the forest ecosystem therefore forms an integrated complex within which the herb species often play a significant role.”

The dynamic and symbiotic relationships within the vertical structure of a forest should inform restoration plans. Available restoration space that is not planted with diverse shrub and herb species adapted to growing beneath tree canopies will invite the recruitment of opportunistic species, most likely invasive exotics from surrounding areas. ‘Facilitation’ will be suppressed, and the forest balance upset, as invasives come to dominate a site. Practitioners should take a lesson from mature forests, where there is low invadability due to higher species packing so there is less space available for invasive exotics to establish. (Bazzaz, 1996).

The well established forests in “the clove” section of Inwood Hill Park in northern Manhattan exhibit the multi-storied vertical structure of a mature forest. (photo by Mike Feller)

HEALTHY FORESTS VS. STRESSED FORESTS

Healthy forests are characterized by:

- Complex and varied ecosystems adapted to the region, with a range of layers of vegetation, including canopy and understory trees, shrubs, wildflowers, grasses, ferns, and vines.
- Well-structured soils in which invertebrate and decomposition activity is considerable, and nutrient levels are supportive of native plants.
- Water regimes in which rainfall and run-off is effectively filtered, and stored in soil and plant roots.
- A resistance to disturbances, from disease, storms, and invasion by exotic species.
- Reproduction of native species.

Stressed forests are characterized by:

- Compacted or eroded soils that have a decreased capacity to absorb or retain rainwater, resulting in a simplified forest structure manifested by a lack of understory and groundcover plants.
- Soil contaminated by pollutants and characterized by reduced nitrogen cycles, drier conditions, extremes of pH, and altered decomposition rates.
- Soils lacking essential fungi and bacteria.
- Decreased fitness and resilience of native plants and animals.
- Increased presence of invasive plants and animals.
- Litter and dumping, as well as damage by fire and other types of vandalism.

The Croton Woods section of Van Cortlandt Park in the Bronx, an example of an intact urban forest. (photo by Chris Crews)

Stressed forests often have large gaps in the canopy as at this location in Givans Creek Woods in the Bronx.

HORIZONTAL DIVERSITY AND LANDSCAPE ECOLOGY

Healthy forests display not only vertical diversity - the layering of ground cover, understory, mid-story, and canopy - but also horizontal diversity, within the site at the landscape scale, and from site to site at the regional scale. Site variation at both scales can be the result of topographic changes that create different moisture regimes, soil depth, and slope aspect. Disturbance history, including past land use and natural events, can have a profound influence on the horizontal patterning of plant communities. Remnant building foundations, gardens, silviculture, and farming are also among the factors that have long-lasting effects on the horizontal structure of forests across landscapes.

Although restoration can occur at various scales (site, stand, etc.), the framework for NRG's restoration efforts is the greater landscape throughout the city and region. The science of landscape ecology, which informs NRG's approach, examines spatial patterns and their relationship to ecological processes and changes. Landscape ecology looks at the movement and dispersal of organisms, the effect of habitat adjacencies, and the interplay of ecological processes across scales. By understanding how individual sites function within the overall landscape pattern, forest restoration projects can be situated within a more expansive restoration strategy.

Landscape ecology presents the landscape as comprised of three major components: patch, edge, and matrix. The patch is the basic unit of a landscape, a spatially and temporally discrete area of land characterized by homogeneous environmental conditions. The edge is simply the border between patches. The background in which patches are imbedded is called a matrix. A matrix, however, may also be considered a patch in relationship to other matrices: a meadow may be a patch within a larger forest matrix, and a forest may be a patch within an even larger farmland matrix. The size and structure of patches, as well as the scale of the matrix of which they are a part, determines the landscape pattern. This pattern directly affects the flow of water, energy, nutrients, and pollutants across and through the landscape. Some landscape matrices may remain relatively fixed because of land use patterns or physical features (i.e., urbanization, a degraded landscape, or an intact forest). In other cases, patterns might reflect shifting mosaics of vegetation types and disturbances.

In New York City, forest patches exist within the matrix of the urban environment, which is dominated by buildings, roads, and maintained ornamental landscapes. These isolated patches are characterized by edge habitat. Connecting forest patches by expanding forested areas or creating corridors facilitates the movement of wildlife and vegetation and is among the goals of forest restoration in urban settings. Those "connections" take on different forms when considered at different scales. For example, if a 10-acre site is treated to remove invasive vines and planted with tupelos, that is a site-scale restoration. When birds eat the fruit of the tupelos and then distribute the seeds to nearby forest patches, there is a landscape-scale effect. Over time, an "archipelago" of forest patches colonized by tupelos develops, creating a migratory corridor for birds between two far-removed forest patches, representing a regional-scale effect. In these instances, scale can be measured in absolute terms (the real distances between patches) or in relative terms (functional distances). Forest patches a mile apart in a grassland matrix are functionally closer together than forest patches a mile apart in an asphalt matrix.

Shape, size, and juxtapositions of forest patches are particularly relevant to the robustness of forested areas, due to their direct relationship with sunlight availability. Forest plants have evolved for millennia to adapt to the low ambient light levels found beneath the tree canopy. Forest floor wildflowers known as spring ephemerals, for example, send forth leaves in April, quickly go to flower just in time to be pollinated by bumble bee queens that have overwintered as adults, and set fruit, all before canopy trees leaf-out in late May. The phenology - the seasonal sequence and timing of life cycle events - of forest ecosystem organisms is a complex choreography following the rhythm of light-dark cycles resulting from canopy leaf-out and shading.

Forest-interior songbirds such as the hairy woodpecker and scarlet tanager (pictured) require large, mature, multi-level forests for breeding. Increasing the size of forested areas will benefit these more unusual urban species. (photo by Mike Feller)

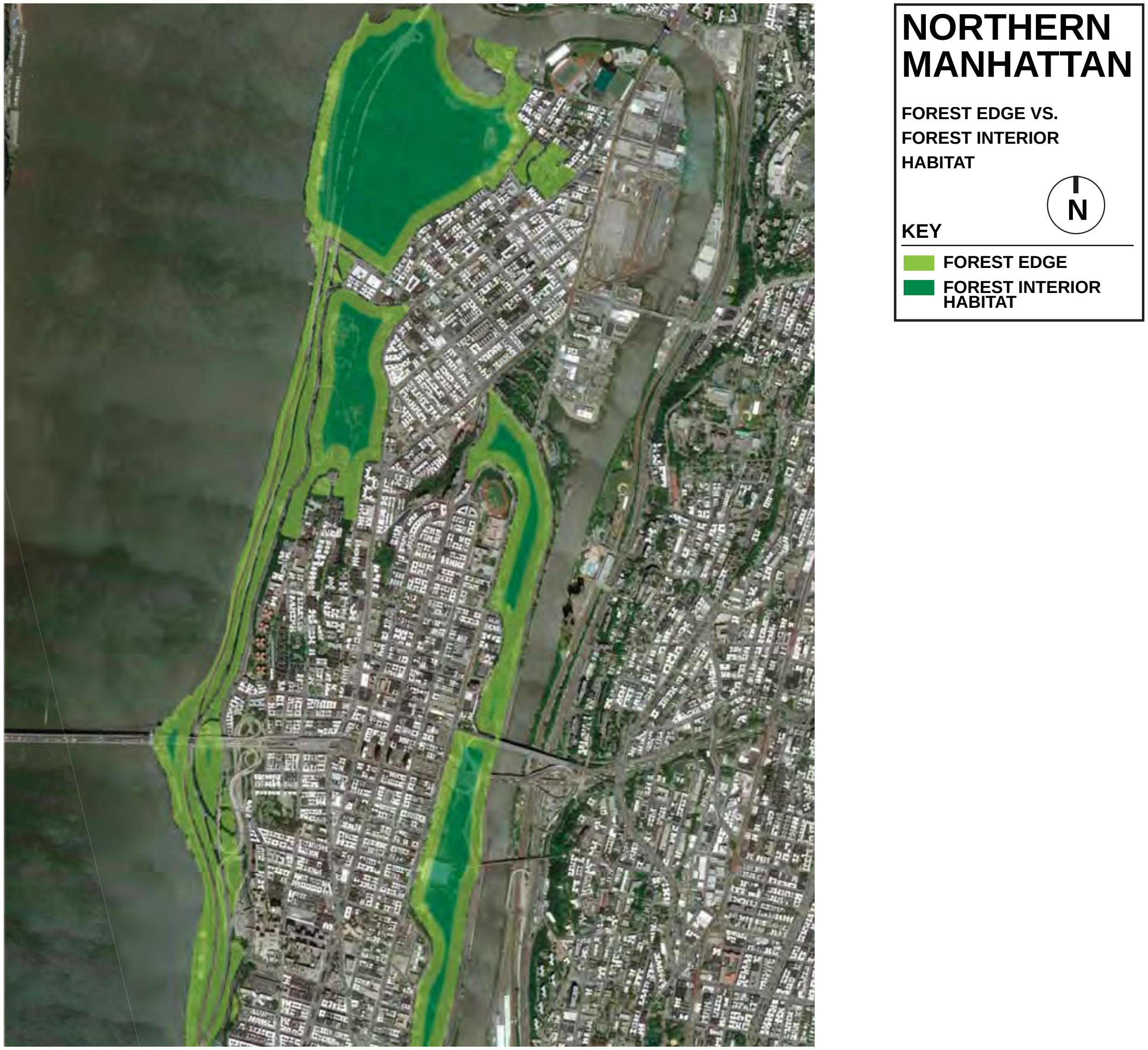
“Forest Edge Habitat” is a zone approximately 100 to 200 feet wide around the periphery of forests, and adjacent to areas within the forest where the canopy is absent or sparse, where light levels are not sufficiently limiting to maintain these fine-tuned relationships. The width of edge characteristics varies based on the type and height of vegetation on the edge, and the prevalence of foot traffic and other disturbance in a given location. A 200 foot wide edge zone may be typical where mature oaks or other large canopy trees come directly up to the border of the forest and abut hard-scape or active use areas; a more naturally curved edge with shorter denser vegetation such as shrubs and small trees on the perimeter, and taller trees in the interior, may exhibit a narrower band of edge characteristics because of its ability to deter foot traffic and limit light. The larger, rounder, and denser the forest patch, the smaller its “Forest Edge Habitat” to “Forest Interior Habitat” ratio. For example, a 200-acre round forest patch might be half edge and half interior, thereby having a 1:1 edge to interior ratio. Alternatively, a 200-acre long, narrow forest patch might be 100% edge. The greater the amount of interior habitat, the stronger the ecosystem will be.

Forest Edge habitat is often accompanied by a rapid decrease in fungal/mychorrhizal activity and increase in evapo-transpiration, resulting in increases in species turnover, extinction rates, desiccation, soil erosion, and ecosystem destabilization (Laurance, 2002). In New York City, while some sizable remnant forests remain, most forests are mainly or entirely composed of edge habitat.

In a multi-story forest, such as shown in Fairview Park, fungi are important for decomposition, plant nutrition, and as food for invertebrates in the soil. Fungi are reduced in abundance by invasive earthworms and garlic mustard. (photo by Ellen Pehek)

Some species benefit from edge habitat, such as the American robin (pictured), the gray catbird and the brown thrasher. Because urban development increases the proportion of edge habitat, the American robin and gray catbird are the most common birds found in wooded urban areas. (photo by Mike Feller)

Figure 2.3: Forests in the Urban Matrix



Forests in the urban matrix can exist as isolated patches or as part of linear forest corridors. Small or linear park forests will only be able to create an edge habitat. Only in larger, round parks, such as Inwood Hill Park at the tip of manhattan, is there the possibility of supporting a significant forest interior habitat.

FORESTS IN NEW YORK CITY

By the end of the American Revolution in 1783, nearly all of New York City's forests had been cleared for fuel or to make way for strategic vistas. The land then remained open, used for agriculture and woodlots, until the early twentieth century. At that time, the first of several building booms accelerated New York City's transformation into an emphatically urban metropolis. In the mid-twentieth century, the City filled thousands of acres of wetland with household trash and construction and demolition (C&D) rubble, the refuse of rapid growth and development.

New York City's extant forests can be divided into four categories of previous land use. Each category of previous land use usually only covers a portion of the park given as an example. Van Cortlandt Park is used in several examples because NRG has conducted restoration work there for many years, and has conducted two entitations of this property.

1. Seventeenth-Century Forests

Seventeenth Century Forest: Northwest woods in Van Cortlandt Park. (photo by Mike Feller)

These forests regenerated in locations where forests had existed before the Revolutionary War. They occur chiefly where agriculture was not feasible, including steep and/or rocky slopes in Manhattan, the Bronx, and Staten Island, and along the glacial terminal moraine in Brooklyn, Queens, and Staten Island, where stony infertile soil was not amenable to farming. Such forests were managed for timber and firewood. Rapid regrowth of such native forests was enabled by soil seed banks representative of pre-Revolutionary War forests, by the presence of surrounding agricultural matrices that, as late as the nineteenth century, were still relatively devoid of invasive exotics, and by relatively low levels of soil disturbance.

Examples include New York City's highest quality forests dominated by mixed native oak species:

- Bronx: Northwest Woods, Van Cortlandt Park
- Brooklyn: The Midwood, Prospect Park
- Manhattan: The Clove, Inwood Hill Park
- Queens: Forest Park
- Staten Island: High Rock Park

2. Farm Fields

Historical photo from Alley Pond Park showing former farm field in the late 1800s.

Forests that eventually colonized abandoned farm fields occur primarily on the relatively flat glacial outwash plains in Queens and Staten Island, where farming continued well into the twentieth century. Years of repeated plowing removed the original forest soil seed bank and disturbed the soil by creating a “plow pan,” a compacted layer of soil about three feet below the surface that restricts drainage. At the time of agricultural abandonment - the 1930s and 40s in Queens and the 1960s in Staten Island - many of these sites were surrounded by suburban matrices containing invasive exotic species. This resulted in colonization by Norway and sycamore maple (*Acer pseudoplatanus*), tree of heaven (*Ailanthus altissimia*), white mulberry (*Morus alba*), and others.

Examples of forests that colonized farm fields occur in:

- Queens: Alley Pond Park
- Queens: Cunningham Park
- Queens: Kissena Park

3. Estates

Former estate forest on Hunter Island, Pelham Bay Park, with day lily dominating the understory. (photo by Mike Feller)

Although difficult to imagine now, large parts of upper Manhattan, the Bronx, and eastern Queens were destinations for wealthy New Yorkers escaping the summer heat of the city. These affluent landowners planted their country estates with species that were in vogue at the time, often transplants from Asia and Europe. Some of New York City’s present-day parks are remnants of such estates and are characterized by intact soil structures, albeit with seed sources that do not reflect native plant populations and often include invasives. These species include day lilies (*Hemerocallis spp.*), periwinkle (*Vinca minor*), wisteria (*Wisteria spp.*), and Norway maple. There are also remnant trees such as giant ginkgos (*Ginkgo biloba*) and purple beech (*Fagus sylvatica*) that do not reproduce.

Examples of forests that colonized former estates occur in:

- Bronx: Hunter Island, Pelham Bay Park
- Bronx: Van Cortlandt Mansion and Parade Ground,Van Cortlandt Park
- Staten Island: Conference House Park
- Bronx: Bartow-Pell Woods, Pelham Bay Park
- Staten Island: Wolfe’s Pond

4. Anthropogenic Soils

Forests have also colonized “made land” resulting from New York’s extensive twentieth-century landfill operations. Landfill material is of three broad classes: construction and demolition fill, sanitation fill, and ocean dredge sand. Each results in a distinctive flora, and each presenting a characteristic set of restoration constraints. In some parks two or three of these types are mixed or present in layers.

4A. Construction and Demolition Fill

Construction and demolition fill at Kissena Corridor Park. (photo by Mike Feller)

Soil derived from construction and demolition (C&D) rubble includes stone, concrete, brick, timber, coal cinders and incinerator ash. Particle sizes range from large concrete slabs to gravel-sized coal clinkers to small clay and dust-like particles of rock, bricks, and gypsum. The resulting soil tends to have low nutrient levels, low permeability, high pH, high soluble salts, and low moisture. Most vegetation growing on such soils in New York City are non-native trees, herbs and grasses such as tree of heaven, white mulberry, mugwort (*Artemisia vulgaris*), wormwood (*Artemisia absinthium*), sweet clover (*Melilotus officinalis*), and orchard grass (*Dactylis glomerata*). In addition, some native species such as the native eastern cottonwood and black cherry can grow on these sites. These low nutrient soils are frequently found to support a prevalence of nitrogen-fixing legumes.

Examples:

- Bronx: Soundview Park
- Brooklyn: Spring Creek
- Queens: Powell’s Cove, Kissena Park

4B. Sanitation Fill

Sanitation fill at Marine Park. (photo by Mike Feller)

Sanitation fill sites are those that were filled during the mid-twentieth century with household refuse, including food, clothing, paper, metal and glass. Thousands of acres of New York City wetland were filled with sanitation landfill and many formerly unregulated landfill sites are now fallow natural areas of substantial size. The soil that resulted from this fill tends to be characterized by very high nutrient content, high moisture, high organic matter, and low permeability. Soil particles at such sites are very small clay-like organic muck or very large crushed glass and other non-putrescible debris. These sites often support monocultures of the highly invasive grass phragmites (*Phragmites australis*). Trees - including gray birch (*Betula populifolia*), black cherry (*Prunus serotina*), and red maple (*Acer rubrum*) - sometimes colonize phragmites-dominated sanitation fill sites in the absence of fire.

Examples:

- Brooklyn: Marine Park, Brooklyn
- Queens: Alley Pond Park, Queens
- Staten Island: Fresh Kills Park, Staten Island

4C. Dredge Material

Dredge fill at White Island. (photo by Mike Feller)

Throughout the 20th Century, the City dredged its rivers to accommodate the shipping industry's needs. The surplus of sand from the mouth of New York City's harbor was used to cover sanitary landfills and salt marshes. The dredging of Rockaway inlet and shipping channels, especially the Arthur Kill and Kill Van Kull, continues as needed. These soils have high sand content and exhibit low nutrients, low organic matter, low moisture, circum-neutral pH, and high permeability. Characteristic herbaceous vegetation includes warm season grasses and forbs representative of native coastal communities. Woody vegetation includes native coastal scrub such as bayberry (*Myrica spp.*), and sumacs (*Rhus spp.*) and sassafras (*Sasafrass albidum*), tupelo (*Nyssa sylvatica*), willow oak (*Quercus phellos*), and American holly (*Ilex opaca*).

Examples:

- Queens: Idlewild
- Brooklyn: Marine Park
- Brooklyn: Plum Beach

ECOSYSTEM STABILITY

Resistance, Resilience, and Robustness

Ecosystems are complex communities of biotic (plants, animals, and microorganisms) and abiotic (water, minerals, atmosphere and light) features that occupy the same habitat. Over time, the biota of an ecosystem adapt to one another and their abiotic conditions through the process of natural selection, creating a self-regulating system. Within this stable but dynamic system, populations fluctuate as organisms respond to their circumstances and surroundings. For example, predators exert pressure and limit the growth of prey populations, yet predator populations also depend on, and vary directly with, prey populations. Thus, though an ecosystem is healthy and balanced, change is inevitable and expected.

It is helpful to consider ecosystem stability as encompassing three essential characteristics (Society of Ecological Restoration, 2004) - the three Rs - as follows:

- Resistance: The capacity of a system to sustain small perturbations and absorb them in such a way that they are not amplified into larger disturbances (like a boxer able to roll with the punches);
- Resilience: The ability of a system to return to its original state after a perturbation (like a boxer who is able to get back up and continue boxing after being knocked down); and
- Robustness: The amount of perturbation a system can endure without switching to another state (like a boxer who is repeatedly knocked down, yet remains conscious).

While ecosystems do display great capacities for self-perpetuation, they have also proven to be vulnerable to the activities of humankind. This is nowhere more obvious, in extent and rapidity, than in and around cities where fragmentation and spatial isolation decrease ecosystem stability. The pressures exerted by urban development test the resistance, resilience, and robustness of even our strongest systems. The two largest national parks in the USA - Everglades and Yellowstone, each more than one million contiguous wilderness acres in extent - require active management and restoration to combat invasive species, over-abundant nutrient sources, and erosion from overuse. These two parks are five orders of magnitude larger than most natural areas in New York City and are surrounded by even more wild and rural land. Our isolated and exposed urban forests, therefore, will likely demand even greater attention to become and remain stable.

Restoring Ecological Function

Ecological restoration is a process that facilitates the recovery of degraded or destroyed ecosystems (SER, 2004). This process may be approached in a literal sense, with restorers identifying ideal reference sites and attempting to mimic their physical, biological, and aesthetic characteristics in order to return a forest to a prior state (SER 2004:1; Morrison 1987:160). Alternatively, restoration may be approached from a functional or ahistorical perspective. NRG necessarily embraces a functional approach, in large part due to the fact that the historical contexts of the sites under its aegis no longer exist. Long ago, the remaining forests of New York City were part of a relatively continuous forest stretching west to the tall grass prairies of the Midwest. The American chestnut, a species virtually extinct since the 1930s, was predominant. This pre-colonial environment is unrecognizable in the current urban landscape to such an extent that it is practically irrelevant. Therefore, in New York, as in most urban environments, embracing a functional rather than a literal approach to forest restoration is far more rational.

NRG restores forests so that they provide the same ecological functions as historical ecosystems, while using soils, hydrological systems, and species that differ from the literal site history. Morrison (1987:160) offers an apt summary of NRG's landscape restoration strategy: "The reintroduction and re-establishment of community-like groupings of native species to sites that can reasonably be expected to sustain them, with the resultant vegetation demonstrating aesthetic and dynamic characteristics of the natural communities on which they are based."

Establishing a natural trajectory towards self-sufficiency - the ultimate goal of restoration - begins by enabling the return of a forest ecosystem's fundamental components. Such a process may occur organically by means of natural seeding over time, but in a modern urban context where forest structure and health have been severely altered or destroyed, people must step in to stimulate this process. By improving species composition, community structure, ecological function, and connectivity with the surrounding landscape, restoration practitioners give compromised ecosystems the chance to get back on track (Clewell and Aronson, 2007).

CHALLENGES TO NATURAL FOREST SUCCESSION IN URBAN ECOSYSTEMS

From the inventories it assembled during the 1980s and '90s, NRG identified several frequent causes of disruption to ecosystems that cannot be remedied without human intervention and management, including: urban fill soils, invasive plants, fragmentation, and fire.

Urban Fill Soils

Soil is the substrate where the physical and chemical weathering of rock and the decomposition of organic material by microbes, invertebrates, and water make minerals available to plants - an essential process in terrestrial ecosystems. Many spaces available for reforestation in New York City consist of anthropogenic soils, as described previously. These soils often contain toxins like heavy metals and petroleum hydrocarbons and diverge in almost all relevant characteristics from native forest soils. In the Northeast, forest soils are typically well-drained sandy loams or loams having relatively low available nitrogen, with pH levels ranging from neutral to slightly acidic (7.6 to 4.5). In New York City, urban fill can have dramatically variable texture, pH, and nutrient characteristics. This highly compromised medium presents critical, though not insurmountable, challenges to urban reforestation.

Invasive Species

A wide variety of non-native plants have been introduced to North America - and they will continue to arrive - both intentionally, through horticulture, and unintentionally, through ship ballast and packing materials. In some cases, newly arrived species do not spread: they do not migrate vegetatively into surrounding areas; they do not produce viable fruit, due to a lack of appropriate pollinators or other factors; or they do not out-compete native vegetation. Many times however, newly arrived plants become invasive: they thrive and expand rapidly in the absence of natural controls, such as competing plants, predators, or diseases. A climate similar to that of their original habitat coupled with adaptations to the light and disturbance levels common in cities can allow non-native invasive species to smother, crowd and strangle existing vegetation. These plants tend to decrease overall biodiversity and available habitat and water, disrupt natural disturbance regimes, and alter soil conditions in ways that prevent the germination and/or establishment of native plant species. The presence of these aggressive newcomers threatens the structure and function of our native forests.

The persistent reproductive strategy of invasive plants, both vegetative and by seed, is such that eliminating or controlling them can take multiple seasons. For example, porcelainberry, a woody perennial vine that was introduced into New York City's parks as a landscape plant in the 1870s, escaped and spread across the region. Porcelainberry vigorously spreads across wooded and open habitats and climbs over other vegetation, sometimes growing up to 15 feet in one growing season, thus quickly shading out native plants. Because porcelainberry can resprout from seeds that lay viable in the soil for many years, eradication takes dedication and time.

Several studies have been performed to compare the historical flora of New York City's boroughs with the distribution of species found in recent decades. All have found an approximate 40% loss of native plant species, and attribute this largely to the rapid increase in invasive exotic plants that began in the second half of the twentieth century (Buegler and Pairisi, 1981; Handel et al., 1994; Decandido et al., 2004).

Fragmentation

Throughout the Northeast, and in New York City in particular, forest was the dominant vegetation cover type following the stabilization of the planet's climate approximately 7,000 years ago. Local plant communities varied from forest to scrub and meadow in response to variations in soil depth and hydrology. Where soil cover is thin, and where soil is toxic (as at a few sites on Staten Island where serpentine bedrock is a soil parent material), herb- and shrub-dominated upland plant communities prevail and persist.

In the area of present-day New York, a mosaic of mostly stable ecosystem types evolved together over millennia: forest where there was sufficient soil, scrub and meadow along rocky outcrops and disturbance-derived gaps, and marshes and shrub swamps where hydrology was non-conducive to tree growth. Succession occurred without disturbance. For example, a forest dominated by maple and beech would evolve to one dominated by oak. Such successions also occurred in small, discreet areas due to disturbances such as windfalls, drought, beaver activity, or fire, resulting in birch and tulip tree regeneration.

Native American land management practices, European agriculture, and suburban and urban development dramatically altered the structure and disturbance regimes of the region's forests. Transportation corridors further divided these stressed environments. Instead of having expansive cloaks of forest, the region now has isolated patches and occasional corridors dominated by forest edge habitat. Only rarely is there sufficiently broad canopy coverage to create a true forest interior of the type in which many of our native species coevolved.

Since historically forest edges were rare, there are relatively few native species capable of surviving over multiple generations in such conditions. Meanwhile, many invasive exotic species thrive in edge areas, and successfully create new suitable habitat by knocking down, crowding out, or trellising over the existing edges. The occupation of these edges by invasive species seriously threatens the continued existence of the indigenous plant, animal, and invertebrate communities of our remaining forests (Gargiulo, 2007). For example, birds that are adapted to forest edges, including American robin (*Turdus migratorius*), mockingbird (*Mimus polyglottos*), blue jay (*Cyanocitta cristata*), and cowbird (*Molothrus ater*), are frequently nest predators that suppress breeding success of birds adapted to forest interiors. They also disperse seeds of edge-adapted plants, many of which are non-native and invasive (Meffe et al., 2002).

Fire

In New York City, the natural fire regime is no more than once every thirty years, however, over the years, arson in many of the city's forests has created extremely unnatural fire regimes. NRG discovered that some forest areas were burning as frequently as five to six times a year. These unnatural fires were commonly caused by car thieves who would dispose of stripped cars by setting them on fire in remote natural areas. Frequent fires suppress regeneration in the understory and even kill large, thick-barked, fire-tolerant trees such as oaks. Often, the only native tree regeneration is by clonal fire-resistant species such as sassafras and quaking aspen. In addition, the fire scarred landscapes created new light regimes, propitious for exotic vine invasions (Nixon, 1995).

Hunter Island, in the Bronx, had a history of fires occurring at least every other year for many years, creating an artificial savannah-like open condition. In 1987, NYC Parks effectively excluded traffic from the mixed deciduous forests, initiating a fire-free period during which the forest saw much regeneration, especially of oaks. However, when fire returned seven years later in 1994, it killed back a significant proportion of the regenerating saplings. Resprouting has not made up for this loss, nor has recruitment of new trees into the canopy taken place. NRG has concluded that fires spaced as closely as seven years are a detriment to the health and regeneration of forests, even oak forests, and that forest managers should strive for fire-free intervals longer than this period.

Fire suppresses regeneration of the forest understory. (photo by Mike Feller)

Conclusion

The challenges to urban forest restoration are many, but they can be overcome with thoughtful and realistic planning and intervention. Observing the composition and ecological function of a healthy multi-story forest shows us the ideal. In the city, we use that understanding to work towards the attainable. Building robust urban forests requires navigating both the practical and the political, maneuvering around and through environmental roadblocks, as well as public/private interests and budgetary constraints. The chapters that follow will take you through NRG's process of maximizing ecological value in the city.

CASE STUDY: Restoration Lessons from the Urban Forest and Education Program (UFEP)

Project Duration: 1991-1996

Site Location: Multiple Parks including: Alley Pond Park, Forest Park, Cunningham Park, Fort Tryon Park, Inwood Hill Park, Pelham Bay Park, Van Cortlandt Park, Riverdale Park, Prospect Park, Wolfe's Pond Park, Blue Heron Park, and the Staten Island Greenbelt (mapped by initials)

Size and land type: 8,000 acres of forested parkland.

Forest Type: Oak/hickory, Oak/tulip, Oak/sweetgum, various disturbed and invaded forests.

Soil Type: Glaciated native soil, former farmland, disturbed edges.

Pre-Restoration Site Conditions

Entitation results from 1986-1990 revealed management concerns in forested areas of NYC Parks across the city such as invasive plants, dumped vehicles and household waste, arson, and vandalism.

Restoration Goals

- Remove invasive plants and restore native forest structure including canopy, understory and herbaceous layers
- Determine the best type of tree stock and method of planting for effective forest restoration

Production of seedlings used for UFEP restoration work.

Methodology and Results

The Urban Forest and Education Program spanned five years and planted over 150,000 trees. When the project began, UFEP followed the standard contemporary silvicultural practice of focusing first and foremost on planting trees as the main structural element in the forest. It was assumed that the forest's other elements (understory, herbaceous layer, soil, and wildlife) would follow naturally after the formation of a canopy. Practitioners assumed that once trees were installed and established, the trajectory of the forest would correct itself: altered light conditions and reduced disturbance would inhibit or eliminate the growth of invasive species, trees would grow taller and help form a healthy forest floor, and native shrubs and herbs would emerge. Over the years NRG began to see that the trajectory of sites planted using these strategies varied considerably. The dense plantings of two to three tree species favored early in UFEP quickly became dominated by a single species. Stands of sweetgum (*Liquidambar styraciflua*) mixed with red oak (*Quercus rubra*) became mostly sweetgum. Stands of white pine planted together remained a monoculture. In addition, the understory and shrub layer remained vacant for many years, thought to be due to a lack of any nearby seed source, lack of recruitment, or the dense crowding of the stand.

UFEP teams also experimented with different tree planting stock and techniques. At the first sites planted, teams tried seeding acorns, however 95% were lost to predation by small mammals. Later efforts included planting four-foot tall balled and burlapped (B&B) trees at eight to ten foot spacing, bare root trees at three-foot spacing, and two-foot whips in containers at four-foot spacing.

Though the UFEP plantings did not have any funding for research, a series of plots were established to obtain rudimentary data on the efficacy of various planting techniques. UFEP collected data on seedling survival and growth rates periodically for 1-5 years after planting. In monitoring the early plantings, staff observed that the widely spaced B&B trees were slow to close their canopies and required significant management to keep invasive plants in check. NRG also saw that small bare root trees easily succumbed to predation. Ultimately, the tightly spaced container trees created a closed canopy the most quickly. One and two-gallon potted trees were inexpensive to purchase or grow in-house, easy to handle, and often caught up in size to B&B trees in just a few years.


UFEP Planting.

Lessons Learned

The five years of UFEP planting and observation of UFEP plots lead to the following key conclusions:

1. Shrub and herb layers do not develop independently in direct consequence of tree reestablishment, but must be planted in order to restore the structure of native forests
2. Higher diversity plantings seem to be more successful in encouraging in-growth of desirable species, while still discouraging invasive plant growth.
3. Small container-grown trees can establish a canopy at a similar or faster rate than B&B or bare root stock.

Follow-up investigation of UFEP sites by Lea Johnson of Rutgers University in 2010 showed that after 15-20 years, these initial restorations had resulted in persistent change in species composition, decreased abundance of invasive species, and more complex forest structure and increased native tree recruitment compared to sites that were invaded but not restored. She also found that greater post-planting maintenance was associated with more desirable restoration outcomes. More information about Johnson's findings are in the Chapter 6 section on Adaptive Management and Research.

UFEP white pine planting in Alley Pond Park in 1992.

UFEP white pine planting in Alley Pond Park in 2008.

PART 2

PART 2

PART TWO:

PLANNING THE WORK

Figure 3.1: Restoration Site Selection Process

CHAPTER 3: SITE INVENTORY, ASSESSMENT, AND SELECTION

In this chapter, we move from the conceptual to the practical. Creating self-sustaining multi-storied forests is the fundamental goal of forest restoration, and achieving that end in the challenging context of a dense urban environment, with its myriad of ecological and logistical constraints, is no small feat. To find success, mindful planning and decision making from the earliest stages of a project are essential.

After many years of tending to New York City's forest ecosystems, NRG has established a clear set of steps to guide its teams from site selection through installation and beyond. All sites may be unique, yet the same basic framework of questions and considerations can apply to forest restoration at any site, in any city.

The first part of the planning phase is the selection of a viable site. NRG breaks this process down into four main steps that will be expanded upon below:

- Establish Goals
- Review Opportunities and Constraints
- Assess Sites in the Field
- Evaluate and Prioritize Sites

Debris.

Invasives.

Many sites available for forest restoration are characterized by conditions and contexts that make forest establishment challenging. Debris and invasive species are two of the common challenges found at potential forest restoration sites.

Figure 3.2: Setting Goals at Different Spatial Scales

ESTABLISH GOALS

Before a project begins, formulate clear programmatic goals and objectives. Articulating overarching goals will help guide your process, as you return to those ideas to make decisions along the way, and enable you to communicate more effectively both internally and externally to stakeholders. Ultimately, these goals and objectives will become the basis for evaluating project success and will help shape adaptive management strategies.

For major initiatives that span a wide geographic scope and have a multi-year horizon - like New York's MillionTreesNYC - goals will likely be defined at multiple spatial and temporal scales. Establish long-term and large-scale goals first, making your way down to those that address site-level hands-on implementation. The broader goals will be helpful for defining individual work projects.

For MillionTreesNYC, an example of goals across temporal scales would be:

- Long Term: Planting of 480,000 trees in natural areas over 10 years.
- Short Term: Planting of 20,000 trees in a season with volunteers.

For the same project, an example of goals across spatial scales would be:

- Regional: Maximize the area of healthy forest canopy citywide.
- Landscape: Reforest sixteen acres in Kissena Corridor Park.
- Site: Plant the right species in the right place, such as sweetgum and tupelo at the bottom of slopes and white pine (*Pinus strobus*) at the top of hills.

REVIEW OPPORTUNITIES AND CONSTRAINTS

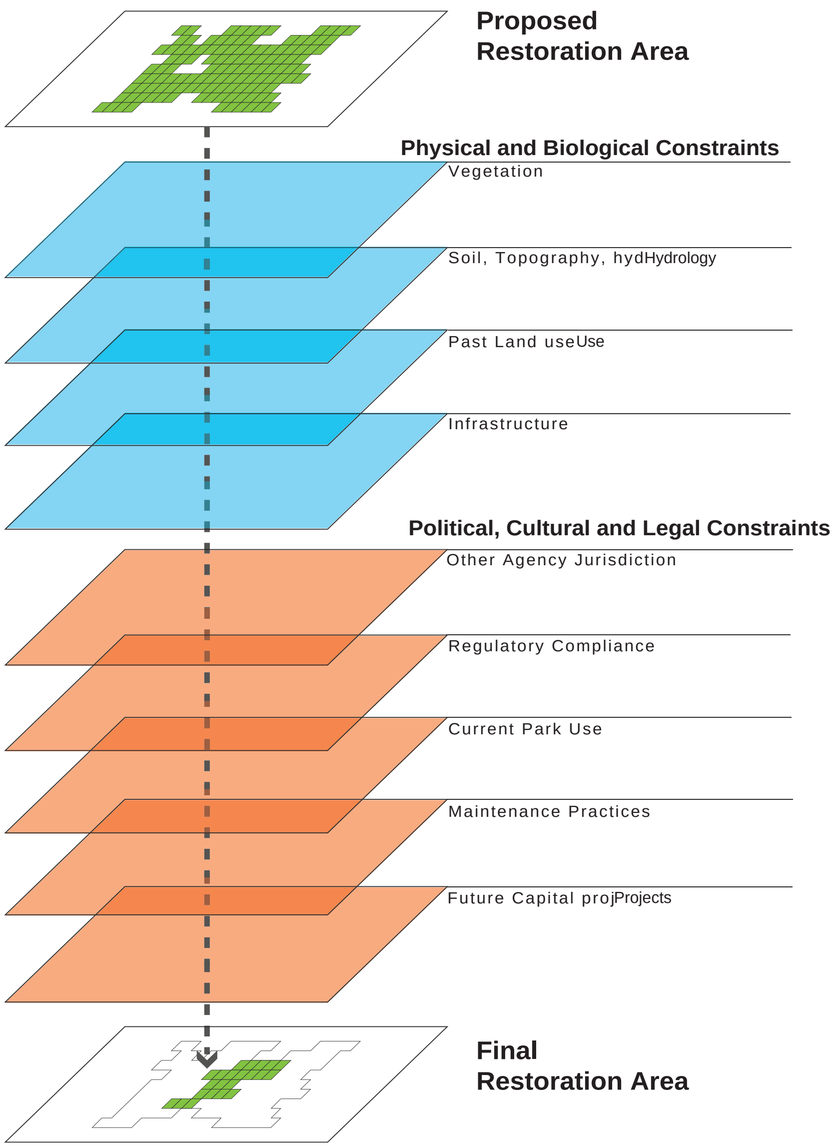
Figure 3.3: Opportunities and Constraints Diagram

Criteria	Constraints								Opportunities
Space	Private Owned						Federal Owned	State Owned	City Owned
Shape	Linear								Round
Size	Small < 10 acres								Large > 10 Acres
Soil	Absent (paved)	Anthropogenic Soil Hazardous Fill	Anthropogenic Soil Clean C&D Fill	Anthropogenic Soil Clean Sanitation Fill	Anthropogenic Soil Ocean Dredge	Cultural Soil (Horticultural or agricultural)	Natural Soil Disturbed	Natural Soil Undisturbed	Present Green Space
Existing Habitat	Federally Endangered flora/fauna	State rare flora/fauna	Locally Rare flora/fauna	Native Plant Communities			Invasive plant Dominated	Lawn	Canopy Gap
Park Use	Programmed	Active		Passive					Unprogrammed
Access	Difficult								Easy
Ecological Context	Surrounded by Invasives	Adjacent to Invasives	Near Invasives	Near Native Plants	Adjacent to Other Native Plants	Adjacent to Native Forest	Surrounded by other Native Plants	Natural Soil Undisturbed	Surrounded by Native Forests
Conservation Policy	No Policy				Tree/Forest Protection Policy				Funded Initiative
Regulatory	Regulated Wetland	Mapped DEC Freshwater Wetland	Mapped DEC Freshwater Adjacent Area	Mapped DEC Tidal Wetland	Mapped DEC Tidal Wetland Adjacent Area				Unregulated
Historic/ Cultural	Significant	Designated Landmark	Archeological sensitivity	Notable Designer	Anthropogenic Soil Ocean Dredge				No Significance

Many constraints are hurdles, not barriers. Look at the entire constellation of opportunities and constraints and use this method to identify sites that can be restored with the greatest ease. In time, programs will move beyond the low hanging fruit and on to increasingly challenging sites.

The factors to be weighed when evaluating a site cover a wide spectrum: from the political to the practical, from the ecological to the social, and from the spatial to the financial. Though the technical question, “Can trees live here?” and the political question, “Can we get permission to work here?” will lead the review process, from there, a rather nuanced approach will be required. Restoration involves looking at all the virtues and liabilities of a site together and assessing how they relate to the needs and resources of a community. It is an exercise situated in gray areas, where black-and-white answers are neither available nor relevant. Though sites with many constraints often cost more to restore and thus may limit a project’s total acreage, some values less tangible than size and budget may be important to consider. For example, a prospective site in a neighborhood with great public health needs might have multiple constraints (e.g. degraded soils, small size, little ecological context, poor access), but may remain compelling because of the potential benefits provided by a forest in this context.

Figure 3.4: Review Site Constraints Diagram



A review of multiple categories of information can help to focus forest restoration work on where it will be most successful.

Geography and Land Use Context

In any urban context, and especially in New York City, forest restoration competes with many other land use priorities. Housing and real estate development demands limit the area that is available for parkland. Within parks, natural resource conservation and restoration compete with other desirable uses of the park for active and passive recreation, such as sports fields, bike trails, and playgrounds, lawns, and ornamental gardens. Review current and proposed uses of the land carefully. In existing park areas, public programming and active recreation can conflict with the goals of site restoration. Passive uses, such as unpaved walking paths and nature interpretation programming, are usually compatible with reforestation with only slight adjustments.

The abundance of geographic resources at NRG's disposal have been essential to its efforts to restore existing forests and find appropriate space on which to restore forests. With present-day remote sensing data, NRG can identify vegetated areas, infrastructure, access points, prominent features, adjacent neighborhoods, and the general outlines of parks. Existing maps can also provide information about a site's size, shape, and matrix, as well as its regulatory and cultural framework. Such data will give you an analytic framework for understanding spatial patterns within the historical, ecological, and cultural context of each site.

NRG'S USE OF GEOSPATIAL DATA AND TECHNOLOGY

NRG has been using and developing geospatial data since its inception.

1984: NRG used existing tax maps to identify all New York City parkland and affix park boundaries to New York State Department of Transportation Planimetric Maps at a scale of 1:24,000 (the same scale and geographic coverage as USGS topographic quadrangles). Knowing the extent of New York City's parkland was NRG's first step towards assessing the extent of NYC Parks' natural areas and formed the base layer for all further analyses.

1985: NRG contracted with the Cornell Laboratory for Environmental Applications of Remote Sensing (CLEARS) to use aerial photography at a scale of 1:24,000 to map land use and vegetation cover for all New York City parkland, including state and federal properties. This resulted in transparent Mylar vellum maps that could be overlaid onto park boundary maps. For the first time, the distribution of parkland and greenspace across New York City's five boroughs was made visible. These maps delineated formal parkland and categorized natural areas in four vegetative cover types: grassland, forest, tidal marsh, and freshwater wetland.

1985-1990: NRG field staff used entitation surveys to map plant communities in the city's largest natural areas at a scale of 1:1,200 according to dominant cover type. The mapping process included all plant communities larger than 100 square feet.

1990-2000: NRG extended this entitation effort to smaller properties outside NYC Parks' portfolio that were being recommended for acquisition by the department. In 1992, NYC Parks became the first city agency to use Geographic Information Systems (GIS).

2000-present: NRG has been re-entitating some parks to assess changes in plant communities and to inform restoration planning. NRG's restoration work now relies heavily on the orthoimagery collected every few years by NYC's Department of Information Technology & Telecommunications. Complementary to these efforts, in 2010, NYC Parks partnered with the University of Vermont's Spatial Analysis Lab to use object-based image analysis to create a high-resolution land cover map of NYC's entire land area using an innovative combination of LiDAR data, aerial imagery, and planimetric vector data (see Appendix 1 for where data is available for download). GPS technology is widely used to map planting areas and other features of interest for land management. Most recently, a web-based mapping application was developed for NRG's field staff to map their work activities on a daily basis. NRG also began a program to evaluate the site conditions of our past planting areas using GPS data collectors with customized forms. The data collected is used to review how our past restoration practices have worked and to help inform future restoration practices at individual sites based both on their past histories and current conditions.

Future Data Collection: Through NRG's partnership with the Natural Areas Conservancy, the 2010 land cover OBIA (Object Based Image Analysis) mapping methodology will be extended and further refined by the Spatial Analysis Lab to develop a comprehensive, NYC-wide map of ecological communities.

Ecological and Vegetative Context

The ecological context of a proposed site, in terms of what surrounds it (i.e., its matrix) and what land types are adjacent to or near it, affects the sustainability of a future forest. A reforested site within a matrix of native forest or adjacent to a native forest will benefit from both existing ecological processes, including sources of native forest plants and animals, and a buffered micro-climate. Conversely, a matrix of, or close proximity to, invasive species or hardscape is a constraint.

Larger sites generally allow for more efficient work plans and yield better overall results, often with less effort expended. All else being equal, larger sites can produce more robust and resilient forests that provide greater benefit and require less maintenance. As discussed in Chapter 2, circular or square habitat patches possess greater integrity, are more resistant to invasive species, and are more sustainable than oblong and linear sites of the same area.

Existing vegetation on a site can be a strong indicator of soil quality and hydrology, which in turn can be suggestive of the potential ease or difficulty of restoration. A comprehensive vegetation survey may also identify: where healthy or rare plant communities exist in relationship to one other, which areas of a site are in greatest need of restoration, and where targeted restoration will most enhance ecosystem function.

It is quite likely that sites dominated by invasive plants will rise to the top of your restoration list. These areas often began as forests, meadows or wetlands, but, after years of disinterest or abuse, became ecologically unhealthy and imbalanced. At these sites, positive uses that conflict with forest restoration are rare. Surrounding communities often perceive them as eyesores and as the loci of undesirable activities, and by restoring them they can develop a higher value in the eyes of surrounding communities, as well as a higher ecological value. These factors will contribute to the appeal of these sites for restoration work. Acquire as much information as possible about the extent to which a site is dominated by invasive species so that you can adequately assess the time and resources that will be required for its restoration.

The site should be carefully evaluated for the habitat values that still exist and may be lost. The outcome of planting new forests should be the largest, least ambiguous gain in habitat function. An expanse of mowed lawn does not possess much habitat value; planting a forest in its place results in an unambiguous habitat gain. On the other hand, a coastal grassland that is dominated by native plants may already be providing significant habitat functions as migratory habitat for monarch butterflies and peregrine falcons. It may also support rare plant species. Converting such a meadow into a forest could result in a net habitat loss. Changes to landscapes are often irreversible; thus, when native plant communities exist, proceed with extreme caution.

Soils and Climate

Soil and climate are the most important physical determinants of terrestrial ecosystem composition. Soil can vary greatly, even at the site scale. Understanding the naturally occurring heterogeneity of soils will help practitioners better evaluate how to manage the existing soil at a specific site. Climate varies little at the regional scale, with relative uniformity in the average rainfall and number of growing days per year. However, the micro-climate of a site may vary significantly from its surroundings, creating opportunities and constraints for germination and young plant growth.

Natural variations in soil occur for many reasons, including the formation of catenas (in which soil varies according to its position on a slope due to drainage and moisture differentials) and disparities in underlying parent rock (Bird, 1957). Upper slopes, for example, might be acidic and depleted of nutrients due to leaching and erosion, while lower slopes might be less acidic and richer due to the accumulation of alkaline deposition from soil or organic matter from above. These differences can be pronounced even across horizontal distances of only a few feet, especially in knob and kettle terrain where a dry hill covered in white oak and mountain laurel (*Kalmia latifolia*) may exist next to red maples and sweet pepper bush (*Clethra alnifolia*) growing in waterlogged soil.

Great natural variation of soils occurs across the New York landscape and region. New York City sits astride three physiographic regions: Appalachian, Coastal Plain, and Piedmont. The high ridges over Appalachian bedrock in the Bronx and Manhattan have dry, thin, glacially scoured mineral soil and exhibit white oak canopies over low bush blueberry (*Vaccinium pallidum*) shrub layers. On the deep, moist, organic-rich soil of the valleys below, tulip tree canopies grow atop spicebush shrub layers. The Coastal Plain on Staten Island, Brooklyn, and Queens extends from the Wisconsin Glaciers terminal moraine where oak/hickory forest grows on high hills formed of rocky till. The Coastal Plain extends over the sandy loam on the outwash plain where sweetgum, pin oak (*Quercus palustris*), and red maple favor the lower elevations and holly (*Ilex spp.*), swamp white oak (*Quercus bicolor*), willow oak, eastern red cedar (*Juniperus virginiana*), and sassafras grow on the sandier sites near the shore. The Wisconsin Glacier and its outwash never reached the southern tip of Staten Island. There, pitch pine (*Pinus rigida*), black jack oak (*Quercus marilandia*), and scrub oaks (*Quercus ilicifolia*) grow on soil derived from Cretaceous clay, a part of the Piedmont region, exemplifying forest and soil composition more typical of the Mid-Atlantic and South than of New England.

Observing soil and associated indicator vegetation on site and sending soil samples to be tested in the laboratory will help you assess a site's soil constraints, determine the necessity of amendments, and select a suitable plant palette. In some cases, soil quality can be improved passively, through planting, and in other cases, you will have to undertake active soil renovation prior to planting. The magnitude of soil improvement actions will depend on soil conditions. At some sites, all that may be needed is removal of trash, invasive plants, and debris. At other sites, however, soil may need to be tilled, toxic materials removed, and compost added. There will be situations - such as in the Bronx, Manhattan, and Staten Island - where soils are shallow and bedrock reaches within a few feet of the surface; such growth restrictions cannot be changed.

As described in Chapter 2, the majority of the sites available for forest restoration in New York City rest on anthropogenic soils. Different landfill types vary in the degree to which they are suitable for restoration - the most limiting is construction and demolition (C&D) rubble, because of its inherent structural and quality constraints, and the least limiting is ocean dredged sand, as several naturally occurring forest communities grow successfully on sandy soil. Despite the challenges these urban soils present, forest restoration on landfill is possible. Existence of woody plants in these landscapes, even invasive vines, indicates the potential for successful growth of native trees and shrubs with appropriate species selection. While challenges to installation may be formidable, close examination of the condition of plants already on site can help you understand what is possible.

When working with these sites, careful site preparation and invasive weed removal can be highly effective. Planting native species will, over time, help bring forest ecosystems back to life. Closing tree canopies will alter light regimes. Accumulated leaf litter will introduce organic matter, soil microbes, and invertebrates to the forest floor. Leaf litter and some coarse woody debris accumulations will also improve the site by impacting the micro-climate: they can change ground-level wind patterns, slow down the flow and infiltration of water across the surface of the site, and lower the temperature of the soil surface. These improvements to the forest floor, working in conjunction with a modified light regime, encourage the germination and growth of native forest plants.

Concrete and debris to be removed at Soundview Park before restoration can proceed. (photo by Mike

Cultural Significance

Some sites that appear to offer a perfect constellation of opportunities for reforestation may be constrained due to their historical or cultural significance. In New York City, designated historic landmarks must be maintained according to specific layouts with specified vegetation types. New York City's Landmarks Preservation Commission restricts activity at other sites due to their archaeological importance, requiring certification by an archaeologist ensuring that site preparation and planting will not disturb archeological deposits. Modification of tools or techniques may be required in areas of archaeological significance. A host of NYC Parks, particularly those with pre-1950s formal landscapes, require special sensitivity to the intent of the original design. Many such sites were designed by notable landscape architects, including Frederick Law Olmsted and Gilmore Clarke, and are valuable representative examples of period design. In New York City and many other cities, landscape historians can assist in addressing these constraints.

Policy and Regulations

Local state or federal policies can hasten or hinder restoration work. In New York City, the PlaNYC sustainability plan helped usher in an era of tree planting and reforestation unparalleled in New York in the last half century. Increased canopy cover is a featured goal of PlaNYC's MillionTreesNYC program and with it has come increased funding for planting and forest restoration. New York City's recent Green Infrastructure Plan, which promotes using existing or newly constructed green space for capturing storm water, is another policy initiative furthering conservation and restoration. Practitioners can both benefit from favorable policies and help drive policy by describing the need for and identifying the outcomes of their work effectively.

Some sites are subject to local, state, and/or federal regulations. Depending on project size, location, and agency jurisdiction, several permits may be required for forest restoration. Contact the appropriate federal or state permitting agency early in the planning process to determine what submissions will be required and the projected timeframe for their approval, which may take a year or longer. For example, federal agricultural regulations controlling invasive plants and animals limit what and where certain species may be planted. New York City has a tree restitution law that specifies that all trees taken down on parkland must be replaced using a specific formula specifying the numbers of trees for replacement or a restitution fee to be paid so that NYC Parks can plant replacement trees. Although this law contributes to a tree-friendly environment, it also can obstruct removal of invasive tree species from restoration sites.

In New York, many reforestation opportunities exist in undeveloped and unprogrammed natural areas that were former landfills near the city's tidal and freshwater wetlands. The New York State Department of Environmental Conservation has jurisdiction over mapped wetlands and over adjacent area buffers of up to 100 feet of freshwater wetlands, and 150 landward of tidal wetlands. Mapped wetlands themselves are usually too constrained by hydrology or salinity for reforestation. Areas adjacent to them, however, are often dominated by phragmites or invasive vines that, with appropriate site preparation, could be controlled long enough to establish forest canopy. Such sites require wetland permits. (See Appendix 1 for a list of the New York State and City Environmental Regulations that may apply to a reforestation project in New York City.)

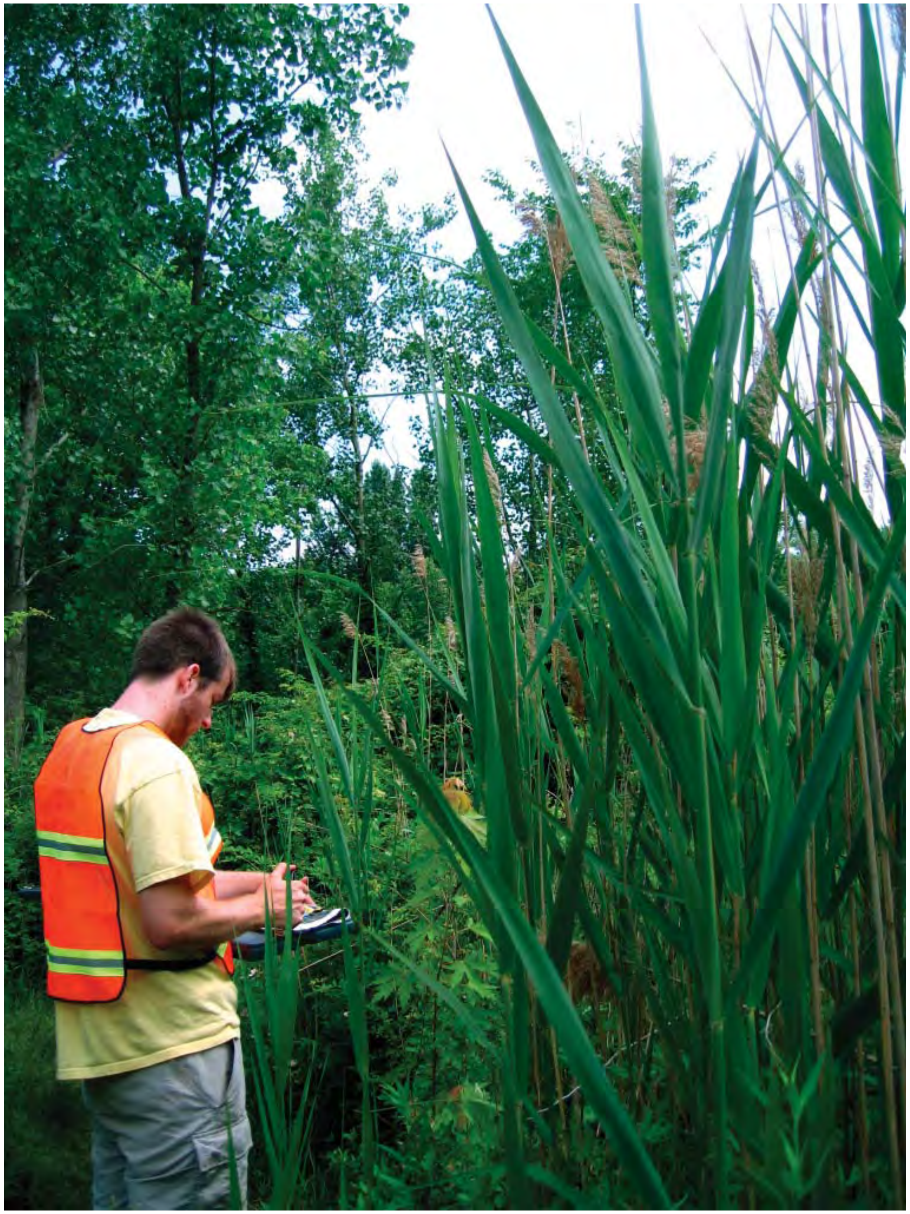
Figure 3.5: Hutchinson River Parkway Plan

Gilmore Clarke, April 1925, Westchester County Archives.

ASSESS SITES IN THE FIELD

After evaluating the opportunities and constraints as presented in readily available site documentation, such as existing vegetation surveys or capital work plans, and determining that a site is worthy of further investigation, visit potential sites to collect the necessary data to make final site selections. During a field visit, collect information to confirm conditions, assess planting feasibility, and determine the site's potential for successful reforestation. Assessments can take as little as 20 minutes or up to several hours, depending on the size, access, and condition of the site.

Having a standard format and protocol for collecting information will ensure that all potential sites can be reliably compared and prioritized. Create a site assessment form or checklist and use it along with an aerial photograph to record details that will help you plan the restoration work. Data collected during the field visit should include information relevant across different site types and contexts, to help you compare and prioritize the sites in question. If there are specific pieces of information that are only relevant to one type of site or that seem unique, be sure to record these too. These kinds of characteristics may shape later decision-making or help prioritize sites of the same general type. Consider incorporating the logistical and ecological information described below into your records to create a seamless transition from assessment to action.



Staff making roadside field assessments should wear safety vests.

INCLUDE ALL DECISION-MAKERS IN SITE SELECTION

Consult all levels of decision makers in advance of an assessment, invite them to participate in the field visit, and confer with them to review site analyses and recommendations. This includes senior managers as well as grounds crews. Not only will they be familiar with site conditions, they will also know if adjacent communities will welcome and support a forest restoration project.

Consult knowledgeable parties about:

- Current site uses, including active, passive, and seasonal recreation
- Neighborhood context and social functions
- Areas of cultural significance, such as gathering places or memorials
- Community members and stewardship organizations involved with the park
- Scenic areas and views to be preserved
- Potential to use planting to block undesirable views
- Future capital construction projects
- Maintenance patterns
- Water sources
- Location of infrastructure, including utilities and drainage pipes
- Seasonal drainage and flooding patterns that cannot be spotted on a single site visit
- Unique ecology, or rare plant or animal populations at the site

Park managers meeting in Queens.

Logistical Information:

- General directions and location. Record the closest intersections and driving directions to the site as well as GPS coordinates. Coordinates should be recorded at the site entrance during the initial site assessment. After the site is selected, record and map the site boundaries in GIS.
- Location, access, and context within the park. Record and map the general boundaries of the potential site and include proximity to paths, recreation areas, infrastructure, water sources and access routes, keeping in mind personnel and equipment must be able to reach the sites. Using GPS to map these locations can be extremely helpful.
- Regulatory conflicts. Record the proximity to any sensitive areas that could require procuring a permit in order to work.
- Photo points. Establish exact photo points during this phase so initial and subsequent photographs can be compared visually over time.
- Contact information. Include any points of contact or recommendations and notes from other parties.

Ecological Information:

- Vegetation. Record the diversity, abundance, size and health of vegetation on your site and in surrounding areas, including native, rare and invasive species. The types of plants growing will inform the forest restoration planting palette, while the types of invasive plants will determine the amount of site preparation needed at the site. NRG categorizes reforestation sites primarily by dominant invasive species, as this has the greatest impact on the time and resources required to complete many projects in New York City.
- Topography. Record slope stability and areas of erosion to identify potential risks of erosion and/or drainage issues. Mapping significant areas of erosion, rocky outcrops, subsidence, deposition, and/or slopes steeper than twenty-five percent will determine the scope of the planting.
- Hydrology. Map any drainage patterns at the site, visiting at different times of the year to observe seasonal variation. Poorly drained sites will require a different plant palette than dry, upland sites. The existing flow of water over, through, and under a site will provide the necessary support for successful reforestation. Note barren areas with compacted soil, streams that lack natural banks, and/or piped storm sewers. Such areas require special care to restore natural infiltration and prevent erosion.
- Soils. The soil should be visually assessed and sampled for laboratory analysis. The results of these tests will influence planting potential, soil renovation, and species palette. Soil condition is the most significant physical constraint to native forest establishment. Recommendations for detailed soil analysis are included below.

Evaluating Soils

Soil is critical to the success of a forest restoration project. On site, look for organic matter, barren or compacted areas, and the growth habits of existing vegetation, as these are indicators of soil health. For example, stunted growth and sparse vegetation cover might indicate the presence of a soil constraint (e.g. heavy metals, shallow depth to bedrock). If rills and gullies are present, erosion and surface runoff may be a problem. More detailed analysis of the soil should be determined by laboratory analysis.

The basic characteristics of soil to consider are as follows:

- Depth. While soils as shallow as six inches may support the growth of naturally germinating woody vegetation, it will not allow for the installation and establishment of container-grown or larger plant material. If planting is part of the restoration strategy, it is important to ensure early on that there is sufficient soil to allow for it, or adjust plant size and species selection to accommodate soil depth constraints.
- Texture. Soil is a mixture of sand, silt, clay, and organic matter. The relative proportion of each determines the texture of the soil. Texture affects air and water movement through soil, thus directly influencing water and nutrient holding capacity. Sandy soils have the largest particles and the fastest drainage rate, due to their large pores. Clay soils have the finest particles and the slowest drainage rate. Silt and loamy textured soil characteristics fall in between.
- Moisture. Soil moisture is a measure of how much water is in the soil at a given moment, and it fluctuates with precipitation and plant uptake. Higher levels of moisture can be expected at lower elevations and in bowl-shaped depressions. Soils at higher elevation or on convex slopes tend to be drier. Soil water holding capacity is a measure of how much water the soil has the potential to retain and is largely a function of soil texture, bulk density, and organic matter content. Soils with a higher water holding capacity tend to be better for plant growth. Note if site conditions indicate the possible presence of seasonally dry wetlands. These special habitats may be important to preserve, or may otherwise impact success.
- Structure. Soil structure refers to the arrangement of particles within the soil. Soil structure influences water availability and movement. Soil compaction is the most common structural constraint. Highly compacted soils will limit root penetration, gas exchange, water movement, and seedling germination. Soil bulk density (a measure of soil compaction) depends on the texture but ideally should be <1.10 (g/cm3) for clays and up to 1.6 (g/cm3) for sandy soils.
- Nutrient and Toxin Levels. The movement and concentrations of nutrients (i.e., nitrogen, phosphorus, potassium) available for plants in the soil will influence the establishment and growth rates of plants. Nutrient availability is a function of a wide variety of factors, including soil pH, organic matter content, plant composition, microbial communities, parent material, moisture, temperature, nitrogen deposition, and disturbance history. Nutrient levels naturally fluctuate over time due to their sensitivity to these numerous variables. In urban areas, soil chemistry, pH, and nutrient and toxin levels differ greatly from those of non-urban areas and can vary drastically from site to site, and within sites. In addition, due to nitrogen deposition from fossil fuel combustion as well as fertilizer runoff, urban soils often have excess nitrogen. This can shift species composition from native plants to invasive plant species that thrive in nitrogen-rich environments.

Digging a test pit can reveal the soil horizons and can be used to test the drainage rate of a site.

To obtain more detailed information on soils from a laboratory, collect soil samples with a soil core (one- or two-inch in diameter), to a depth of one to two feet, at intervals across the site. Place each sample in a plastic bag clearly labeled with the site location and date and keep the bags in a cool place. If you plan to test for organic matter content and soil nutrient levels, keep samples on ice or refrigerate them as soon as they are collected and have them analyzed within 48 hours, otherwise samples should be taken out of the bag to bench dry. The size of the reforestation site, its heterogeneity, site characteristics, and soil survey data will determine how many samples you should take. More samples will provide you with a more representative assessment.

Laboratory analysis can provide data for the following soil traits:

- texture
- moisture (this information can also be inferred from bulk density, soil texture, and organic matter content)
- bulk density (for this test, the volume of soil collected must be recorded)
- plant micro- (e.g., boron, chlorine, manganese, iron, zinc, copper, molybdenum, nickel) and macronutrient content (e.g. nitrogen, phosphorous, potassium, magnesium, calcium, sulfur)
- soluble salts
- organic matter content
- cation exchange capacity
- pH
- toxic heavy metals

Additional methods for determining soil characteristics in the field include close visual inspection, digging test pits or trenches, and taking borings. Resources on interpreting field investigations and soil test results can be found in Appendix 5: Web Resources.

A soil profile from Van Cortlandt Park.


Soil samples from Kissena Park were logged and organized to be sent off for testing.

EVALUATE AND PRIORITIZE SITES

After you have performed your site assessments, review your data and measure it against site selection criteria and restoration goals. Assign the highest rankings to sites that meet criteria and goals alike. For ease of subsequent comparisons, compile site assessments within a single system, organized by location and the date of the assessment. NRG uses a combination of ArcGIS and a Microsoft Access database for this purpose. Retain assessment information indefinitely to enable future comparisons of the site to its original condition. It is most important, however, to organize and analyze the site assessment data (i.e. soils, vegetation, current and past uses, and water availability) so that it is readily available to inform your site design.

Data Management

Regular and consistent documentation and communication is essential during the entire life of a restoration project, beginning with the planning phase. During this phase, think about what aspects of your project you need to track or analyze; remember that you cannot always predict what information will prove useful in the future, so try to balance thoroughness with efficiency. Regardless of the amount and type of data you capture, planning in advance how and when that information will be recorded and managed will save considerable time and resources. Establish a standard format and protocol, including your filing system and file-naming standards, and make sure all staff, contractors, and volunteers understand data management procedures before they commence their work.

On-going and comprehensive record-keeping about site conditions and site work will allow you to:

- Evaluate the effectiveness of invasive plant treatments and other restoration methods
- Provide required information to regulatory agencies (e.g., in New York, the Department of Environmental Conservation requires annual reports on herbicide applications)
- Document the hours and money spent and the materials used during each phase of a project to inform future work planning, scheduling, and budgeting
- Develop site-specific maintenance programs and/or inspection regimes for installed planting
- Adapt site management based on evolving site conditions and/or the observed effectiveness of current management procedures
- Compare data collected from multiple sites
- Ensure project continuity in the event of staff or management changes

Conclusion

Once you have found your optimal sites, engaged stakeholders and managers, and carefully recorded the process, you are ready to begin the next phase of your project: site planning and design. Remember, when working with natural systems, a level of unpredictably is inevitable. Physical and environmental, and even political, conditions can change unexpectedly, leaving your project's schedule, work plans, or funding uncertain. Thorough planning and documentation are an important first step in effective management of the many variables that will come along on the bumpy road to successful forest restoration. Once the site has been selected, it is important to review the site goals as you enter into the next steps of restoration design, implementation, and monitoring.

CASE STUDY: Assessing Sites: Opportunities Vs. Constraints

NRG's restoration managers regularly make decisions to begin, continue, modify, or cease work based on the evaluation of the opportunities and constraints presented by a site. The examples below describe how managers have adjusted site selection and restoration designs to address opportunities and constraints.

1. Conference House Park, Staten Island

Opportunity:
The restoration of valuable and rare coastal habitat on the southern tip of Staten Island, dominated by invasive vines.

Constraint:
A sensitive archeological site with potential Native American remains or artifacts limits installation work.

Due to the archeological value of the site, New York City's Landmarks Preservation Commission restricted all planting holes to a maximum six-inch depth. NRG responded to this constraint by limiting digging on site as required, removing invasives above ground, and planting only seedlings and live stakes.

Outcome:
Despite the limitations to its work, NRG has planted over 14,000 trees and shrubs. In general the plantings have been successful, although some species established better than others when planted at the small size. See the sidebar on restoration at Conference House Park in Chapter 4 (pages 68-69) for more details.

2. Floyd Bennett Field, Brooklyn

Opportunity:
The potential for collaboration between NYC Parks and the National Park Service (NPS) which would dedicate more resources towards the successful restoration of a large naturalized area.

Constraints:
The historic preservation and interpretation goals of NPS limit the extent of the restoration work; variable soil depths.

Floyd Bennett Field was New York City's first municipal airport in the 1930s and became a naval air station in the 1940s. In 1971, the Navy deactivated the Field and the NPS designated it as parkland. Because of the site's history, the NPS supported the continued mowing of the site to preserve the look of the 1930s airport, rather than restoring the entire site to forest.

After years of little management, cleared former runways and surrounding areas regrew with mostly invasives. In some locations, vinelands grew atop old runways where there was insufficient soil depth to support trees.

Outcome:
To balance the cultural and ecological goals for the site, the NPS created a masterplan that designated areas as either cultural landscapes or natural landscapes. Restoration activities are limited to the natural landscape areas within the park. NRG discovered that some pockets of soil between the runways were deep and well-structured and planted these areas with woody plants. NRG also installed planting on the runway surfaces with sufficient soil depth to support herbaceous communities, creating a healthy matrix of scrub-shrub vegetation.

3. Graniteville Swamp Park, Staten Island

Opportunity:
A degraded edge of an under-utilized park.

Constraint:
Shallow Soil.

At the beginning of PlaNYC, NRG hired a consultant to analyze the available opportunities for planting new forests across the city. The consultant analyzed available GIS data, and hired seasonal staff to ground truth their findings, in order to identify potential planting sites. A two-acre section along the southern edge of Graniteville Swamp Park was among the sites proposed. Upon visiting the site, NRG realized that although the consultant had analyzed the vegetation and taken a soil sample, the bedrock was less than a foot below the surface across most of the park.

Outcome:
Due to the limitation of soil space, NRG elected to not work in the park at this site.

4. Marine Park, Brooklyn

Opportunity:
A multi-ecotype restoration to restore a contiguous landscape.

Constraint:
Coordinating the timing requirements and limitations of multiple stakeholders.

An area of Marine Park held promise for coordinated salt marsh, grassland, and forest restoration. Moving forward required collaboration among multiple organizations: NYC Parks, New York State Department of Environmental Conservation (NYS DEC), and US Army Corps. NRG spent many years and dedicated much effort to organizing and aligning the funding and permissions of these bureaucracies to correspond with the restoration timeline. In the end, dredged soils from the marsh restoration created a swath of soil for the upland restoration, reducing the project's carbon footprint.

Outcome:
The restoration of 20 acres of salt marsh, 22 acres of grassland, and 6 acres of forest. More than 10,000 trees were planted by NRG from 2009-2012 and are thriving today.

Marine Park Marsh.

Marine Park Forest.

5. Willow Lake, Flushing Meadows Corona Park, Queens

Opportunity:
A large former ash dump within Flushing Meadows-Corona Park overrun by phragmites and vines.

Constraint:
An NYS DEC permit required NYC Parks to limit phragmites removal to reduce the impact of disturbance.

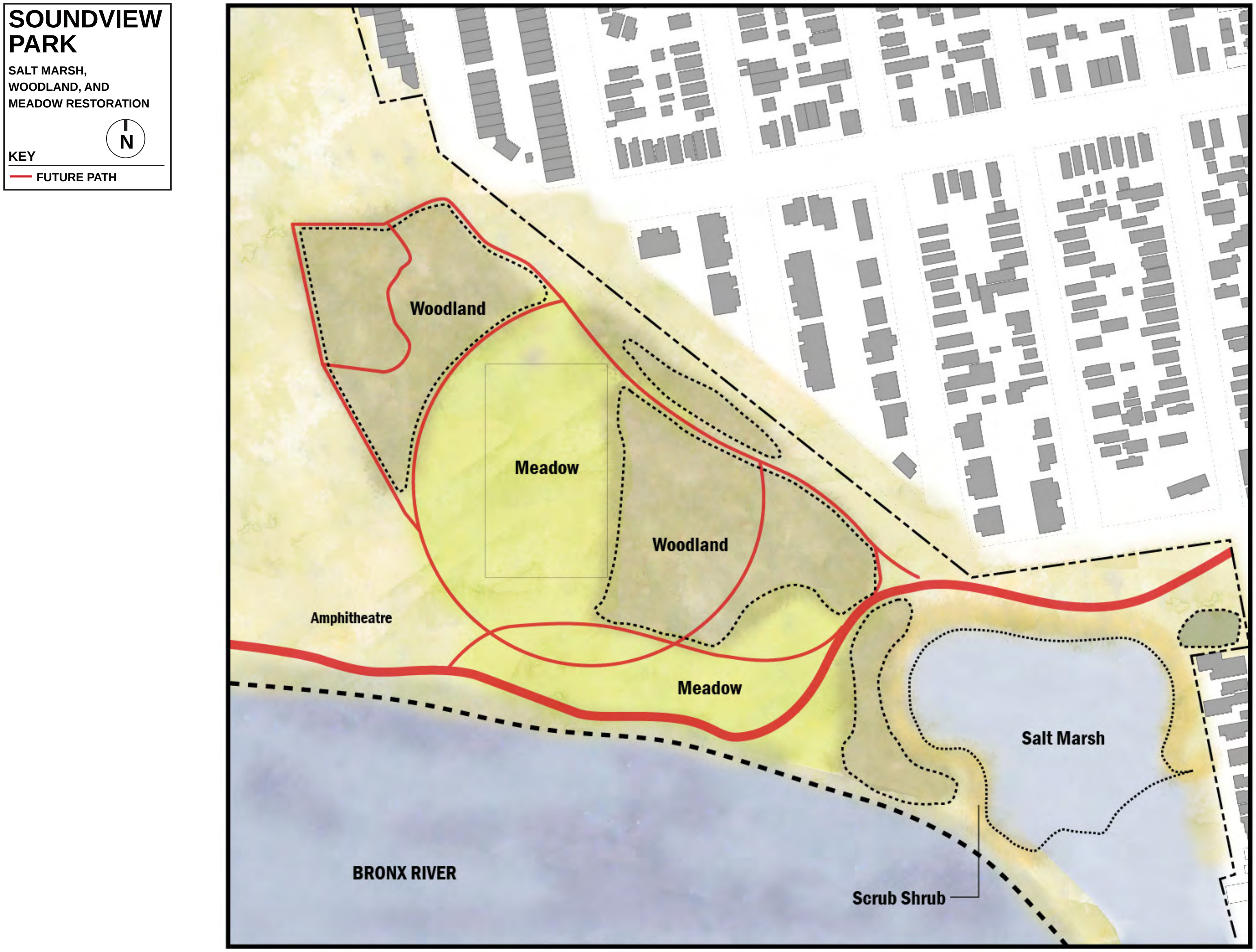
NRG planned to restore 23 acres of forest and grassland along the eastern shore of Willow Lake at the same time as 15 acres on the western shore. Work on the eastern shore began in 2010; however, NYS DEC rejected NRG's permit application to work along the western shore because of concerns that the scale and speed of the proposed vegetation change would negatively impact the wetland and bird populations.

Outcome:
Phase 1 restoration is complete with the planting of 13,755 trees and 4,969 shrubs and 70,560 herbaceous plants. The trees, shrubs and herbs are establishing well, especially in the southern half of the site, which is dense and lush. The northern half of the site, which received less site preparation, has been overtaken by mile-a-minute. NRG is in the process of bidding a contract for groundcover establishment in this area, to control the mile-a-minute and install additional herbs. NRG is continuing its conversation with NYS DEC about the western shore, weighing the benefits of a restored native habitat against the potential disturbance of the existing invasive-dominated wetland.

Willow Lake before restoration dominated by mugwort, phragmites, and porcelainberry vine in 2009.

Willow Lake restoration area showing a diversity of native trees and wildflowers in 2012.

Figure 4.1: Soundview Park Salt Marsh, Woodland, and Meadow Restoration

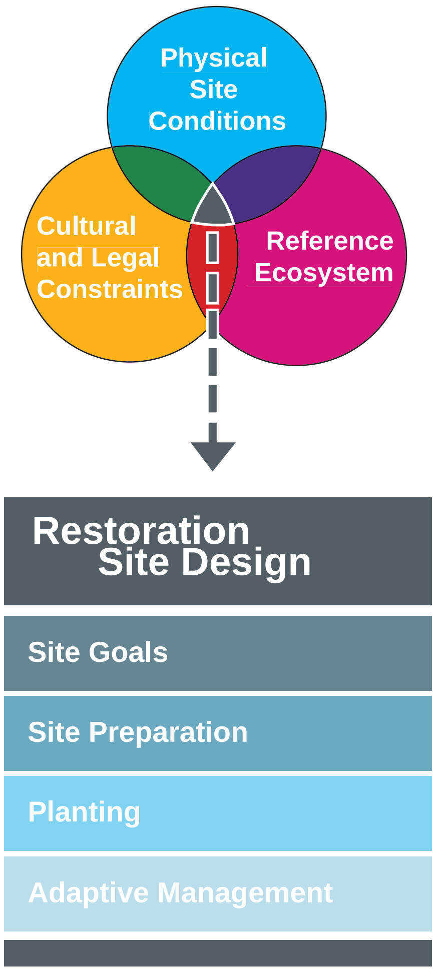


This design shows the full ecosystem restoration from salt marsh to upland forest of more than 15 acres at Soundview Park, located at the confluence of the Bronx River and Long Island Sound.

CHAPTER 4: SITE PLANNING AND DESIGN

After you have selected a site, you will consider and weigh many critical elements as you develop your site plan. This chapter will guide you through the iterative process of integrating broader principles of restoration ecology with what you have learned about a specific site's historical, ecological and cultural characteristics.

Figure 4.2: Elements of Restoration Site Design



The process of determining the elements of a restoration site design will result from the reference ecosystem, physical site constraints and cultural and legal constraints.

GOALS AND OBJECTIVES

Keep in mind the basic design guidelines below as well as the regional context of your site while creating a goal-oriented plan:

Restoration and ecological aims: The primary goal of forest restoration is to create and/or restore self-sustaining multi-storied forests. At each site, use your design to maximize ecological function and habitat value. The healthy forests you create should build soil, encourage the growth of planted native species, recruit additional native species, resist the invasion of non-native species, and enhance the experiences of park users and neighbors. The restoration should result in improved resiliency, robustness and resistance to disturbance.

Aesthetics and social function: As you develop your design, consider all existing features of a site as well as its current uses, both positive and negative, by the surrounding community. Do not interfere with existing or proposed infrastructure (e.g. playgrounds, pools, buried utility lines). Use your plans to reinforce preferred paths and discourage the continued use of undesirable paths. Discuss with park managers how your design might help block dangerous or destructive sports such as all terrain vehicle use or sledding on dangerous slopes. Avoid interfering with passive recreation activities, such as picnicking, and active recreation areas, such as ballfields. Preserve desirable views and mask undesirable views with vegetation. Respect the integrity of historic designs, especially when they are culturally significant.

Practical and administrative requirements: Design within the limitations posed by your funding and your available timeframe. There are a host of variably priced techniques for removal of invasive growth, soil preparation, and plant materials. The time available for work at a site will influence your planting choices as well as your maintenance plans. Make sure that the designs and techniques you propose meet all regulatory requirements.

RESTORATION PLANNING CONSIDERATIONS

Be sure to plan simultaneously for the practical and logistical coordination that will be required to implement an effective, legal, and community-supported project. This planning will fall under two main categories: political/administrative work and physical work on the ground.

ELEMENTS OF RESTORATION PLAN DOCUMENTATION:

- **Goals and Objectives** – Incorporate the restoration and ecological aims, aesthetics and social functions, as well as the practical and administrative requirements into the goals of your site.
- **Timeline** – When developing a timeline, consider political and administrative aspects such as permitting and public outreach, as well as core on-the-ground requirements, like the type and availability of the workforce and the length and intensity of invasive control measures you will undertake.
- **Planting Plan** – Making decisions early on about species selection, provenance, size and packaging, and spacing will make it easier to secure appropriate plant material for your site.
- **Site Management Plan** – Your timeline, site protection and planting plans are critical for developing a post-planting management strategy for your site.
- **Maps** – include maps of existing conditions and restoration activities including site preparation, protection, and planting.

Political/Administrative

- Timelines: Look at administrative and restoration cycles in tandem when establishing your project timeline. Administratively, you will need to allow time for receiving funding for the work (whether the source is public or private), hiring employees, establishing contracts, and/or recruiting and training volunteer teams. Grants may also come with specific start and end dates and milestones that must be incorporated into your schedule. Your restoration timeline will depend upon the rhythm and length of seasons, as well as the appropriate timing for procedures like invasive plant removal, sowing seeds, and planting trees. Building contingencies and flexibility into your overall work plan will allow you to maximize synergy between administrative and biological cycles.

- Permitting: Understanding your permitting requirements will entail research and coordination among various agencies. Obtaining permits and approvals may take as long as several years, so initiate the filing process as soon as is practicable.

- Public outreach: Public outreach will be an ongoing process throughout the life of your project. Establish regular and respectful communication with all stakeholders early on to promote community investment and stewardship, discourage negative behavior like vandalism, expedite approvals, and diminish potential conflict. Initiating communication when a project is still in its conceptual stage, and engaging the public before site construction begins (in some cases, this may occur years after the conceptual phase), will help clarify expectations and build consensus.

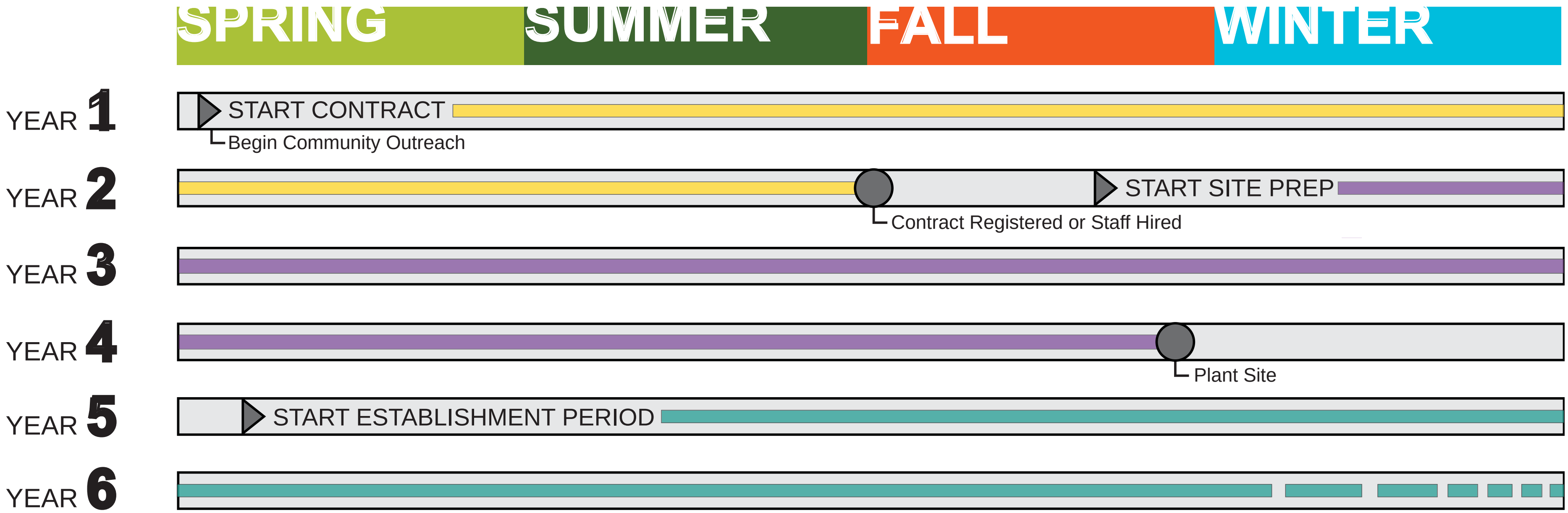
On the Ground

- Workforce: Consider each site individually to determine the most appropriate workforce. NRG often uses contractors for invasive removal and site preparation and in-house personnel and volunteers for planting. In-house crews are extremely useful for sites where invasive plants are intermixed with many native species and treatment timing and technique must be nuanced and flexible. Contractors tend to be expensive to employ, but can be cost-effective on large sites where the use of heavy equipment or other specialized tools are necessary or extensive permitting is required. Preparing sites for volunteers may take more effort and time (since large debris must be cleared away first for safety), but providing adequate and well-trained staff to oversee volunteers can maximize efficiency once planting begins, and including volunteers in restoration can improve community stewardship of the site in the long-term. NRG regularly plans events during which thousands of volunteers install as many as 25,000 plants at sites across the city in a single day.

- Site protection: Installing fencing may help protect existing trees, prevent herbivory of newly planted trees, prevent damage by bicycle and ATV use, and discourage active recreation within, and trail creation through, reforestation sites. If the site has many informal trails and/or a long history of active use, fencing may also formalize a path through or around the site to channel access by users. However, in some locations, a fence is an invitation to vandalism rather than a deterrent and it is important to have a thorough understanding of the specific site.
- Invasive plant management: This can be a multi-year process entailing the eradication of mature invasive plant species from the site, the control of invasive seed sources in adjacent areas, and the control of invasive seed laying dormant in the soil (i.e., the seed bank). Customize the site preparation timeline to the specific invasive plants found on the site. Refer to the invasive plant management timeline in Chapter 5 for typical timing.
- Debris clearing: Debris clearing is usually performed in conjunction with invasive plant removal as debris is often revealed beneath the dense layer of invasive plants. For sites without invasive plants, debris clearing may make up the bulk of the site preparation. In some cases, it may be better to leave debris on-site because its removal would cause excessive disturbance to existing vegetation or other site characteristics.
- Soil Preparation: The constraints of the typical urban soil can be diminished by decompaction. Decompaction produces better drainage, allowing for the leaching of soluble salts and the moderating of pH. In some cases, additional soil remediation will be required, or adding new soil may be appropriate.

After carefully considering and prioritizing the relevant aesthetic, cultural, ecological, logistical, and temporal issues presented by your site, you are ready to design the physical layout of the forest. Incorporate your project's goals, needs, and constraints into a well-reasoned plan that establishes work boundaries, distinct planting areas, circulation routes, and any other requirements related to the overall configuration of your site.

Figure 4.3: Administrative and Biological Timelines



DESIGNING THE FOREST

Now that you have the basic layout in place, contemplate the components of your forest in detail. The plant selection decisions before you are nuanced and numerous. You will be balancing your understanding of site conditions as they are today with your vision for a forest that will develop over decades.

Plan to install all layers of a multi-story forest simultaneously, keeping in mind how the plant community will respond to changing light conditions over time. Each layer of plant material in the forest performs a vital function. Shrubs adapted to sunny locations planted with trees will assist in creating a closed canopy and controlling invasive plants, such as mugwort, knotweed, or phragmites. Native grasses and wildflowers planted as seed or plugs will fill the space previously occupied by invasive plants, help to prevent a reinvasion of the site, stabilize the soil, and prevent erosion.

Some versatile understory plants will tolerate full sun until canopy closure provides the shade in which they can thrive. While some of the early successional species you plant (trees, as well as shrubs and herbs) may ultimately be shaded-out, planting a high diversity of species will compensate for this loss. Depending on the site's proximity to other forest patches, shade-tolerant herbs may show up on their own as recruits, transported as seeds blown in by the wind, deposited in bird droppings, or carried as hitchhikers on the bootlaces of field staff and park patrons. Your planting choices can encourage this natural progression of plant recruitment. For example, planting shrubs, such as silky dogwoods (*Cornus amomum*), that yield red, late-summer-ripening, high-fat fruit, can attract fall-migrating songbirds that also consume the similar fruit of the tupelo tree. Thus certain plants become sinks for the seeds of additional native species with the same modes of dispersal. If native seed recruitment and germination is low, you may need to return to the site to install shade-tolerant native shrubs and plant or seed perennial herbs into the forest floor to ensure the forest's continued health.

NEW YORK CITY NATIVE PLANT LAW AND NATIVE PLANTING GUIDE

In 2013, The New York City Council passed Local Law 10 and 11. The law encourages the planting of native plant species and the minimizing of the presence of exotic monocultures on city-owned property. The law requires Parks to develop a Native Planting Guide and a design manual to increase biodiversity in all public plantings.

The Native Planting Guide is a great resource for all restoration practitioners working in and around New York City. It lists the species that are to be found in the city's surviving distinct ecosystems and serves as the basis of species selection for land management and restoration within these ecosystems. Utilizing The Ecological Communities of New York State by Carol Reschke, Parks' Greenbelt Native Plant Center (GNPC) staff identified twenty six natural ecosystems still distinguishable within the City borders and describes species found within. The guide contains detailed information for the tolerances, preferences, and value of over 430 native species. This information assists managers and designers in choosing the right plants to increase biodiversity in ecosystems.

Your planting plan should take into account these natural potentialities and address the needs and opportunities presented uniquely by your site. The following topics, which are expanded upon below, will inform your selections and decisions:

- Species
- Provenance
- Climate Change
- Size and Packaging
- Spacing
- Pests and Wildlife

Species

Ecosystems develop and mature through the processes of succession. Ideally, succession is a predictable process by which plant species and communities replace one another over time following a disturbance, as demonstrated by bare rock exposed by a glacier succeeding to climax forest over millennia, or a post-agriculture landscape succeeding to secondary woodland over decades. Typically, bare ground is colonized by annual herbs that give way to perennial herbs and grasses; shrubs gradually colonize this open meadow; shrub land, in turn, is colonized by young trees, known as "pioneer species," that are adapted to full sun; and, ultimately, shade-tolerant trees create a closed-canopy forest. This is a raveling process that results in greater complexity and stability as plants respond to light gradients, build soil from accumulated and decomposed organic matter, and form myriad food webs as animals colonize plant communities.

NRG's forest restoration process is rooted in an effort to mimic succession, while designing planting palettes that will tolerate challenging urban environments. In open sites, following the removal of existing invasive plants, the immediate goal is to establish cover that is appropriate to the site conditions and that will help exclude the reintroduction of invasive species in the near future (Gargiullo, 2007). A planting design that incorporates both fast- and slow-growing native species will eventually create a sustainable system that allows succession and ecological processes to re-establish. These plants will help build a vigorous native seed bank representing plant communities that will be resilient to future disturbances.

Fast-growing pioneer species that need full sun are usually the first to attain full size. These plants provide habitat that encourages the recruitment of other native plants and animals. The slower-growing, longer-lived, and more shade-tolerant species (oaks, hickories, sugar maple, and beech) tend to follow. Mirroring this process, NRG often plants tulip and oak trees together. Tulip trees require bare soil to establish, thrive in sunlight, but tolerate shade, and grow very quickly. The tulip trees, then, quickly provide shade to hold invasive plants at bay, giving the slow-growing oak trees time to establish. Acorns do not typically travel far from the mother tree, but tulip tree seeds can be dispersed by the wind, thus making them the more likely candidate to appear naturally as new recruits in an open field. Oak saplings put energy into their roots under the sheltering tulip trees, leaving them well-prepared to fill in any gaps that may appear in the tulip tree canopy.

Not every site is the equivalent of an open field, however. In other situations, NRG looks at the current state of the site and selects plants with complimentary establishment requirements (shade level, soil type, etc.). Typically, NRG proposes a diverse range of species, but in some cases, staff find that the selective use of single species stands is beneficial. For instance, in some areas it may be appropriate to plant a grouping of white pines or eastern red cedars. These conifer stands are found in nature and provide habitat for native animals, like great-horned owls (*Bubo virginianus*), and sawwhet owls (*Aegolius acadicus*) which use them for winter cover. Elsewhere, when planting small forest gaps, grouping together slower growing species can assist in their ultimate success. In these instances, separating groups of white oaks and hickories from tulip trees and red maples may result in better success rates for the former species by limiting competition from faster-growing trees for the limited light. Conversely, some species that grow in monotypic stands naturally, like sassafras, do not need to be clustered when planting. Sassafras is a clonal species, and many stems may emerge from a single root system - interspersing this type of species with non-clonal species can be of greater benefit to the site overall. Bazzaz (1996:51) tells us, referring to Sassafras, that, "…the patterns of clonal distributions in the field can greatly influence the spatial distribution of late successional trees."

Forest types (e.g., floodplain forests, coastal maritime forests, etc.) have a range of ideal growing conditions that are important to consider when developing a planting list. Existing site hydrology and vegetation can provide insight into which forest communities may thrive there. A moist lowland site will require a different plant palette than a dry upland site. A canopy gap of an existing forest with rich moist soil might suggest a tulip tree and spicebush association; a seasonally flooded site might indicate that red maple, pin oak, and sweetgum with a shrub layer composed of sweet pepper bush and arrowwood (*Viburnum dentatum*) would be most appropriate. See Appendix 3 for detailed plant lists typical of common forest communities in New York City's region.

Provenance

Beyond selecting suitable native plant species, you must also ensure that the actual specimens derive from local provenance. Provenance means the place of origin of plant material. All plants adapt genetically to the environmental forces they encounter in the places where they grow. They exchange the majority of their pollen within a remarkably limited distance from the parent plant, which along with its local cohorts, forms a local population of the species. At the same time, there is always some pollen that is dispersed further and some pollen disperses over long to very long distances. In this way, novel genes are exchanged between populations over evolutionary time and face the test of newly encountered local conditions to see if they will persist or die out in the local population. Species can be thought of as a sort of "super organism" made up of many local populations over the range of the species. The species range is dynamic, slowly changing as it probes and tests new environments.

The integrity of a local population's genetic makeup is critical to overall species health because the local populations are the reservoirs of local adaptations that may prove critical to the species survival through evolutionary time as well as to rare but severe shifts in conditions.

Some plants, especially those with fruits that do not disperse widely or that self pollinate, tend to have a much narrower genetic makeup, since gene exchange is much more limited and individuals within a population tend to be genetically very similar, with little variation. These species tend to be narrowly adapted, relatively rare, and relatively vulnerable to environmental disturbances.

For all of these reasons, selecting source material for restoration and management of local ecosystems needs to be carefully considered. Using non-local seed sources that are not adapted to local growing conditions can predispose those translocated plants to novel stresses, decreasing their chances for success. For example, in the 1990s, UFEP purchased a large quantity of plant material from a nursery in Tennessee to be installed in New York City and soon saw that the imported trees were highly susceptible to gall forming wasps, whereas local red oak stock resisted these pests. Just as importantly, if the translocated trees manage to survive to reproductive maturity in their new location, they will then begin exchanging their genes with the resident population. Then, over time the progeny of the resident and the translocated parents will have incorporated these maladapted traits into their gene pool and if the number of translocated survivors is large enough relative to the overall population size, it will result in lowered mean population fitness, a phenomenon known as outbreeding depression. NRG subsequently changed its procurement practices, and now selects native plants derived from locations as close as possible to planting sites or from locations of as similar an ecotype as possible and requires plants to have been growing in the desired hardiness zone for at least a year to ensure that they will survive field conditions. (NOTE: it is not sufficient to determine just the source of the translocated nursery stock, but rather it is critical to determine the ultimate seed source of that nursery stock. In at least one instance, upon detailed questioning, NRG learned that the source of "native" nursery stock used by one grower was Ukraine).

NRG is fortunate to have the Greenbelt Native Plant Center (GNPC) as part of its operations. The GNPC is a thirteen-acre greenhouse, nursery, bulk seed production and seed bank complex located on Staten Island. Its mission is to provide native plants and seeds from properly sampled local plant populations in support of the restoration and management of New York City's most valuable natural areas. The GNPC propagates and grows over 500 species, representing about two thirds of the surviving flora of the City including species that are difficult to find elsewhere. It also sells seed and tubelings to commercial nurseries that then sell to City projects and programs.

CONFERENCE HOUSE PARK: A CASE STUDY IN SPECIES SELECTION

Conference House Park is a 226-acre park on the southern tip of Staten Island with 150 acres of forest, a 2.5-mile shoreline, coastal meadow, dunes, and recreation areas. The forested ecosystem in the park is unusual due to its un-glaciated soils, including cretaceous clay hardpan, and of the occurrence of pre-historic Native American oyster shell deposits, which have resulted in a high-pH soil that is both drought- and flood-prone. This combination of factors led to the growth of the Pin Oak-Hackberry (*Celtis occidentalis*)-Sassafras community that exists throughout the park, as well as a rare example of a Hackberry-dominated forest (Greller et al., 1992).

Due to disturbance and decades without management, invasive vines such as Oriental bittersweet, porcelainberry, and Japanese honeysuckle thrived and damaged the tree canopy, impeding the regeneration of native species.

NRG's restoration work at Conference House Park began in 2007 and included the assessment and subsequent treatment of invasive species with manual removal and/or herbicides and the replanting of cleared land with a mix of native species appropriate to site conditions. In order to prevent the disturbance of archaeological deposits, all planting holes had to be less than six inches deep and two inches wide. This constraint restricted plant material to small-size plants such as live stakes, herbaceous plugs, tubeling-size trees and shrubs, and bare-root plantings.

On the smallest sites within the park, where only a few shrubs were removed, replanting consisted of native grass seed and herbaceous plugs. On the largest managed site within the park, the South Low Restoration Area, NRG oversaw the installation of more than 14,000 individual plants, including trees and shrubs. The species were selected based on the criteria that they: already existed and thrived within or near the park; were capable of tolerating the conditions at the site; and/or had been successful at similar sites.

Species of mature trees existing within and around the South Low Restoration Area at the time of species selection included: swamp white oak; black walnut (*Juglans nigra*); green ash (*Fraxinus pennsylvanica*); hackberry; American elm; black cherry; pin oak; black locust (*Robinia pseudoacacia*); and osage orange (*Maclura pomifera*).

Of these species, NRG selected only those that are native to the region for planting. Due to its success on the site, the team considered making an exception for the non-invasive osage orange, but ultimately rejected the species because it was not available commercially as a live stake and the thorny flexible stems of young trees make it extremely difficult to plant with volunteers. The team also phased out green ash from later plantings, after Emerald Ash Borer (*Agrilus planipennis*), a pest species that targets ash, was found to be rapidly approaching New York City.

NRG also considered species growing elsewhere in the park, ultimately selecting silver maple (*Acer saccharinum*), black willow (*Salix nigra*), and American sycamore (*Platanus occidentalis*) for use in low-lying and damp portions of the site. Sassafras, although common across the park's forest, was not commercially available at the desired size at the time of planting.

NRG's post-restoration monitoring of the South Low Restoration Area provided initial data on species success in the face of the flooding, drought, and deer browse that characterize the site. Swamp white oak and green ash, two of the tallest bare-root species planted, performed well in varied conditions across the site. Black cherry, on the other hand, another tall bare-root, did not transplant well. Swamp white oak demonstrated the ability to endure both flood and drought in soil types ranging from pure sand to heavy clay. American sycamore, planted as shorter bare-roots, also thrived. Silver maple seedlings suffered greatly from deer browse, with only those planted in the middle of a protective thorny thicket surviving.

Before Planting 2007: This sloped site had not been managed at the time the first photo was taken. The area consisted of a mature but sparse native canopy including northern hackberry, black walnut, sassafras, black cherry, and the red oak seen to the left of the photo, as well as many ailanthus saplings. The understory of this woodland was dominated by well-established Japanese Knotweed, which had already reached six-foot heights by early May. In the foreground is a gravel runoff swale. (photo by Cheri Brunault)

After Planting 2010: Landmark Preservation commission restrictions due to concerns for potential archaeological resources limited plantings to smaller bare-roots, livestakes, and tubeling trees. (photo by Cheri Brunault)

Climate Change

There is much speculation on the effects of and the course of climate change. Much of it is not grounded in science. There are valuable guideposts to possible climate change scenarios in the sciences of population biology, population genetics and in paleobotany.

Many plant species exist over a wide geographic range, and have distinct populations with localized adaptations within those ranges. As temperature and moisture patterns change, it is likely that some, maybe even most, plant species will stay in place and adapt to new conditions or may already have the genes in their population for hotter and or drier conditions, obviating the importance of maintaining intact local populations in the face of climate change.

Other species may die out locally and their ranges will expand in new directions to new locations or they may die out completely if they can't migrate to suitable habitat. This speaks to the importance of regional, landscape-scale responses to climate change to insure that corridors of plant migration exist to allow for migration.

Studies of species ranges reveal that some, perhaps many or most species have local populations that are more plastic or adaptable at the edges of their ranges, rather than in the center of their ranges. Thus, simply selecting nursery stock from a certain distance south of a forest restoration site in an effort to create resistance to warming temperatures is not necessarily a compelling strategy.

All of these forces and more will alter the species composition and structure of ecosystems in a changing future, but not necessarily in ways that are easily predictable, making it difficult to formulate practical, operational policy, especially for a narrow geographic location such as the five boroughs of New York City. One policy that can be acted on now that will almost certainly prepare us for an uncertain future is to act to promote genetically healthy plant (and animal) populations. Populations that have maximal numbers of individuals derived from the broadest base of local genetic adaptation will be maximally primed to face that uncertain future. Our policies on how and when we translocate plants in practicing land management will be critical in that effort.

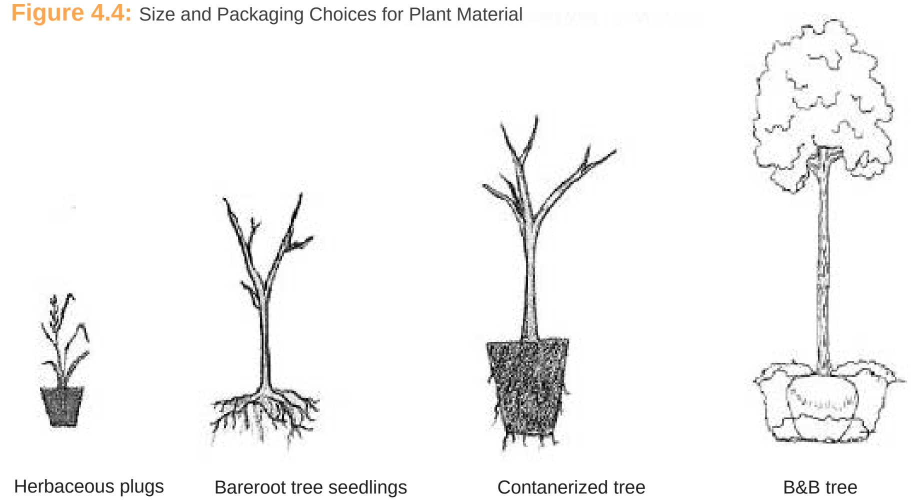
Size and Packaging

Plant material is available in four basic packaging types: balled and burlapped (B&B), container grown, bare root, and live stakes; each with advantages and disadvantages that you should weigh carefully during the design phase. As you make decisions, take into account quality, likelihood of establishment and success, aesthetic considerations, public perception at time of planting, costs, species availability, and sources of seed or propagule.

NRG's planting preferences have developed over time after much experimentation and observation in the field. Currently, NRG primarily uses trees or shrubs grown in No. 1 (one gallon) or No. 2 (two-gallon) containers for restoration projects. They are relatively inexpensive, easy to handle, and exhibit higher rates of survival (See p. 9) with little aftercare. Trees with a higher ratio of root to shoot size provide the best balance between mortality and initial investment. Most species in No. 2 containers are two- to three-feet tall upon delivery, and have stems at least one-quarter of an inch in diameter. Although it will take years of growth before young reforestation sites resemble dense forests, large expanses planted with hundreds of small trees have a dramatic visual impact nonetheless.

You can introduce native wildflowers and grasses to a site through seeding or by planting as peat pot plugs. The decision to use seeds or plugs will be based on budget and site scale. Plugs ensure establishment of plants exactly where desired

Figure 4.4: Size and Packaging Choices for Plant Material



NRG PROCUREMENT PROGRAM FOR CONTAINER TREES

NRG foresters pull trees out of their pots during inspections to check that trees are well-rooted but not pot-bound.

NRG entered into tree procurement contracts with nurseries that grow trees specifically for New York City forest restoration sites. The contracts specify: minimum qualifications for each nursery; details about tree quality, species, and types; and requirements for tree delivery and seed source. Through these contracts, NYC Parks is able to ensure that its large-scale forest restoration projects are not subject to nursery availability, as each contract nursery grows stock specifically to sell to NYC Parks.

Each nursery is subject to annual on-site inspection and evaluation by NRG to ensure that its operations continue to meet the contract standards. NRG also inspects the trees themselves at multiple points during the year, including at the time of delivery. The contract requires that nurseries make every effort to obtain plant material that is local to the New York City metropolitan area via NYC Parks' Greenbelt Native Plant Center's seed collection program.

NRG's commitment to procuring a diverse range of native tree species has spurred nurseries to plant species for which there has been little previous commercial demand, such as American linden (*Tilia Americana*), bur oak (*Quercus macrocarpa*), chinquapin oak (*Quercus muehlenbergii*), scrub oak (*Quercus ilicifolia*), and various hickory species (*Carya spp.*). Some species NRG requests from nurseries, like boxelder (*Acer negundo*), may be considered weeds elsewhere, but have great value to local restoration work.

Through engaging directly with native plant nurseries via plant procurement contracts, NRG obtains the best material for successful forest restoration in New York City. The long-term contracts allow the agency to cultivate relationships with the individual plant growers so everyone understands and can work towards the common goal of creating the best plant for the unique urban forest habitat.

Another benefit is the opportunity to tweak production and delivery systems. For example one nursery developed a labeling system using stickers on nursery pots in place of plastic tags. These produce less waste and do not have the potential to harm the tree.

Tags in pots help to label trees without harming the stem of the tree.

which is important when soil stability or aesthetic effect is required. Plugs also have higher initial root to shoot ratio, providing faster growth, greater initial floral display and eye-appeal, and quicker reproduction by vegetative means or by seed.

Larger B&B trees are well-suited for highly visible and well-trafficked park areas and highway rights-of-way. At such locations, smaller stock is more vulnerable to trampling and motorized maintenance equipment. B&B trees are also appropriate for formal walkways due to their visual impact. However, this type of stock is expensive and challenging to handle due to the trees' size and weight. B&B trees have most of their roots removed when they are dug from nursery soil and as a result of their low root to shoot ratio often suffer from transplant shock.

Bare root plant material is delivered from the nursery with no soil. Bare root trees are typically seedlings, with just one or two years of growth, though some trees can be harvested bare root at caliper size (with one- to two-inch diameter trunks). Bare root seedlings are the least expensive and easiest to transport of all packaging types, but they are also extremely sensitive to dessication and rodent predation. Store bare root trees carefully in a temperature-controlled location or plant them immediately. Once planted, they require a heavy initial watering. In sites with shallow or very wet soil, or locations where soil disturbance is restricted or regulated, bare root plantings may be the best option.

Native trees grown in two gallon containers for forest restoration projects in NYC.

Spacing

Your plant spacing design will reflect your project's goals, budget, and maintenance capacity, as well as the properties of the species and packaging size you select. In general, the more densely you space plantings, the faster the forest will achieve canopy closure. Close spacing also reduces both competition from invasive species and the amount of post-planting care needed (Sharew, H., 2005). At sites previously dominated by invasive vines or at risk of invasion, NRG plants a mixture of native trees and shrubs, approximately three- to five-feet-on-center, in order to create rapid canopy closure and promote the ultimate goal of establishing a multi-story forest. In all cases, determine the exact spacing by looking at actual site conditions, including types of invasive species previously at the site, soil conditions, remaining native vegetation, surrounding plant communities, and topography. NRG recommends planting roughly one shrub for every four trees planted; these should be interspersed with a native seed mix or herbaceous plugs.

For large projects designed to include a mix of plant species and sizes, the following table shows plant number estimates, based on spacing, per acre (Coder, 1996):

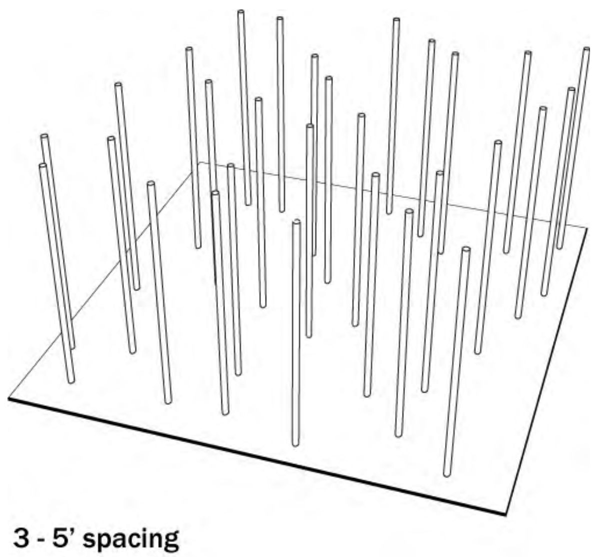
Figure 4.5: Estimates of Trees and Shrubs for One Acre (43,560 sq ft)

Spacing (feet)	Square Feet per Plant	Number of Tree/Shrubs per Acre
3x3	9	4,840
4x4	16	2,723
5x5	25	1,742
6x6	36	1,210

When calculating proposed plant numbers, be sure to look at the areas that are truly usable - it is unlikely that an entire site will be available for planting. Keep in mind the quality of the site, its current vegetation, the presence of natural objects (such as boulders), and existing built structures. The soil may not be homogenous and portions of the site may be unsuitable for planting for a number of reasons. NRG often finds that only fifty to seventy-percent of a restoration site can be planted. At a one-acre site with 70% of the area available for planting, using four-foot spacing between trees and shrubs, the number of woody plants that would fit on the site would be estimated as follows:

2,723 x 0.7=	1,906 x 0.8=	1,525 trees
2,723 x 0.7=	1,906 x 0.2=	381 shrubs

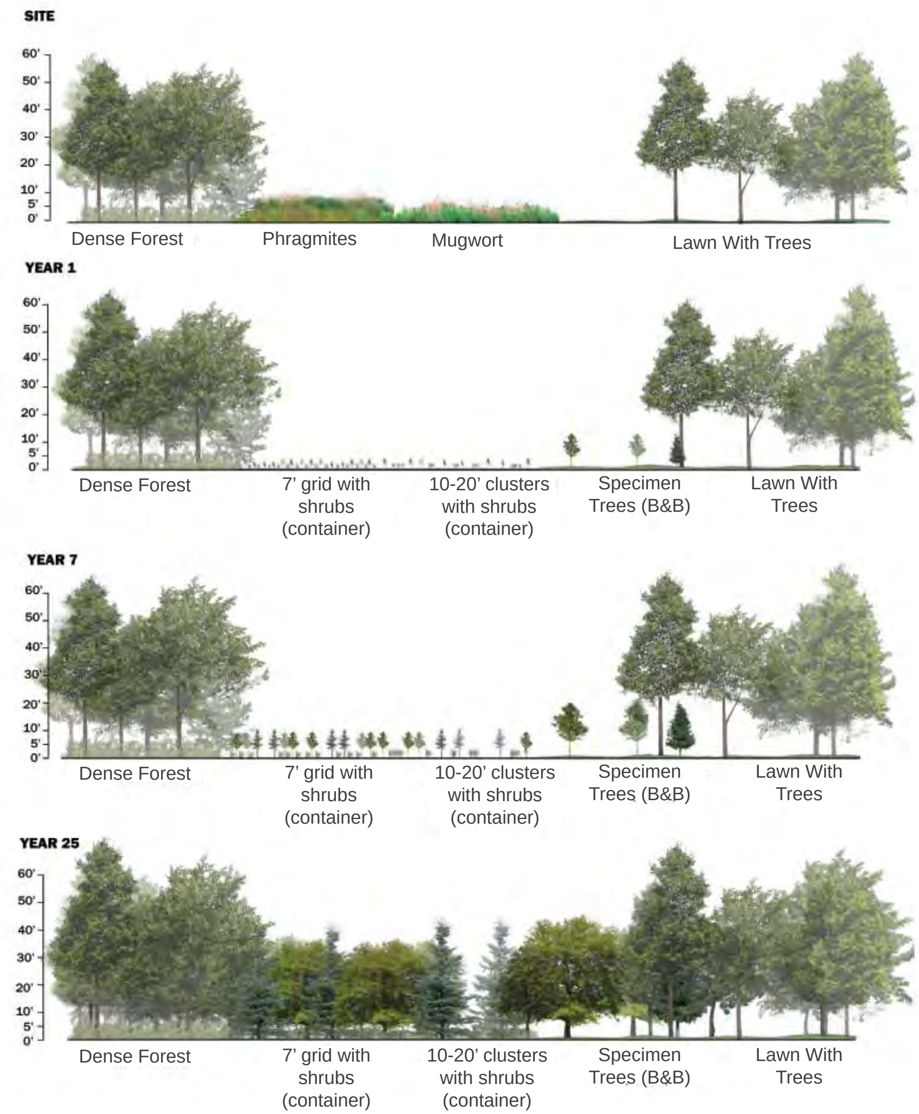
Figure 4.6: Visualizing 3 to 5 Foot Spacing



Pests and Wildlife

Consider potential pests when selecting plants and specifying spacing. In most cases, do not use species that are known to host insect pests, such as the Asian Longhorned Beetle (*Anoplophora glabripennis*) or emerald ash borer, or pathogens. These species are also often restricted by state or federal regulations. Consult the latest information from the USDA Forest Service to get information about existing pest epidemics in your area. Herbivory can also be a significant problem: deer, rabbits, or voles can devastate large areas of plant life in a matter of days. Incorporate protection against predation by these species into site planning if needed.

Figure 4.7: Visualizing Restoration over 25 Years



ESTABLISHMENT AND ADAPTIVE MANAGEMENT

The success of restoration depends heavily on management after planting. Methods of watering, continued invasive control, litter removal, and protection from herbivory are the main components of a long-term management plan. A site management plan that locates the closest water source, describes the expected length of the intensive establishment period, and designates responsibility for maintenance activities should be incorporated into forest restoration site designs. The plan should also include descriptions of potential future problems and strategies for their resolution, as well as a clear description of the projected future state of the site. These recommendations could include prescribing planting palette changes in future planting years based on the observed success of the originally selected species.

Conclusion

A thoughtful design for site preparation and installation can only be achieved through the close study of a given site. Understand that you may need to experiment with and adapt your strategies and techniques over time. Though complexities may abound, from understanding the symbiosis of species combinations to addressing numerous competing public concerns, giving each component of your project due deliberation will yield a cohesive, flexible, and effective plan. Once that plan is in place, it is time to get to work on the ground.

CASE STUDY: PlaNYC Reforestation In Kissena Corridor Park

Project Duration: 2006-present

Site Location: Kissena Corridor Park, New York

Size and land type: 100 acre municipal park

Forest Type: Sparse, invasive-dominated

Soil Type: Construction and demolition debris

Restoration Goals

- Control invasive plants and restore native forests.
- Enhance aesthetic value and visitor experience.
- Increase ecological connectivity to a greenbelt of parkways, and other green spaces between Nassau County, Queens, and Brooklyn.
- Incorporate scientific research to quantify the impacts of low- and high-diversity planting designs and the success of MillionTreesNYC efforts.

Pre-Restoration Site Conditions

NYC Parks assembled Kissena Corridor Park in pieces, beginning in 1938, to create a 4.5 mile contiguous corridor of green space from Kissena Park to Flushing Meadows-Corona Park. The City purchased most of the land between 1944 and 1948, and created additional land by filling in the glacial river valley and freshwater stream that flowed between Kissena Boulevard and Flushing Creek with construction and demolition debris. During the 1950s, the City closed streets to provide more land to complete the Park's consolidation. NYC Parks converted the majority of the newly created land to ballfields and playgrounds and allowed some acres within the park to naturalize as fields and forest patches.

In 1988, based on analysis of land use history and vegetation dynamics, NRG wrote a natural area management plan for Kissena Park, including Kissena Corridor. This analysis showed that invasive species, especially mugwort and phragmites, dominated the naturalized areas in these parks, and that park-goers significantly overused and abused these areas as well. Two decades later, as shown in a 2008 assessment, although car dumping, off-roading, and other damaging activities had declined, the same invasive vegetation patterns persisted. Based on local land manager accounts, NRG found that the negative view of the park held by residents in 1988 had endured.

Restoration areas adjacent to ballfields in Kissena Corridor Park. (photo by AECOM)

Methodology and Results

Planted: 6,135 container trees, 247 B&B trees, 1,830 shrubs
Total Acres Restored: 11

In 2006, NRG began preparing for MillionTreesNYC. Kissena Corridor Park was an attractive target for forest restoration because it offered a wide-open naturalized landscape with significant potential for improvement, as well as a vital habitat connection through the densely-populated and developed borough of Queens.

Prior to commencing work, NRG consulted with the Kissena Corridor Park manager to determine where in the park community members would most support the restoration and expansion of forest. Although the park had many open lawns and meadows, most of the lawns were heavily used by local residents for pick-up ball games and passive recreation. Ultimately, NRG selected mugwort and black locust dominated fields and lawn areas that were little used by the public.

After selecting programmatically and culturally acceptable sites within Kissena Corridor Park, NRG collected multiple soil samples to understand existing conditions. The Natural Resources Conservation Service (NRCS) undertook a parallel detailed examination and classification of Kissena soil, which informed NRG's work. NRCS dug seven test pits, two of which were stopped at a shallow depth because of strong petrochemical odors; the remaining test pits revealed soil that ranged from alkaline to acidic and varied in its water-holding capacity, and typically contained more than 10% artifacts like concrete rubble and other debris from filling (NRCS, 2009).

As soil analysis progressed, NRG contracted with EDAW (now AECOM) in 2008 to assess and design two large pilot forest restoration sites. The design engaged local researchers to explore and quantify the success of less resource-intensive, more typical urban forest restoration efforts. NYC Parks began working with EDAW and researchers from Yale University to create an experimental design for the site that would help quantify the impacts of low- and high-diversity planting designs.

The design delineated a forest restoration area for smaller container stock as well as a buffer area between the restoration site and active recreation by lining the formal paths with larger stock B&B trees. The design also designated a fenced staging area for contractor machinery and storage. In finalizing the designs for restoration staging and planting areas NRG and EDAW met with community leaders to get their feedback and support for the changes to park uses that would follow the restoration implementation.

As part of the contract design, NYC Parks and EDAW worked together to develop New York City's first set of contract specifications for invasive plant removal, including cut and spray sequencing for target invasive species with graduated payments. These specifications essentially took the years of experience of UFEP and NRG in-house crews and carefully described the work step by step for contractors to bid on and implement.

These specs, along with maps and sequencing instructions, directed the contractors to conduct an initial foliar spray of herbicide to control mugwort, phragmites, and porcelainberry. After the herbicide took effect, the contractor mowed the interior of the site and removed dead plant stems, concrete rubble, automotive parts, household appliances, and other debris that had been dumped on the site. Workers then spread wood chip mulch to a depth of six inches on paths used for construction access to reduce compaction. The crew then re-treated invasive species with herbicide and cleared them as needed. Following this site preparation, the crew incorporated compost into the backfill for each individual tree planting hole within the research plots and, outside of the research area, hydro-seeded a meadow-mix of herbaceous plants. Finally, mulch was spread across the entire site.

The contractor planted the site in fall 2010 and spring 2011 with a species palette that included a mix of American linden, eastern red cedar, American hornbeam (*Carpinus caroliniana*), eastern redbud (*Cercis canadensis*), sweetgum, shadblow (*Amelanchier Canadensis*), and oak species.

Per the planting specification, the contractor was required to water early and continuously throughout the growing season as part of the regular maintenance planned at each planting site. The specification also required the contractor to maintain or replace plantings for two years. Although the specification did not include requirements for follow-up herbicide application, the contractor returned to the site at NYC Parks' request to perform a spot treatment of herbicide on recurring invasive species.

Before Invasive Removal: Mugwort fields at Kissena Corridor before restoration in 2009. (photo by Marjorie Ely)

After Phase 1 Planting: Kissena Corridor restoration areas showing newly planted trees in the foreground, and preparation for more planting in the background. (photo by Marjorie Ely, 2009)

Lessons Learned

1. Most urban parks are in demand for a host of competing purposes. Engaging the community and park managers early in the design process allows for successful site identification. Having community support for the restoration locations means less vandalism to the restoration area, and a higher likelihood of engaging stewards in caring for plantings as they become established.

2. Implementation timelines, developed during the design phase, should allow enough time for sufficient control before planting occurs. One year was not enough time to control phragmites and mugwort at this location, and often is not enough in well-established or large stands. NRG conducted inspections in 2011 and 2012 and found that the invasives that had covered the site previously had returned along with the growth of newly planted natives trees and shrubs.

3. NYC Parks is still monitoring the site to determine the efficacy of soil amendments, and working with research partners at Yale to quantify the long-term implications of the high-diversity and low-diversity plantings that were part of the planting design.

Figure 4.8: Site Categorization: Kissena Corridor Park

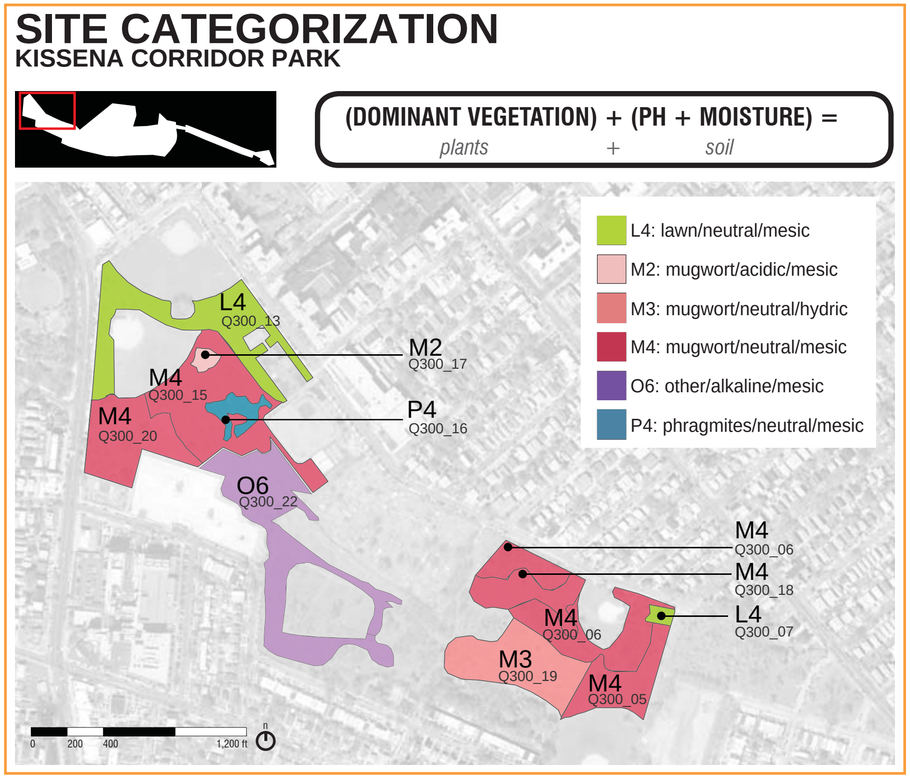


Figure 4.9: Invasive Plant Removal: Kissena Corridor Park

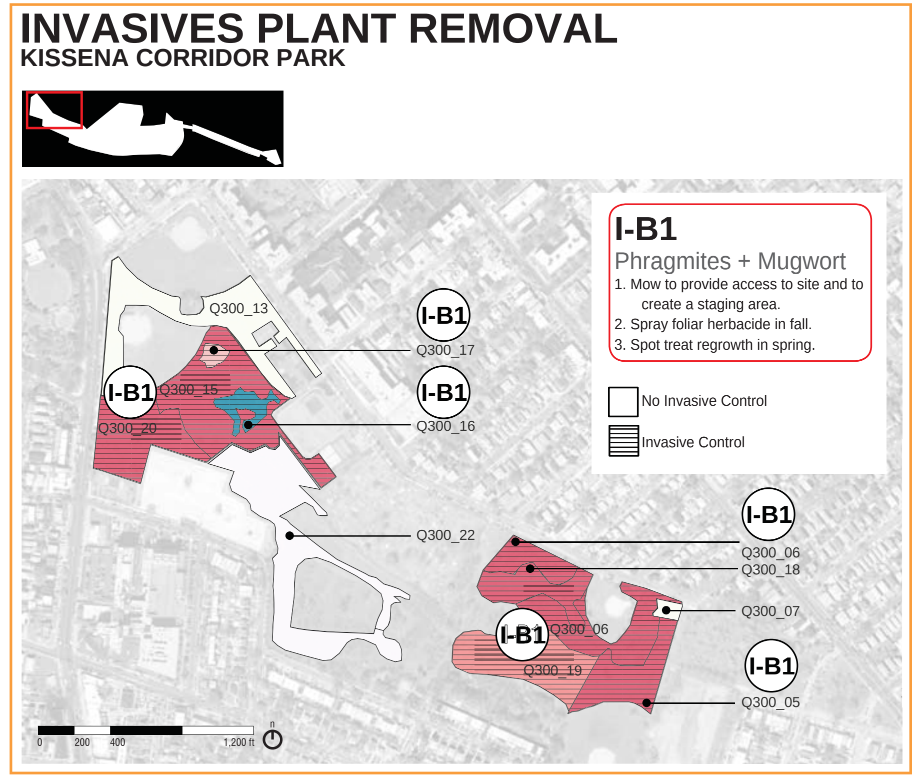


Figure 4.10: Kissena Corridor Park: Detailed Planting Year 1

Figure 4.11: Kissena Corridor Park: Detailed Planting Year 25

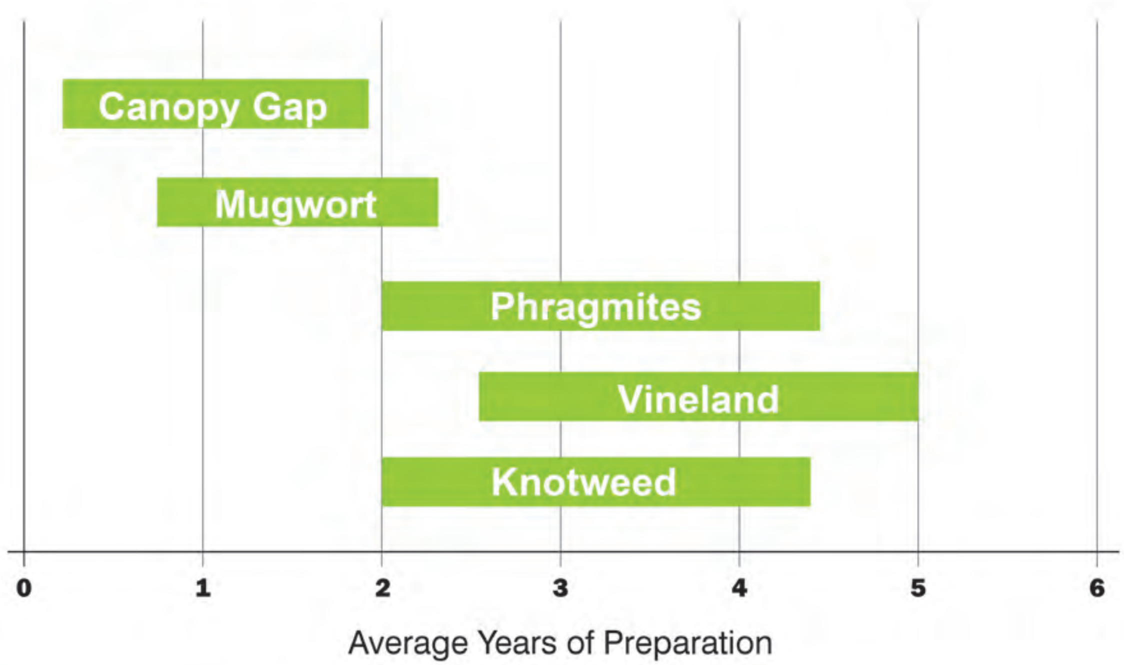
PART 3

PART 3

PART THREE:

BUILDING THE FOREST

Figure 5.1: Site Preparation Time Needed to Control Invasive Plants



CHAPTER 5: SITE PREPARATION

Site preparation underway with a front end loader at Cunningham Park.

Site preparation is not simply a phase that occurs prior to the commencement of restoration work - it is a fundamental part of the restoration process. Many of the efforts you take to ready your site for planting, particularly when it comes to the removal and management of invasive plants, will be the first steps of ongoing management regimes. This chapter will guide you through NRG's typical procedures for preparing urban sites. Your project's timeline and budget will determine your site-specific implementation strategy, but regardless of the techniques you use, thoroughness is crucial. A well-prepared site will give your planting the greatest chance of success and significantly reduce maintenance costs in the long run.

The principle components of site preparation are:

- Site Protection
- Invasive Plant Management
- Site Clearing
- Soil Preparation

SITE PROTECTION

Wetlands

If your reforestation site is in or adjacent to wetlands, you must make provisions to protect the wetlands from sedimentation and damage from herbicides. In New York City, you will already have an erosion control plan in place as part of the wetland permit application required by the New York State Department of Environmental Conservation (DEC). If a site is sloped or it requires significant earthwork, such as tilling or grubbing, consider installing a silt fence and hay bales and/or establishing a wetland protection buffer area. An Aquatic Pesticide Permit will be required before you can apply any herbicide to your site.

Existing Vegetation

Many forest restoration sites already support healthy native trees, shrubs, and herbs. These plants are valuable assets, so take care to protect them. Many site preparation activities can lead to scarred tree trunks, compacted soils, damaged roots, and broken branches. Herbicide use can also have unintended effects on healthy plants nearby. Some herbicides have active ingredients, such as triclopyr, that have the potential to mobilize among roots in porous soils. Tree species in the legume family, such as catalpa (*Catalpa speciosa*) or black locust, are especially sensitive to herbicide drift. Spicebush, sassafras, and sumac are also sensitive species.

Whether the work is to be performed by in-house crews or by contractors, do not begin site preparation without first putting in place a tree protection plan. This plan should also include directions about protecting beneficial shrubs, herbs, and soil. At a minimum, include the locations of temporary wooden tree guards, construction fencing, temporary snow fencing, and range fencing. Specify means for soil erosion and sediment control, excavation, soil compaction prevention and mitigation, and trenching and/or cut and fill operations. You should also address operational needs, by designating staging areas, establishing site access routes, and describing where and how materials should be stockpiled in your plan and how these areas will be restored afterward.

Wildlife

Select sites and phase their preparation in a manner that enhances the habitats of beneficial wildlife. In areas where birds nest, for example, NRG clears the site and makes larger structural changes during winters to eliminate nesting conflicts, and selects new shrub and tree species of adequate stature to create nesting opportunities. In addition, make sure that suitable habitat, to which organisms can safely migrate during site work, is available nearby. Implement the least damaging restoration methodology possible, and if herbicide application is necessary, select the chemical and application technique that will cause the least damage to non-target plants.

INVASIVE PLANT MANAGEMENT

It is extremely unlikely that non-native invasive species will ever be entirely eradicated within urban areas. Urban conditions are in a constant state of flux and new arrivals appear regularly via many points of entry. Nonetheless, targeted control of invasive plants followed by appropriate native plantings can result in the improved ecological health and stability of native plant communities. Focusing restoration work on building strong plant interactions and system function, encouraging native diversity and regeneration, and improving vegetative structure can promote the formation of a dynamic and resilient native-dominated community. While non-natives may still be present, they can be contained until native plant communities reestablish. Over time, pests, diseases and predators will emerge to reinforce the control activities you undertake.

On a site that is heavily dominated by invasive species, site preparation requirements will likely be extensive and invasive plant management will be a part of your project before, during, and after planting. Planting must be timed carefully to coincide with complete control of mature invasive plant populations present on site and in the surrounding area, and to precede the influx of new invaders that follow disturbance. Newly planted trees and shrubs will limit your access to the site and your options for invasive treatment; therefore, failing to manage established patches of invasive species prior to planting will inevitably increase maintenance burdens. Any remaining mature invasive plants, even if weakened by prior herbicide application, will threaten newly planted trees and shrubs by competing with them for water, nutrients, and light. Expect to continue weeding and treating invasive plants periodically until the tree canopy closes. Even after full canopy closure, monitor sites every few years for new invasions, especially after storms where fallen trees create new gaps.

Methods for Invasive Removal

The Partnerships for Regional Invasive Species Management and the Long Island Invasive Species Management Area have created a ranking system for invasive species that identifies their potential for disrupting ecosystem processes and establishes priorities for their management. Many sites will have multiple invasive species growing in the same area. Any invasive removal technique should be selected based on the specific suite of invasive plants present at a particular site, and should follow the principals of Integrated Pest Management (IPM).

Select removal methods based on the most aggressive and/or dominant of the invasive plant species present, and adapt them throughout the site preparation process in response to changes in the composition and vigor of the remaining invasive vegetation to be managed. The size of the area and maturity of the invasive plants will also influence your technique selection and the duration of treatment required. You will not need to treat a small or new patch of mugwort, for instance, as aggressively or as frequently as a large or well-established patch.

Porcelainberry vines overwhelm and choke trees in a section of Cunningham Park.

In areas with a high density of vegetation during the initial treatment, multiple follow-up treatments will be necessary to address the bottom layer of plants and re-sprouts. In many cases, after the first round of treatment, additional species may emerge from the seed bank or expand vegetatively. While a site may start out as a patch of multiflora rose draped in Oriental bittersweet and Japanese honeysuckle, the initial round of treatment targeting the vines may alter the composition of the site substantially, creating a field of mugwort mixed with bedstraw (*Galium mollugo*) and bindweed (*Convolvulus arvensis*). A second round of treatment targeting the mugwort may further complicate things by ushering in a new flush of Japanese honeysuckle, now mixed with native jewelweed (*Impatiens capensis*). Continual monitoring and adjustment of the treatment technique and timing will likely be required as you discover what is buried under layers of invasive vegetation and hiding within the seed bank. Incorporate new invasive plants that appear on site into the treatment plan as work proceeds.

Invasive plants growing on fill, primarily Phragmites and porcelainberry. (photo by AECOM)

You can utilize mechanical, chemical, and/or biological methods for invasive plant control. Each category is described below. Practitioners often incorporate multiple methods into a single comprehensive strategy for a particular site, in which case timing treatments appropriately becomes critical.

INVASIVES MANAGEMENT: FACTORS TO CONSIDER

To determine the best approach for invasive control, assess each site based on the following information:

- Species of invasive plants
- Treatment area size
- Density and maturity of invasive plants
- Length of time available for treatment
- Time of year that invasive plant control or planting work needs to begin
- Sensitivity of native populations to herbicide
- Proximity to wetlands
- Available workforce
- Current city and state laws
- Budget for site preparation and maintenance

Mechanical Control

Mechanical control generally involves either cutting or pulling plant material. Where appropriate - and when permissions from city, state, or federal authorities have been granted - chainsaws may be used to selectively fell and cut up existing invasive exotic tree species. Many trees can be controlled by girdling, a process where the cambium is stripped in a continuous ring around the tree to disrupt the flow of water and nutrients.

Chainsaw being used to cut and remove vines at Fort Totten, Queens.

Another common method for controlling invasive herbaceous species is covering areas in sunny or warm locations with black or clear plastic. Though not found to be feasible on a large scale, this method can be effective in areas less than 400 square feet. Mowing is a mechanical control method that is effective when combined with chemical control methods to be more effective.

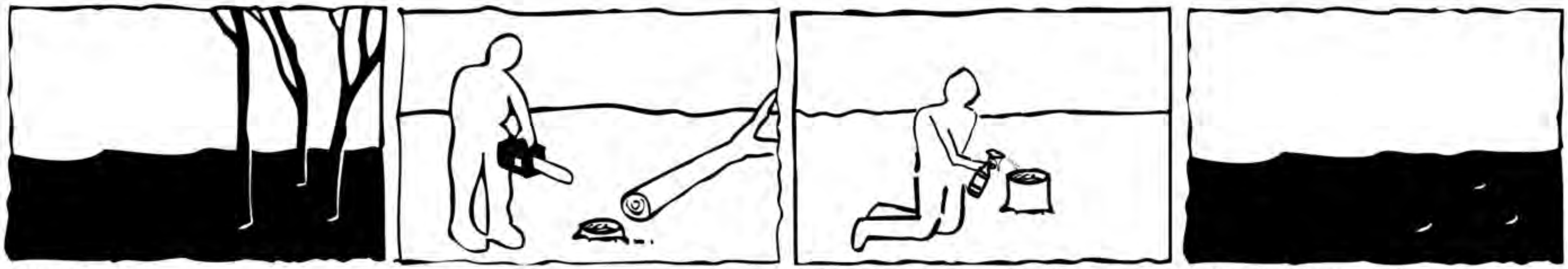
Chemical Control

Chemical control involves the targeted use of herbicides to kill invasive plants. In many situations, chemical control may be more effective than mechanical control. Careful use of herbicides can also minimize the negative impacts of soil compaction by eliminating the need for repeated visits for mechanical removal.

Whenever you plan to use herbicides, research the most effective chemical choice, timing, and application method for each plant species. Also learn how to best minimize chemical exposure to non-target species. Herbicides should only be used by, or under the direct supervision of licensed applicators as per the manufacturers' label instructions.

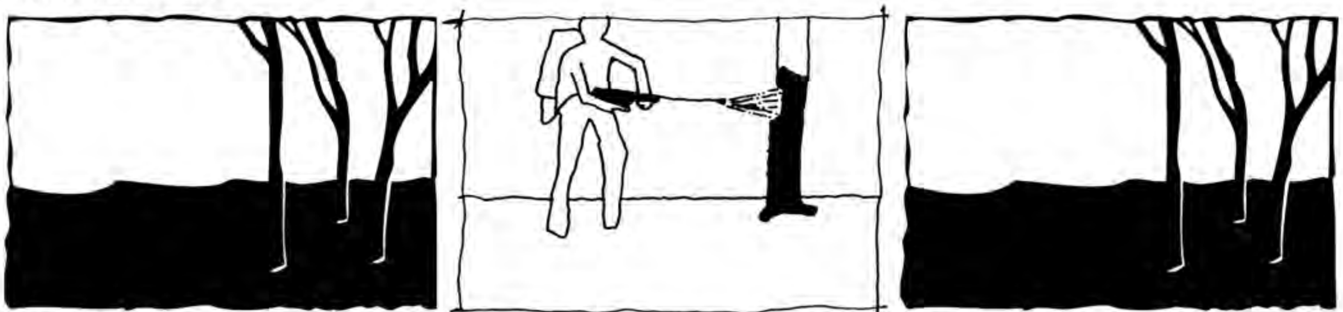
Figure 5.2: Illustration of Methods to Control Invasive Trees

Cut Stump Method



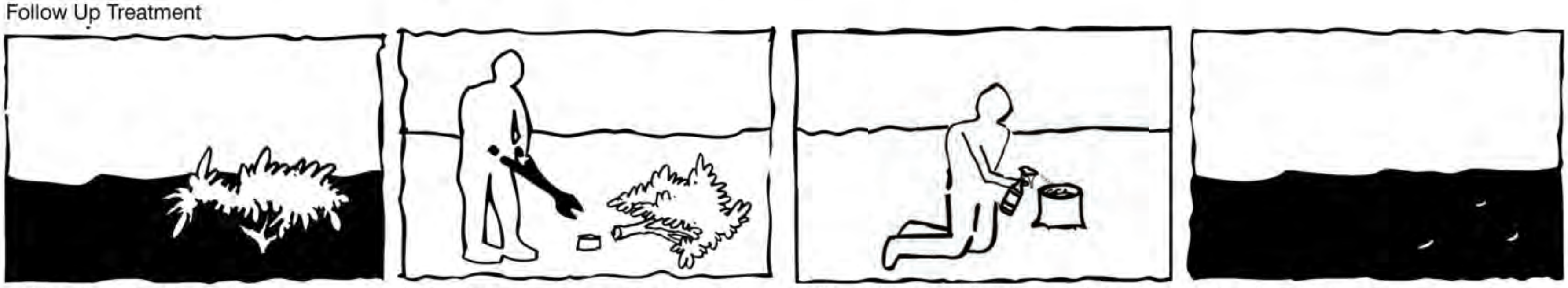
1. Existing Conditions.
2. Cut down tree.
3. Spray herbicide on to stump immediately after cutting.
4. Clear site of all cut and dead vegetation. Site is free of existing invasive trees.

Basal Bark Method



1. Existing Conditions.
2. Spray a band of herbicide on to the trunk of the target tree.
3. Leave treated tree in place.

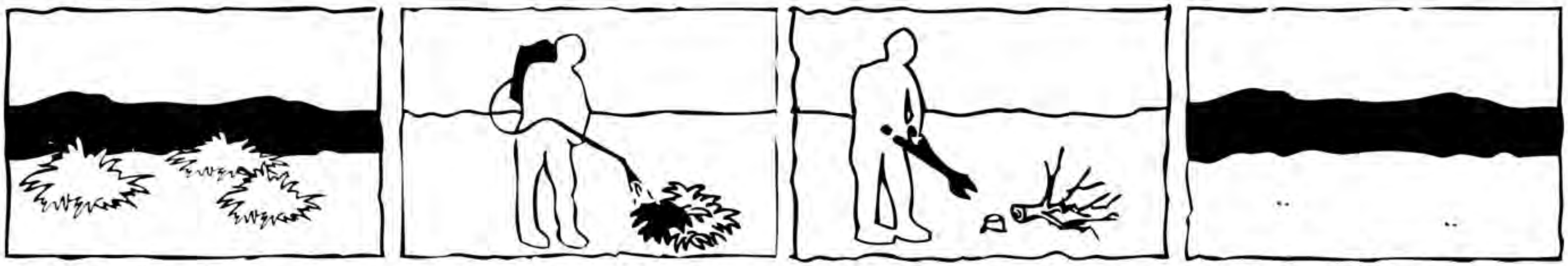
Follow Up Treatment



1. Existing Conditions; Tree has resprouted.
2. Cut off regrowth and cut stump again if possible.
3. Spray herbicide on to stump immediately after cutting.
4. Clear site of all cut and dead vegetation. Site is free of existing invasive trees.

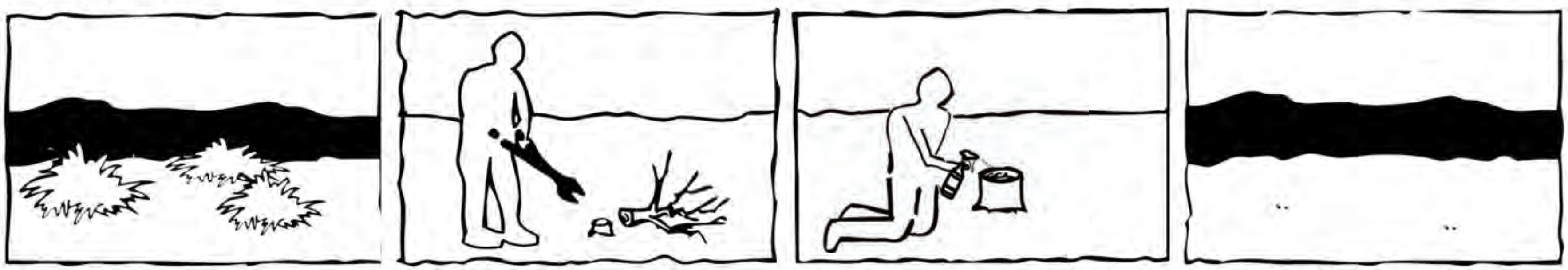
Figure 5.3: Illustration of Methods to Control Invasive Shrubs

Foliar Spray Method



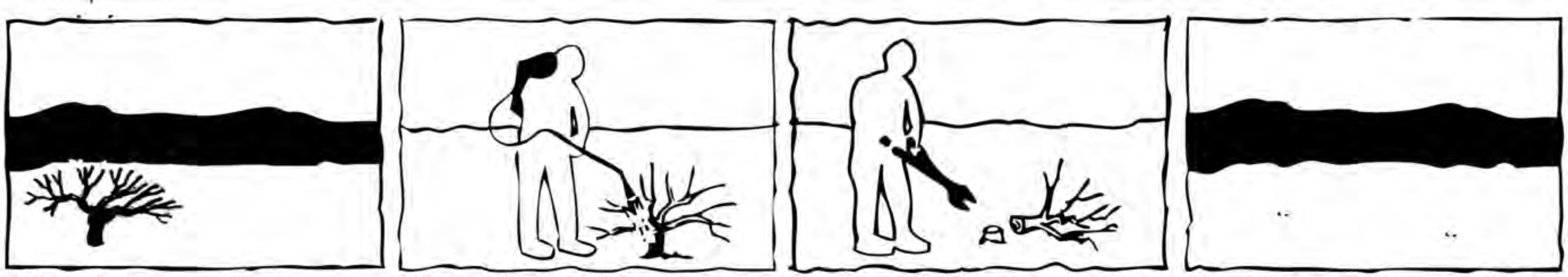
1. Existing Conditions.
2. Apply herbicide to all foliage of shrub.
3. Cut down treated shrub no less than 30 days after herbicide application
4. Clear site of all cut and dead vegetation. Site is free of existing invasive shrubs.

Cut Stump Method



1. Existing Conditions.
2. Cut down shrub.
3. Spray herbicide on to stump immediately after cutting.
4. Clear site of all cut and dead vegetation. Site is free of existing invasive shrubs.

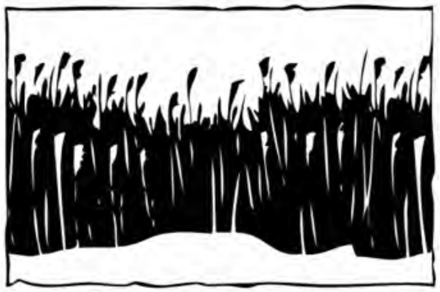
Follow Up Treatment



1. Existing Conditions.
2. Spray herbicide on to all visible bark of shrub.
3. Cut down shrub no less than 30 days after herbicide application.
4. Clear site of all cut and dead vegetation. Site is free of existing invasive shrubs.

Figure 5.4: Illustration of Methods to Control Phragmites

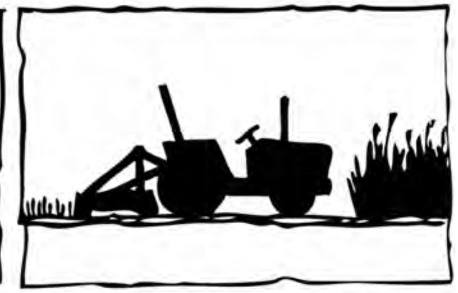
Mow and Spray Method



1. Existing Conditions.

2. Mow existing Phragmites as close as possible to the ground.

3. After designated window of time for plant regrowth, spray herbicide on to vegetation.



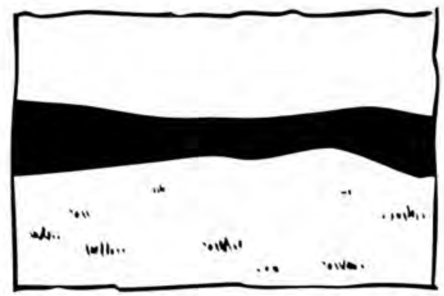
4. Mow dead vegetation no less than 30 days after herbicide application.

Foliar Swipe Method

1. Existing Conditions.

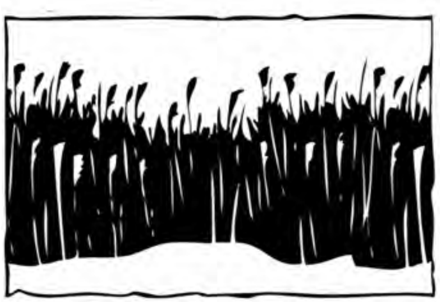
2. Swipe vegetation using a glove saturated with herbicide. Also known as the "bloody glove" method.

3. Cut down dead vegetation no less than 30 days after herbicide application.

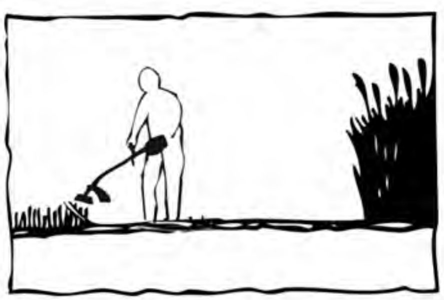


4. Site is cleared of existing Phragmites. Option to leave dead vegetation on site.

Mow and Swipe Method



1. Existing Conditions.



2. Cut existing Phragmites as close as possible to the ground.

3. After designated window of time for plant regrowth, swipe vegetation using a glove saturated with herbicide.

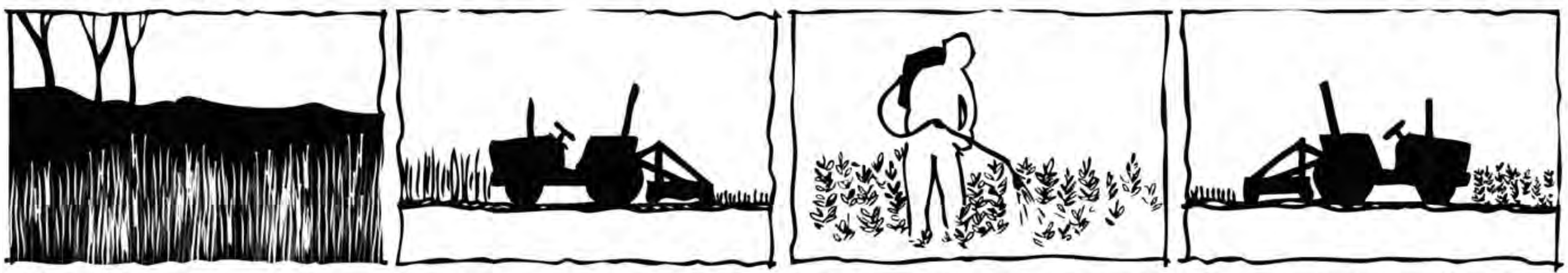
4. Cut down dead vegetation no less than 30 days after herbicide application.

Figure 5.5: Illustration of Methods to Control Herbaceous Plants

Foliar Method

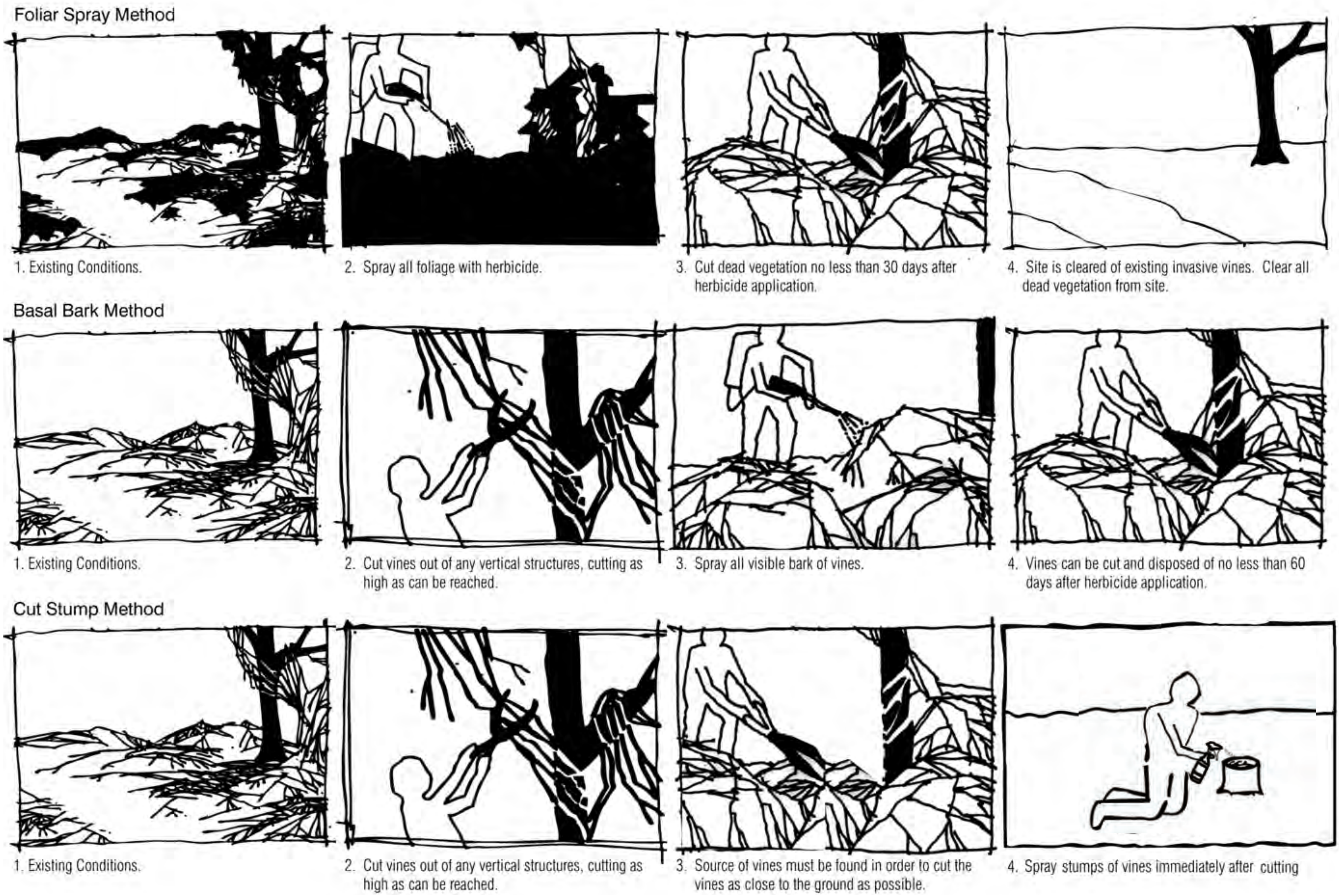
1. Existing Conditions.
2. Spray all foliage with herbicide.
3. Cut dead vegetation no less than 30 days after herbicide application.
4. Site is cleared of existing invasive herbaceous plants. Option to leave dead vegetation on site.

Mow or Pull and Spray Method



1. Existing conditions.
2. Mow site.
3. After designated window of time for plant regrowth, spray herbicide on to vegetation.
4. Mow dead vegetation no less than 30 days after herbicide application.

Figure 5.6: Illustration of Methods to Control Vines



Biological Control

Biological control involves the release of a pest or predator that will target the undesirable plant species. In large natural areas, biological control of invasive species can be more economical than chemical and mechanical methods. Rigorous testing by scientists in highly controlled settings over many years is required by the USDA before beneficial pests can be released. In New York City, there has been one successful release since the late 1990s of *Galerucella spp.* and *Hylobius spp.* beetles for the control of purple loosestrife (*Lythrum salicaria*). The mile-a-minute weevil (*Rhinoncomimus latipes*) has been approved to combat the spread of mile-a-minute vine. NYC Parks released it at several locations in New York City in 2013.

Sequencing Invasive Management

As mentioned above, invasive removal methods are often combined in a variety of sequences, and tailored for a particular site. The density and types of vegetation present can guide the creation of an appropriate site preparation timeline; the size of the site, accessibility and type of resources often dictate the specific techniques chosen.

Removal of mugwort by volunteers at Ferry Point Park.

NRG has developed several basic strategies tailored to common site types found in New York City that may be useful in other cities. These site types include: lawns and landscaped areas, small canopy gaps, vinelands, old fields dominated by invasive herbs, old fields dominated by invasive shrubs, and knotweed- and phragmites-dominated sites.

Lawns and Landscaped Areas

While lawns and landscaped areas appear on the surface to be uncomplicated planting opportunities with little invasive removal required, they can easily become difficult to manage.

Sites covered in turf grass should be ripped and/or decompacted by other means. The roots of turf grass form a dense mat underground, creating a highly competitive environment with little available air and water. In addition, turf grass sites are often highly compacted below the top 1-2 inches because of the weight of mowing equipment. Mowing regimes can also disguise a wealth of invasive species seeds and seedlings. Ripping will not only improve the soil structure, but also speed up the germination process for any invasive plants hidden in the seedbank.

Once you have ripped a site, allow the vegetation to regrow to a height of 1-2 feet and then selectively foliar spray with a low percentage of broad-spectrum herbicide. Almost all urban lawns have a wide complement of weed species including bedstraw, cleavers (*Galium aparine*), lambsquarters (*Chenopodium album*), clovers (*Trifolium spp.*), bindweed, and orchard grass (*Dactylis glomerata*). Most of these species can remain dormant in the seed bank for decades, but germinate readily following a disturbance. By ripping the site first, and allowing dormant seed to fully emerge, you can successfully eliminate many of these species with a single spray, reducing the long-term maintenance needs for your site.

This sequence can allow for planting within a single year, if the site is ripped over the winter or in the spring; chemical treatment occurs over the summer and planting is scheduled for the fall. Even within a perfectly prepared lawn site, some ongoing maintenance for the first several years following planting will be required. This will primarily consist of hand-pulling or cutting back herbs to create space around the woody plants, and reassuring the public that the site is behaving as expected. Trees and shrubs planted in these sites often grow quickly, and maintenance needs decline rapidly over time.

Small Canopy Gaps

Small canopy gaps within native-dominated forests are ideal reforestation sites. The surrounding intact forest will shelter the site and may have contributed seeds of desirable species to the seedbank. Minimize your site preparation efforts by preparing the site as soon as possible after the disturbance that creates the gap. For gaps created by wind-throw during a storm, or where a large canopy tree has succumbed to insects or disease, site preparation may be as simple as bucking up and dispersing the down wood to create access and space for new plants. For gaps that are several years old, invasive plant populations may have become established. The character of invasive vegetation found in gaps varies from place to place, but is typically dominated by species that are carried by birds, mammals or water. For example, a gap along a stream may quickly be colonized by Japanese knotweed or lesser celandine (*Ranunculus ficaria*) if there is an established population upstream. A gap within a coastal forest may be swiftly colonized by mile-a-minute which hooks onto the feathers of migrating birds.

Whenever working in a gap, first buck up and disperse the downed wood to create access and visibility for staff, and to prevent vine trellises from forming. Once formed, vine trellises can reach quickly into the canopy of surrounding mature trees, causing a domino effect. Cut high any trellises that have been formed around the perimeter of the gap. After taking these initial steps, manage small populations of invasive herbs by hand-pulling if appropriate, or careful foliar spraying. Remove small populations of invasive vines or shrubs by hand-pulling or through cut-stump treatments; foliar and/or basal spray larger or more established patches of vines or shrubs. For these more established patches, check the site again after a period of 6-8 weeks; cut back dead material carefully and re-spray any re-growth. Scout the forest surrounding the site for outlying pockets of invasive plants and treat these areas as well. Continue this sequence until only a small population remains, at which point you can switch to cut-stump treatment.

Once you complete the cut-stump treatment, plant the site densely, with plantings feathering into the understory. Periodically check the site through canopy closure to ensure that there is no further invasive colonization. Once the canopy is fully enclosed, this type of site blends into its surroundings and can be incorporated into the management cycle of the surrounding forest.

Vinelands

Vinelands are areas dominated by invasive vines, including porcelainberry, Oriental bittersweet, and Japanese honeysuckle. New York City contains hundreds of acres of vineland. Due to the persistence of viable seeds in the soil, rapid growth, and the ability of some species to filter out or resist chemical treatment, vineland sites require a long lead time for planting and the longest post-planting maintenance. When treating vineland sites, include the removal of invasive species within a large buffer area around the restoration site to reduce seed sources which could re-colonize the restoration area.

Vinelands often occur in untended canopy gaps, and can cover acres of downed trees and other vegetation. Initial access through a vineland is precarious, and often reveals unexpected elements within your site. In New York City, NRG has regularly found burnt out cars, building foundations, old roads, homeless encampments, and evidence of dumping under carpets of vines. At the same time NRG also discovers uncommon spring ephemerals, salamander habitat, and native seedbanks. Consider the scale of the site, the likelihood of encountering native vegetation, and the available manpower when selecting a removal method.

The first priority with these sites, similar to smaller canopy gaps, is creating access and visibility. Cut any trellises which have formed around the perimeter high, and allow the lower section of the vine to drop to the ground and remain connected to its root. Because NRG typically uses systemic herbicides, the more of the vineland that can be left intact, the more effective treatment will be because the more above ground vegetation remaining the greater the uptake of herbicide to the roots. If necessary, cut additional paths through the vineland at regular intervals to allow access for workers with backpack sprayers or a truck-mounted spray rig for foliar and basal treatments. Take care to minimize vine cutting while creating paths.

Once you have created access, begin work with either a basal treatment if it is winter, or a combination foliar/basal treatment if it is summertime. For sites larger than an acre, a truck mounted spray rig is the most efficient option for initial spraying. For sites smaller than an acre, backpack sprayers are sufficient. In either case, after a period of 4-6 weeks, cut back dead material using hedgetrimmers or chainsaws and/or clear the material using a flail mower or front end loader. Allow the remaining vegetation to re-sprout for several weeks, until lush new green growth has formed, then re-spray the re-growth. The more vigorous and healthy the re-growth is, the more effective it will be at absorbing and translocating the herbicide. Scout the forest surrounding the site for outlying pockets of invasive plants and treat these plants as well.

Establishing control over a vineland takes several years. It is probable that during this time a new flush of plants will appear from the seed bank. The new plants will likely be a mix of natives and invasives and, as you proceed with site preparation, you will need to carefully monitor site conditions. As the balance of vegetation shifts, your primary focus will naturally move from eliminating invasive plants to preserving the desirable volunteer plants. Continue the spray and cut sequence outlined above until only small scattered invasive plants remain within the site. As the patches of remaining invasive plants become less dense and more interspersed with native vegetation, it may make sense to transition from a truck mounted sprayer to backpack sprayers.

As the population of target invasives declines further, move on to the cut-stump treatment. Once you have completed the cut-stump process, plant the site densely, feathering plantings into the surrounding understory. Check vineland sites frequently through canopy closure to ensure that there is no additional invasive colonization. It is a good practice to review available literature about the persistence of seed from the targeted plant in the seed bank, and continue regular monitoring of the site until the danger period has passed.

For some species of vines, such as mile-a-minute, minimizing disturbance to the soil after planting is critical for long-term success. Species like this may also warrant judicious application of pre-emergent herbicide early in the spray-and-cut cycle to clear out the seed bank; undertake these treatments only where you are willing to sacrifice the native elements of the seed bank. Failing to properly prepare a site may lead to the return of large quantities of vines, increasing the weeding and maintenance burden.

Old Fields Dominated by Mugwort

These sites are often former lawns that, after a number of years of little or no maintenance, become overrun by invasive herbs. In some cases, these sites are former wetlands filled with a variety of materials including (but not limited to) incinerator ash, dredge spoils, and landfill. Sites may also contain remnants of runways, roads, or sidewalks. In almost all cases, they have compromised soils and poor infiltration or retention of water, conditions that create an environment ripe for species like mugwort. While at first glance old field sites may appear to be entirely dominated by mugwort, upon closer examination a mix of stunted saplings and pockets of hardy natives like Canada goldenrod (*Solidago canadensis*) may be revealed. Nonetheless, in almost all cases, mugwort, a tenacious perennial that thrives in highly alkaline and low nutrient soils, is usually the dominant invasive plant to treat throughout site preparation.

To prepare a mugwort-dominated site, the application of foliar herbicides is helpful to completely eliminate rhizomes. A small or young patch of mugwort can be effectively controlled as quickly as one growing season with the use of herbicides, but a well established patch usually takes multiple years of treatment to control. At a minimum, mugwort should be treated twice during the growing season before planting. Treatment includes the following steps: mow the mugwort stems and wait 3-4 weeks for bushy regrowth, then spray with a foliar herbicide. For best results conduct both treatments in the summer as new growth is particularly susceptible to herbicide treatment during the hottest time of the year.

Alternatively, you may hand pull or clip mugwort, however, this method is very labor intensive. Mugwort is persistent: it grows and spreads rapidly, and, while a closed canopy will eventually shade it out, it is highly competitive with young trees and shrubs. If you choose mechanical removal, cut mugwort at least 4-6 times per growing season to deplete root reserves.

Although mugwort sites can support forests, mugwort is usually an indicator of a highly compromised site. In New York City, sites dominated by mugwort often have growing mediums, like poor soils or construction fill, on which establishing forest is challenging. Careful plant selection, with species such as sumac, eastern red-cedar, and hackberry, is critical to successful forest restoration. In addition, expect sites with poor soils to require extensive watering and more time overall for forest establishment than sites with native soils. Mugwort sites are also often home to voles or rabbits that eat newly planted trees.

After replanting, mow or treat mugwort as needed until the trees reach sufficient height to create a closed canopy. Check sites once a year, in July or August, until the trees are more than six feet tall or more than a foot taller than the tallest mugwort. If you can sufficiently control mugwort at the time of planting, seeding with native grasses and herbs will increase competition and diversity within the groundcover, thereby improving the litter layer and microclimate, and creating more space for trees and shrubs to thrive.

Old Fields Dominated by Invasive Shrubs

Invasive shrubs often overtake old agricultural fields and house sites and species will vary depending on the contents of the original garden or field. Multiflora rose, bush honeysuckles (*Lonicera spp.*), buckthorns (*Rhamnus spp.*), olives (*Elaegnus spp*.), black jetbead (*Rhodotypos scandens*), and/or other invasive plants dominate old fields.

Such sites generally have loamy and well-drained soil, which is good for supporting multi-story forests. Invasive shrubs are often mixed with vines and/or other invasive species. Depending on time and resource constraints, shrubs can be controlled through a variety of manual and chemical removal techniques. A simple and effective technique for shallow-rooted species is to uproot and remove the plant material. This work can be performed with a variety of specialized tools on the market, including weed hooks and honeysuckle poppers. For shrub species that root deeply, or tend to sucker, cut-stump treatments are often effective. For more vigorous or large scale infestations of multiflora rose, or other species with photosynthetic stems, stumping a field of plants with a hedge trimmer to approximately waist height in late fall, and applying a mixture of herbicide and basal oil in early spring when the first flush of new growth emerges is very effective. Shrublands can often be completely controlled and removed within a single season.

Planting can immediately follow successful control, but take care to double-check the site for invasive vines that may have been masked by the shrubs both within the site and in the surrounding landscape.

Knotweed and Phragmites Dominated Sites

Two invasive species which are particularly vexing and difficult to control are knotweed and phragmites.

Phragmites, or common reed, is an invasive grass that colonizes wetlands and forms dense stands. The roots and rhizomes of phragmites can penetrate ground to a depth of more than six feet. A cost-effective approach to treating an area dominated by phragmites is to mow and apply a foliar spray of a glyphosate-based herbicide to the site for two consecutive seasons prior to planting. While this will not fully eradicate a stand, it should knock the vegetation back sufficiently for woody plants to successfully become established.

After planting, you will need to cut back phragmites within and around the site for three to five years, or until the trees are approximately nine feet high or tall enough to tower over the phragmites and shade them out. If you fail to prepare the site properly, phragmites will return and require even more frequent cutting after planting.

Japanese knotweed is a highly persistent invasive shrub-like herbaceous perennial that colonizes disturbed soil in a variety of habitats. It is often found on road and forest edges and along fresh water bodies. Preparation of sites dominated by knotweed requires at least two to three years of treatment with foliar spray herbicide for three times each growing season prior to planting.

Even after aggressive treatment, knotweed will grow back from rhizomes for many years. Until newly planted trees grow high enough to tower over the knotweed, remove any that re-emerges periodically by pulling or digging out its rhizomes. You can expect to perform this level of maintenance for at least three to five years following planting. Once trees are tall enough to shade knotweed, the size of the colony can be kept in check. Nevertheless, some amount of knotweed will most likely persist indefinitely.

For both knotweed and phragmites, because of their great tenacity, control within a site is not sufficient to ensure that your planting will be protected. These plants frequently move along waterbodies, so include coordinated control of these species throughout the watershed in your restoration effort. Any storm event or significant rainfall can move new rhizomes or root clumps downstream and destroy years of hard work. In addition, soil disturbance such as ripping and digging often makes the stand more vigorous. Plan to dig only in those locations where you will conduct follow-up spray with herbicide.

If not conducted properly, herbicide applications to knotweed and phragmites growing in wetland areas can harm sensitive wetland organisms including fish, frogs, salamanders, and rare plants. Regulations may apply to herbicide treatment in such areas to insure that only chemicals and techniques that are non-toxic to wetland species be used in these sites.

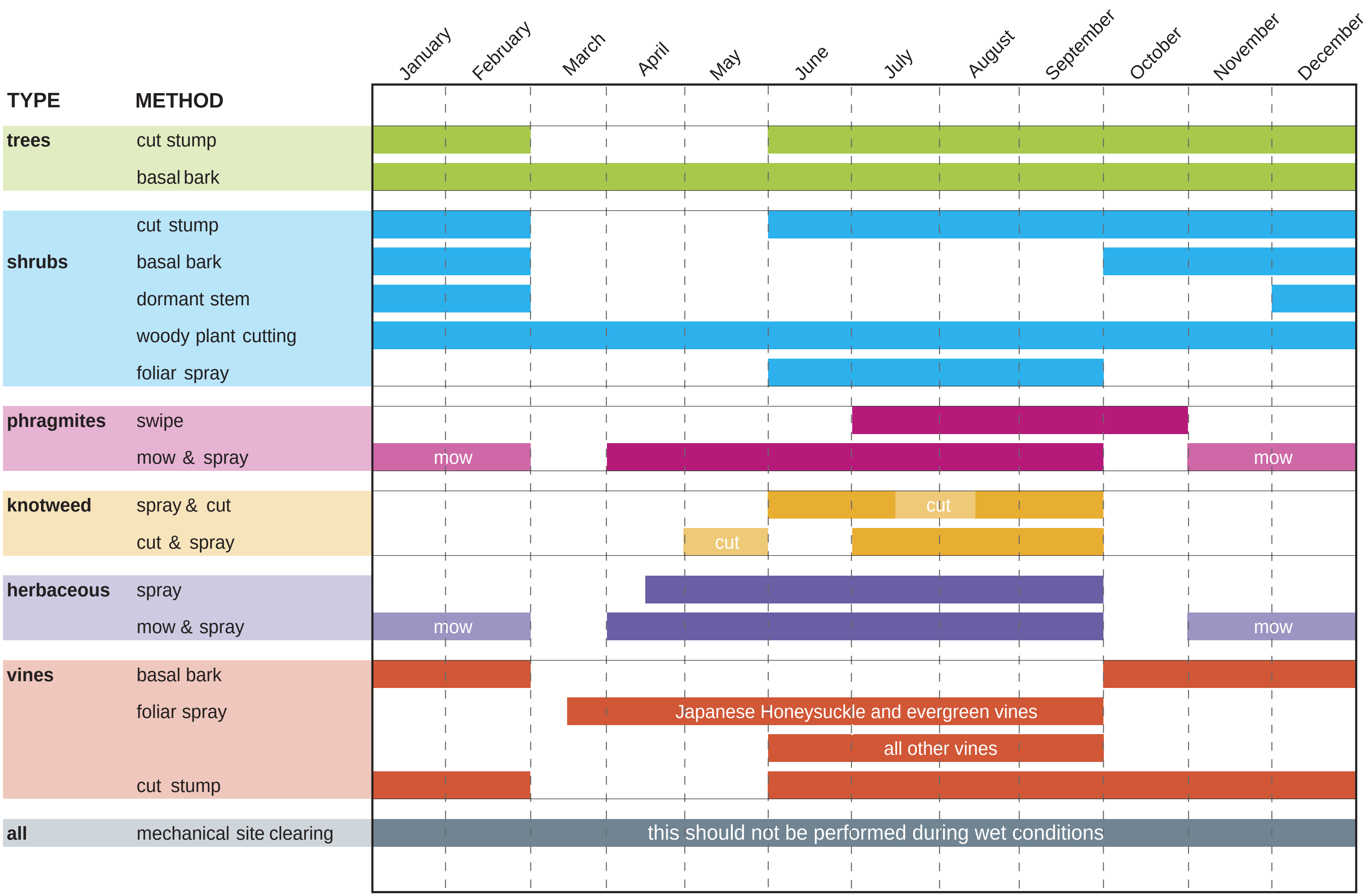
COMPREHENSIVE RESTORATION: INWOOD HILL PARK

Inwood Hill Park, a 196-acre park at the northern end of Manhattan, is relatively modest in size, but a particularly high percentage of its acreage is forest. UFEP began working to restore the park's natural areas in 1991 and NRG continues to actively manage the site today.

After removing debris and effectively blocking vehicle access, a small UFEP team focused on controlling invasive vines and planting native trees. They saw that native regeneration in canopy gaps was not occurring, in part because squirrels and other rodents consumed most of the oak acorns and tulip seeds (Weidel, 2001). With only a very limited budget, the team initially tried installing bareroot seedlings in clearings. The seedlings were indeed inexpensive, but they were also vulnerable to predation and desiccation and did not succeed on the site. This observation led to the decision to invest in larger plant material, typically 1-2 gallon containers, which exhibited greatly improved survival and growth rates.

Over a period of 20 years, NRG staff, building upon UFEP's precedent-setting approaches, gradually achieved a near-comprehensive restoration of the park. Active invasive removal continues today, to keep this hard-won multi-story forest healthy and robust. Inwood Hill Park became a success story for several reasons: its scale allowed a small team to manage the entire forest effectively; UFEP began restoration work before invasive species fully dominated the site; active management continued consistently over an extended period of time; and our intervention allowed regeneration of the forest over time.

Figure 5.7: Invasive Vegetation Treatment Calendar



SITE CLEARING

Site clearing entails removing existing invasive and undesirable vegetation, excess woody debris, large non-woody debris, and other soil constraints to allow for new planting. When performing site clearing, keep as many existing stumps and root structures as possible in place to avoid soil erosion and destabilization except when their placement impedes the desired planting density. Leave brush in place whenever possible. If brush needs to be removed for access or other reasons, preferentially retain larger diameter branches and trunks on site, and remove smaller branches. Only chip wood on site if it can be adequately spread so as not to negatively impact the herbaceous layer. In some instances, distribution of chips onsite can benefit soil by adding organic matter. Chips also help hold moisture in the soil, especially at sites that are open and sunny. On sites where there is a significant invasive seedbank and minimal or no native regeneration, a thick layer of chips may help discourage germination of undesirable species.

If a felled tree is to be left in an area subject to possible colonization by vines, remove and disperse its limbs to prevent them from serving as a trellis for invasive vine species. Alternatively, cut and pile wood debris in four-cubic-foot piles to provide wildlife cover. Check or move such piles periodically to make sure they do not become sinks for invasive seeds. Consult with the local land manager to ensure that any debris piles are placed in areas that comply with land use patterns within the parks.

Large woody debris promotes important ecological processes serving as a medium for proliferation and dispersal of soil enhancing fungi, habitat for insects and other arthropod decomposers that build food webs, and provide microclimates (shade, moisture, and wind gradients) that promote seed accumulation, germination, and plant recruitment.

Clear areas located within the drip lines of remaining trees by hand because heavy mechanical equipment will compact the soil and damage tree roots.

A restoration site in Cunningham Park where debris removal is needed in order for restoration to proceed.

SOIL PREPARATION

Mitigating Compaction

When planting in urban fill, soil compaction is perhaps the single most difficult challenge to overcome. There are a number of ways to mitigate compaction, including rototilling, ripping, and soil replacement. Regardless of the technique you use, disturb only the minimum amount of soil necessary. Soil disturbance can activate dormant invasive seed banks and damage soil structure. Naturally deposited soil frequently supports beneficial vegetation and fungal and bacterial activity.

Rototilling

Rototilling generally refers to shallow-depth tilling that breaks up soil with rotating tines, spoons, or blades. Rototilling devices may be tractor-drawn, which are used for large open sites, or walk-behind, which are used for smaller sites or areas with limited access. Perform rototilling with caution. Remove all rubble or rocks that could inhibit tilling equipment beforehand and remove all rubble that was pulled to the surface during tilling and dispose of it properly. Only rototill when the soil is not wet.

Rototilling presents some disadvantages. As the device breaks up the soil at the surface the pressure can compact the soil below. Rototilling also tends to destroy soil structure by mixing soil strata. Nevertheless, loosening of soil by rototilling gives tree roots opportunities to grow, an advantage which may outweigh potential drawbacks.

Ripping

Compaction to depths greater than 12 inches is best handled by soil ripping (also known as subsoiling), which uses stationary, solid-shank equipment to cut deep channels and break up compacted soil. While NRG has not restored a site where ripping was appropriate, practitioners elsewhere have had proven success with this soil preparation technique. Soil ripping creates a twenty-four- to thirty-six-inch grid of channels across a compacted area. If the slope of the treated area is greater than 33% (18 degrees), these channels should run parallel to the slope. After ripping, soil surfaces are very uneven and furrowed with soil clods. To smooth the surface for planting, cultivation may be required.

Soil ripping cannot be used on small sites, but where there is sufficient space, it is the most effective way to loosen compacted soil and cut through rubble. Because soil ripping only disturbs a portion of the ground plane, much of the valuable organic material in the soil remains intact. Ripping may also be required in lawn conversion areas, where well-established turf needs to be broken up to allow for the installation of woody plant material.

Figure 5.8: Illustration of Rototilling

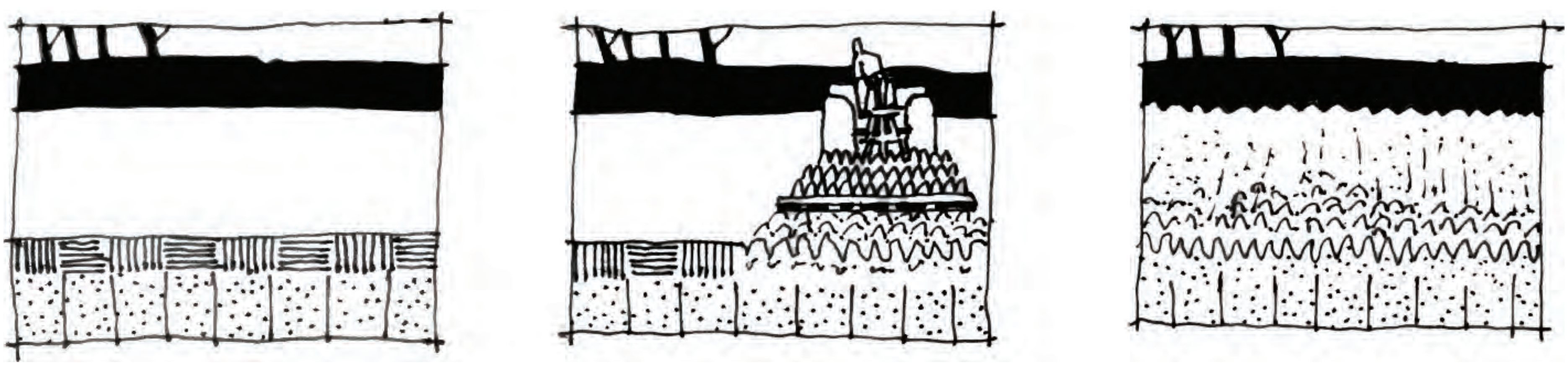
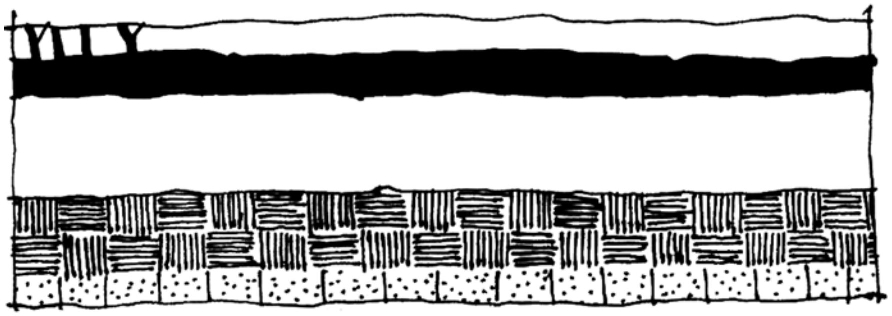
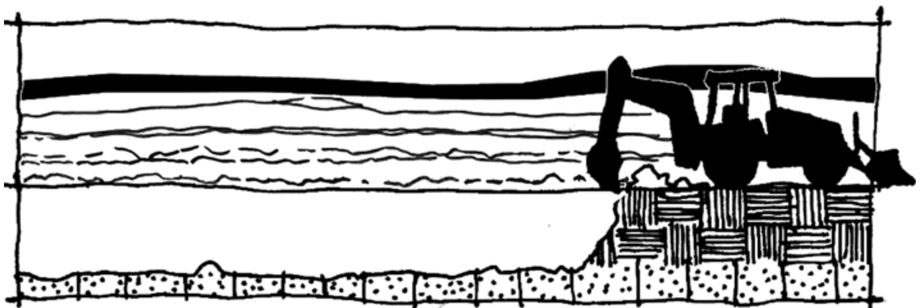


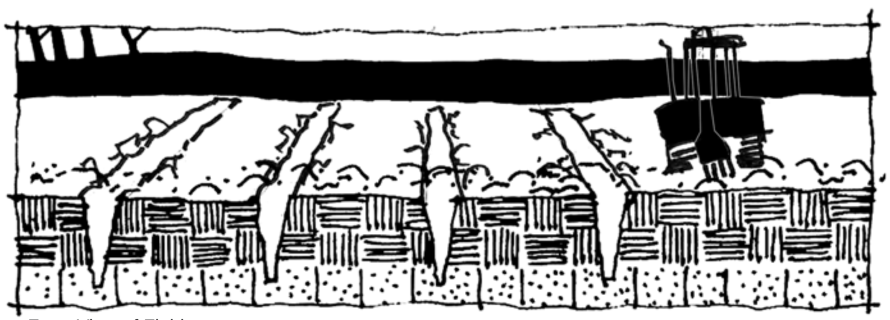
Figure 5.9: Illustration of Ripping



Front View of Field



Side View of Field



Front View of Field

SOIL PLACEMENT AND AMENDMENTS

Importing natural soil for use as cover over urban fill can be a beneficial soil treatment. In areas where ripping, or excavation of large debris is impractical, it may be more cost-effective to import a new soil layer. In all but the most exceptional circumstances, however, the cost of purchasing and importing enough soil to provide a sufficient growing depth (ideally three-foot-deep cover) would be substantial and exhaust most budgets. Exceptional circumstances do arise, however - see 'Soil Sharing' for an example. Due to the high cost and low feasibility of soil replacement, NRG is not often able to replace the soil on a site. Instead, NRG will occasionally utilize soil amendments where conditions are undesirable.

Acidic Soil Amendments

Urban fill often exhibits a high (alkaline) pH. The addition of acidic organic matter, such as dead wood and vegetative debris, helps to simulate natural conditions and reduce the soil pH (Sauer, 1998). If the existing pH cannot be altered, select native plants that are adapted to alkaline conditions.

Mulch

Whenever possible, keep natural accumulations of woody debris on site and use them to cycle nutrients back into the soil. Logs and branches provide organic material to support the beneficial fungi and microfauna populations that actively assist in soil creation and other forest processes. Leaves and twigs add texture and nutrients to the soil, help regulate surface temperatures, and provide beneficial media for germination of native species. At sites with an excess of large woody debris, it may be necessary to chip a portion of the debris to make the site more accessible and safe for volunteers. In areas barren of woody debris and other natural mulches, NRG considers bringing in leaf litter and coarse woody debris from other sites. It is important to check leaf litter for the presence of invasive seed before accepting it at a site.

Chemical Fertilizers

Broad use of chemical fertilizers (traditional N-P-K compounds) is undesirable because of the high expense, as well as the potential to increase nutrient loading to adjacent water bodies and provide nutrient subsidies in the soil that will encourage the growth of invasive plants (Sauer, 1998). However, NRG, in limited circumstances, will apply a slow release fertilizer directly at the base of each plant. This technique can be useful to promote root growth and plant establishment and to ease transplant stress. Fertilizer applied to the root zone also promotes the recruitment of beneficial bacteria and fungi in the rhizosphere, thereby mitigating the deficiency of microbial activity common in urban soils.

Conclusion

Time and budgetary constraints will influence how you proceed through site preparation, but remember: this is not a place to cut corners. The decisions you make during site preparation will influence not only the ease of planting, but also impact the maintenance and management needs of the site during establishment, and ultimately determine whether you achieve the goals of your restoration. Each decision will likely involve trade-offs between multiple objectives, and it is easy to wander off course. For example, an action like soil rototilling may be useful for de-compaction but compromise the root systems of mature trees surrounding or in the site; similarly, a foliar spray of mugwort on a sunny hot day in June may be best for herbicide uptake, but the likelihood of drift and damage to desirable vegetation is also higher. Revisiting your end goal at each decision point to make sure that you are still on track is essential to identifying whether a restoration is "successful."

SOIL SHARING

Every year, “dig jobs” - public and private construction projects requiring deep and extensive excavation - in New York City unearth hundreds of thousands, sometimes millions, of cubic yards of soil. Often, the first ten feet of excavation is urban fill, but under that lies virgin glacial till as pristine as it was 15,000 years ago when it was deposited by the retreating Wisconsin glacier. For contractors, depending on timing and circumstances, such soil is either a blessing or a curse. It is a blessing when it can be sold to another contractor who needs clean fill for a nearby project; it is a curse when there is no local demand for fill and the contractor needs to truck it out of state to stay on schedule. In the latter situation, depending on their degree of desperation, contractors may be happy to deliver the soil at no charge to a restoration site.

In 2007, New York Hospital Queens was building an underground parking garage and the forty-foot-deep excavation generated approximately 20,000 cubic yards of clean glacial till. By donating the soil to NYC Parks, the contractor avoided the costs of moving the soil out of New York City. NRG covered approximately seven acres of mugwort-dominated landscape growing on soil derived from construction rubble with three to five feet of the donated material. In 2008 and 2009, with the help of volunteers, NRG then planted 10,657 trees and seeded herbs in the area. Thus, this donation proved to be good for the contractor, and good for reforestation.

Finding and capitalizing on such opportunities, however, takes dedication, and also requires proceeding with due caution. One should beware of shady contractors looking to lose substandard fill. Always have soil tested for pollutants, basic agronomic/horticultural variables, and compliance with all local and State requirements before accepting donated material.

CASE STUDY: Site Preparation Challenges in Rodman's Neck North in Pelham Bay Park

Project Duration: 2010-Present

Site Location: Pelham Bay Park, Bronx, NY

Size & land type: 2,771-acre municipal park

Forest Type: Successional Mixed Hardwoods

Soil Type: Mostly native soils, some fill by Orchard Beach

Rodman's Neck North before restoration in 2009. (photo by Richard Love)

Pre-Restoration Site Conditions

The site is in the Rodman's Neck section of Pelham Bay Park, north of City Island Road. In 2009 when the site was first surveyed and work proposed, the site was dominated by a ten acre vineland of porcelainberry (*Ampelopsis brevipedunculata*), multiflora rose (*Rosa multiflora*), with a large stand of Norway and sycamore maples (*Acer platanoides* and *A. pseudoplatanus*) immediately adjacent to the site. As with many vinelands, the interior of the site was completely impenetrable and a full assessment of the interior conditions was not possible. It was assumed that the site, similar to other vinelands in the city, was comprised of a matrix of mostly invasive shrubs covered with invasive vines with pockets of remnant native forest species.

Restoration and Research Goals

- Control invasive plant species on site
- Plant and promote native forest species on site
- Reduce risk of wind-throw by reducing vine weight on mature trees
- Prevent re-emergence of exotic invasive vines

European white poplar cleared from the site in 2011. (photo by Richard Love)

Methodology and Results

In 2009, NRG applied for grant funding through the Long Island Sound Futures Fund to undertake invasive control and forest restoration at the site. In the grant application, NRG outlined our restoration strategy for the site: some areas would be cleared and treated by contractors, others would be restored by a crew of grant-funded seasonal workers. The primary tasks identified in the work-plan were the chemical control of specific species on site and the re-planting of the site with native trees and shrubs by volunteers.

As the grant funded crew began working to cut the vine drape around the edges of the site and trails through the site to allow access for a truck-mounted spray tank, it became clear that the mat of vines was supported by a trellis of large downed European white poplars (*Populus alba*), a weak-wooded clonal species prone to mass wind-throw during storm events. Many of the decaying logs were 20-30 inches in diameter, and piled on top of each other creating a hazardous and impassable work space.

The original term of the grant was for a period of two years, and began in late spring. Sawing and clearing the wood to access the vineland to apply herbicide required additional training for staff, the purchase of additional tools (requiring a budget amendment), and approximately 6 months of time not originally included in the workplan. Because of the timing of the start of the grant, this 6 month delay meant that an entire growing season of treatment was missed. As soon as NRG realized the extent of the debris, and considered our overall timeline, NRG realized that it would require not just a one-year but a two-year extension of the grant term to effectively treat the vineland. NRG notified the grantor in our semi-annual progress report that this would be the case, including many photos and asking to alter the workplan. NRG's early identification and connection of the two related aspects of the problem allowed NRG to seamlessly submit an amendment request and begin a conversation with the grantor about funding a second phase of work in the site.

Several sections of the site were planted in 2012 and early 2013, but the majority of the site has yet to be fully restored. After successfully clearing access and treating the vineland, NRG encountered one more unanticipated impact of the delay – over the life of this grant, mile-a-minute vine, a fast-growing annual invasive vine that is relatively new for the city, has rapidly expanded in the park. Removing the porcelainberry, multiflora rose and downed poplars disturbed the top layer of soil in the site, and introduced much more light to the ground, creating a perfect entry point for the vine. In the early spring, immediately prior to the last phase of planned planting, we discovered that mile-a-minute had emerged and blanketed the site.

Mile a minute at Rodman's Neck North in 2013. (photo by Joshua Nakash)

NRG completed our first round of grant funding, and successfully applied for a second phase of funding to continue work in the area which is still a priority for restoration. This portion of the site is now scheduled to be treated by a contractor, to free up staff time for management of mile-a-minute and other invasives in the surrounding plantings to ensure that they become established and provide a buffer against further invasion.

Lessons Learned

When this site was begun, the project seemed relatively straightforward and routine: control the vines, plant new trees. As the work progressed, many unexpected constraints appeared. Flexible resource use and contingency planning have allowed NRG to adjust without having to default on our grant obligations, and to solicit additional funds to continue work in the site.

1. Almost every project will require workplan and timeline adjustments.

2. Building in a buffer of time and resources can allow you to adapt when site conditions change.

3. Work force selection may need to be refined throughout the life of a project.


Multilayer forest in spring at Inwood Hill Park.

CHAPTER 6:
PLANTING, ESTABLISHMENT, AND ADAPTIVE MANAGEMENT

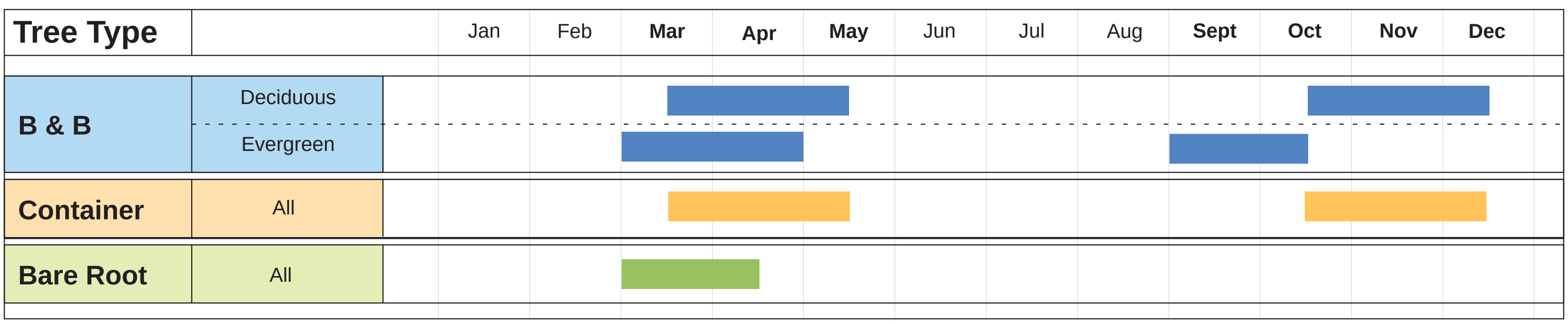
Volunteers planting trees through the MillionTreesNYC program.

The following chapter describes the best practices developed by NRG for the planting, establishment, and management of urban forests. Though improvisation may be required at times when managing natural systems, restoration work is not ad-hoc. NRG and its partners bring rigor to their practice of restoration through the careful installation and monitoring of built projects, and by incorporating research and experimentation into their work.

SCHEDULING

Planting in the fall and spring is ideal. This schedule provides trees with time to establish while their roots are growing most vigorously and before the more extreme, and potentially stressful, weather of winter and summer arrives. The installation timing for container-grown trees is less constrained than it is for bareroot stock because container-grown tree roots are neither disturbed nor particularly susceptible to desiccation during transport. It is also less complicated than B&B trees because container grown trees do not need to be dug, so evergreen and deciduous trees can follow the same installation timeline. The recommendations and techniques described below focus on container-grown trees, as NRG uses this type of stock almost exclusively.

Figure 6.1: Tree Planting Calendar



PROCURING

You can help avert many of the health problems that threaten trees in the field after planting by selecting the best trees from the nursery and handling stock properly during the entire delivery and staging process. Ensuring that trees are robust and healthy at the time of planting requires visiting nurseries and inspecting the quality of both their operations and the individual trees and their roots. Inspect the root growth of at least ten percent of each tree species selected by carefully removing the trees' containers. Refer to the American Nursery and Landscape Association's standards for a full description of nursery stock standards.

In making your selections, NRG also has the following recommendations:

- Trees should have healthy leaders and normal leaf growth.
- Trees should have healthy root formations and root density. Roots should hold the soil together but not be so dense as to begin to circle.
- Tree roots should be white and healthy in appearance. Plants with blackened or otherwise unhealthy roots should be rejected and brought to the attention of nursery managers.
- Trees with J-rooting should not be selected, especially in species such as hickories and walnuts which tend to have deep taproots when young.
- Nurseries should provide documentation of the sources of seeds for all plant material.
- Trees with species tags that are tight around the base should not be selected or the tags should be replaced to avoid tree girdling.
- Upon selection of plant material at the nursery, each plant, or a representative sample of each species, should be marked or tagged to ensure that the proper plants will be delivered.

Oak sapling grown at Clear Ridge Nursery.

Handling Plant Material

Carefully handling plant materials during loading, transport, and unloading is the best way to prevent damage. Always lift and carry plants gently by their containers, never by their stems, to preserve the integrity of the roots and avoid structural damage. Stack containers no more than four high during transport; too much weight on the bottom containers may compress them and damage the root balls as well as the plants. Transport plants in vehicles with appropriate ventilation and take care to ensure that plants do not become desiccated during the trip.

Once plant material is delivered, install plants as quickly as possible. Container grown plants may be delivered a few weeks in advance of planting, but keep them in a secure gated area and carefully monitor and water them at regular intervals until the planting date. If you do use bareroot plantings, install them within hours of delivery or place them in climate-controlled cool storage so they remain dormant.

NRG receiving trees and placing them in order for distribution to sites.

Planting Techniques

Implementing best planting practices is critical to prevent transplant shock, no matter how many or how few plants you plan to install.

On small-scale planting sites, staff or volunteers can dig holes with shovels at the time of planting. On large-scale planting sites, it will be more efficient to create individual pits prior to the day of planting. Perform this work by using handheld gas-powered augers, or an auger mounted to a backhoe (as an auger attachment), which will be less labor intensive. For ease of planting and rooting, the bit size for the auger should, at a minimum, equal the size of the containers in which individual trees or shrubs are growing, but, ideally, will be two to three times the size of the containers.

Pre-dug holes are often not the correct depth. Add soil to or remove soil from the bottom of the hole in order to plant the tree at the proper depth. The potential for settling varies by soil type: clay soils settle less than sandy soils because there is

Two person auger used in creating tree planting holes for large scale plantings.

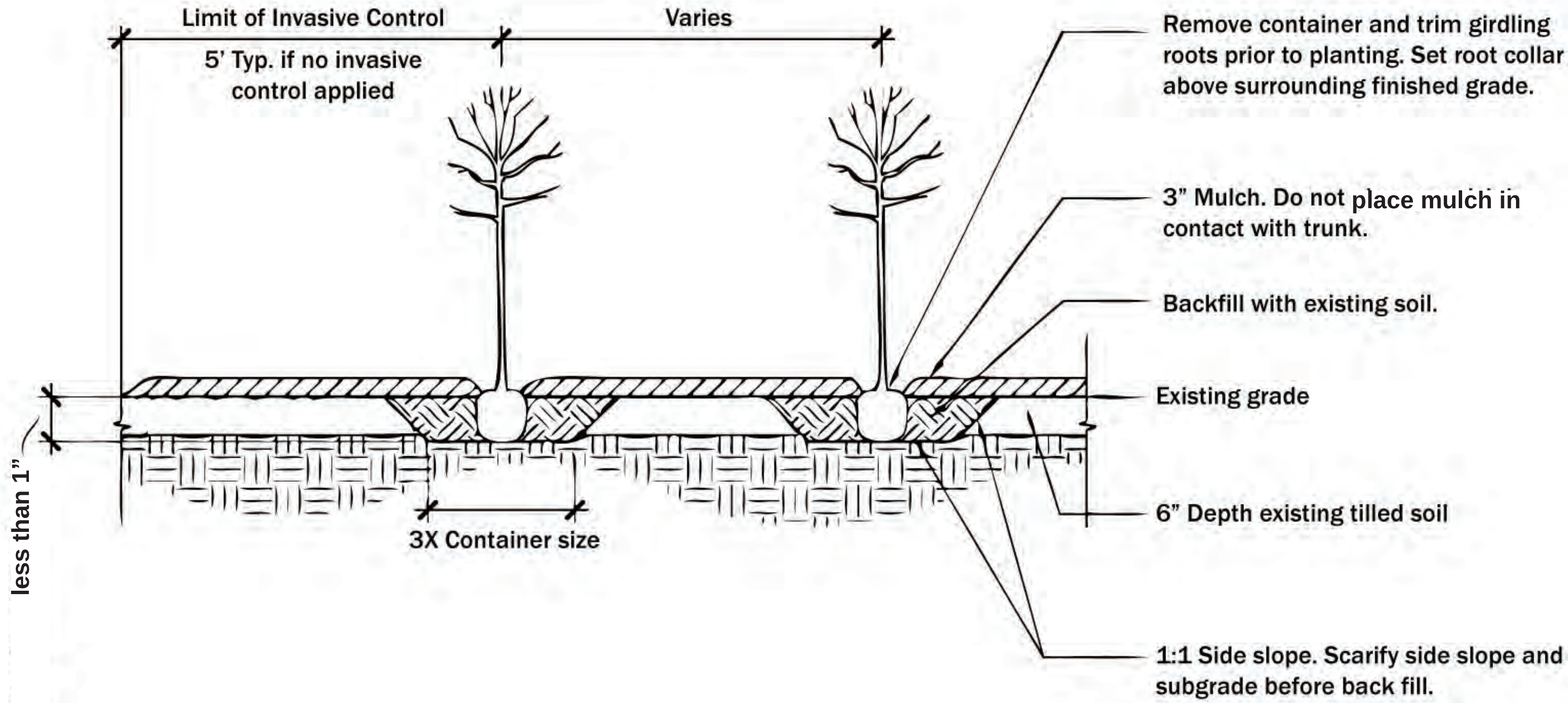
typically less pore space. In clay and loam soils, place the rootball so the base of the root flare is at finished grade or slightly higher (no more than 10% of the total rootball depth), so that once settled, the root flare is flush with the finished grade. However, in sandy soils, the rootball should sit slightly lower than the grade in order to avoid dessication. If the plant is planted too deeply and the root collar is buried, moisture may collect around the stem and cause rot; conversely, if the rootball is not planted to a sufficient depth or the soil in the rootball does not have sufficient contact with the surrounding soil, the plant may either desiccate or be heaved out of the ground by frost.

Pre-dug holes may also be the improper width. At the time of planting, use shovels to expand the augured holes as needed. Scarify the bottom and sides of pits to improve the interface between backfilled and existing soil, as this will mitigate the formation of soil-texture barriers between the two soils. Texture barriers inhibit the flow of water and nutrients and may limit root growth.

When the hole is prepared, weed the plant and remove it carefully from the container, loosening roots that may have grown too densely in the pot, then place the plant in the hole. Do not cover the top of the rootball with backfill soil, but do ensure that the sides of the rootball are fully integrated with the surrounding soil and that no air pockets remain.

Have experienced staff or volunteers plant trees sited on slopes. Trees should be planted either out of hill (i.e. so that at least 50% of the rootball will sit above the slope of the hill's existing grade) or aligned with the slope. In either case, take care to ensure that the root flare is in the correct position in relation to the soil. Container grown stock is sufficiently young and pliable to self-correct the position of their leaders and main roots in order to capture necessary sunlight and nutrients.

Figure 6.2: Detail for Planting Container Trees



A STEP-BY-STEP GUIDE TO PLANTING CONTAINER-GROWN TREES

Volunteer planting a tree in Van Cortlandt Park, Bronx in Fall 2010

- Determine the planting depth that will keep the trees' root flares at grade after settling.
- Dig holes of depths and widths appropriate to rootball sizes. The depth of holes should be equal to, and the width should be two to three times, that of the containers.
- Remove any weeds growing in the pot.
- Remove containers and gently loosen soil.
- Trim any roots that are curling into circles around the rootball to prevent additional girdling.
- Make sure root balls are planted to proper depths. If necessary, remove trees and correct the depths of holes.
- Set trunks of planted trees plumb.
- Arrange roots in their natural positions and back fill pits, taking care to avoid bruising or damaging the roots. Insert soil with hands, trowels, or spades between rootballs and pit walls to minimize soil voids and prevent future soil settlement.
- If soil falls away from the rootball, adjust the depth of the hole. If most of the soil falls off the rootball:
    - Create a mound of firmed soil in the middle of the hole and spread the roots on top of the mound. The height of the mound should allow for the tree to be planted at grade level. Do not bury the root flare.
    - Backfill the hole by lightly packing the soil around the tree. At least two structural roots should be in the top one to three inches of soil.
- If a fabric grow bag surrounds the rootball, cut away the sides of the bag once the tree is in place. Completely remove paper/pulp containers because they are slow to decompose in upland locations.
- Remove any plastic tags at the bases or on stems to eliminate risks of girdling.

PROTECTING

Mulch

NRG sometimes applies mulch across an entire site to help retain soil moisture, deter invasive plants, and keep mowers and other maintenance equipment away from the young and delicate trees. However, if you plan to apply mulch only around individual trees, never mound up the material around trunks, a practice which can rot the trunk, cut off oxygen to roots, cause stem-girdling root growth, prevent water penetration, and, in poorly drained soils, lead to over-saturated roots. If necessary, apply a thin one-inch layer of mulch over rootballs, but always maintain a clear area, at least twice the width of the trunk, around the base of the tree.

Eastern cottontail rabbit (top) and white-tailed deer (bottom) are common herbivores in forest restoration sites.

Wildlife

Within days of planting, meadow voles, cottontail rabbits, and deer can decimate a newly planted area. Voles girdle trees by gnawing on the base of the trunk and roots, while rabbits and deer feed on leaves, small stems, and branches. After trees reach a height of approximately four feet, their bark becomes less appealing to voles and their leaves will grow beyond the reach of rabbits. Deer are found in urban areas, including New York City (especially on Staten Island and in the Bronx) and commonly browse tree seedlings. When herbivory is detected, implement wildlife tree protection immediately. The most effective protection methods include:

- Area-based perimeter protections, such as eight-foot deer fencing. Fencing protects the planting areas from grazing by larger animals and should be installed prior to planting. If there is a significant presence of deer around the site, installation a full season in advance of planting is recommended. All fencing in natural areas should be treated as temporary, and a plan should be made for its eventual removal, so that it does not begin to act as a vine trellis or attract unwanted attention.

- Individual-plant-based protections, such as tree wraps and repellents, help protect young trees from small mammals such as rabbits and voles. This type of protection works best against a small population of predators having alternate sources of food. In areas of high pressure, this type of protection is rarely sufficient.

- Cultural methods, such as the removal of animal cover. These methods provide the most cost-effective long-term solutions. In areas under pressure by predators, install planting in the spring when other vegetation is actively growing and will provide more choice for the predator. Cut back obvious refuges for small mammals, such as raspberry thickets, to reduce cover. Whenever possible, select species that are resilient to herbivory. Alders and elderberry, for example, vigorously stump-sprout; holly is often avoided by herbivores because of its waxy cuticle and sharp leaf edges.

Each of the above planting protection strategies requires maintenance. Check deer fencing periodically throughout the season to ensure that it has not been vandalized or breached. Repellents can wear off after three to six months and will need to be reapplied; check the repellent's label to determine how long it lasts. Cultural methods often require the least follow-up, but pay attention to make sure that they are working as expected.

Fencing

Restoration sites adjacent to ballfields, paths, roads, playgrounds, or other areas with frequent foot traffic may require fencing to protect trees from pedestrian trampling, vandalism, arson, theft, dumping, and mowing.

When installing fences, consider the needs of the site and the best type of fencing for the specific application. In highly trafficked, windswept areas, such as those adjacent to roadways, garbage may begin to accumulate on the windward sides of fences, which may be unacceptable. Likewise, while fencing may help protect a site, a new fence frequently attracts more vandalism or misuse than it deters. For example, at some sites in New York City, residents have used fenced-in areas as dog runs.

Leaving gaps in fencing should deter this type of misuse and can mitigate other potential problems as well. When "desire lines" cross a site, gaps dissuade people from climbing over or knocking down fences by allowing for controlled access to or through the area by pedestrians and maintenance workers. In most cases, frequent monitoring and quick repair of damage are the best ways to discourage disturbance. Monitoring and repair shows that someone is watching and cares about the site, even when they have not witnessed the act of disturbance.

Fencing may also be installed to demarcate reforestation sites from frequently mowed fields. In the height of summer, when grasses and weeds are growing high, such fencing indicates where mowers should stop. A solid fence is not needed or even desirable for such purposes. In some cases, NRG has installed fence posts at regular intervals, or similar-sized logs lined-up end-to-end to mark the edge of a site. Such posts or logs are more visible from the seat of a large mower than small, newly-planted trees and shrubs, and the mower operator will feel the bump should he or she cross into the protected area.

Deer Fence on Staten Island.

Environmental Disturbance

In addition to disturbance caused by people and/or predacious wildlife, natural events like blow downs, disease, and extreme weather can also compromise a vulnerable new forest. Climate change will likely result in a rise in sea level and more frequent severe storm events, both of which can cause significant damage to forest ecosystems. In the long run, the best protection against such disturbances will be maintaining both species diversity and genetic diversity within a given species. Planting understory trees and shrubs as well as trees in anticipation of some mortality can assist a restoration in being more resilient to disturbance. In addition, swift management response is important for keeping a restoration on a trajectory towards healthy native forest. Canopy gaps tend to lead to additional downed trees in the exposed margins. For instance, when a tornado blew down a large stand of black locust trees in Cunningham Park in Queens in 2010, NRG removed debris, treated the small number of emergent invasive species, and replanted the area with native trees within a single year.

MANAGING

Documentation

Managing a forest restoration site begins with clear, accurate, and thorough documentation of the restoration work that has been conducted. “As-built” drawings are final records of what was actually installed at a site. These drawings include all deviations from the original approved plan, e.g. changes in materials, distances, locations, elevations, slopes, and volumes. They provide a basis for the planning of future work at the same location. The as-built drawings must show the extents of the project at the same scale as the original design. File as-built records in a way that facilitates monitoring and the comparison of outcomes with similar sites to improve and inform future work.

Ideally, you will use Geographic Information Systems (GIS) to track site information. Create a polygon for each group of trees planted (there may be several polygons at a single planting site). These planting polygons should be maintained in a GIS database with key information, such as who performed the planting and the date the trees were planted, along with data on planting quantities and species to maintain accurate and reliable records of all restoration efforts.

Inspection

Inspect trees installed by volunteers immediately following planting and make corrections to poorly planted specimens. Water all plants within two days after planting unless there is adequate rainfall - ideally an inch either shortly before planting or right after. Following the initial inspection, inspect planted sites at least annually during the early part of the active growing season. Inspection early in the season enables identification of potentially problematic invasive species and leaves sufficient time for corrective maintenance. If a severe drought or a long series of high-temperature days occurs, further inspections may be necessary to assess the need for watering. Inspections should continue until sites are determined to be resilient to potential new stressors; at most sites, this will coincide with canopy closure.

Establishment

The first three to five years following planting is a critical establishment period during which invasive plant management and other maintenance work should support a site’s transition to a healthy robust forest ecosystem, and prevent its reversion to its pre-restoration state. Challenges during the establishment period can be numerous: many sites are remote and access may be limited to small vehicles or foot travel; isolated sites may suffer from trespassing and dumping and may lack water sources within hose distance; and invasive plants may continue to re-invade the site for many years. The majority of maintenance effort will go into invasive plant management and watering; however, wildlife management and unanticipated disturbances such as damage in storms may also demand significant attention depending on the circumstances.

The methods for managing invasive plants during the establishment phase of restoration are similar to those used during site preparation, however, protecting new plants will limit certain operations. Extra precautions must be taken when applying herbicides to avoid harming the newly planted trees or other desirable vegetation. Only spray foliar herbicide on plants lower in height, by about a foot, than the lowest leaves of surrounding trees, and refrain from spraying on breezy days. Spraying attachments, such as cones, make it easier to restrict or direct the spray. Use of dye additives can help workers direct spraying of herbicide towards small target populations. Techniques for applying herbicides are described in Appendix 5.

For every site, develop individualized plans for management of invasive plants, and adjust plans as needed based on annual inspections. The site management plan should list targeted species, preferred management techniques for each species identified, and schedules for mechanical and/or chemical removal of invasives. Volunteers can be enlisted in invasive plant removal on sites with volunteer-friendly conditions - easy access, flat terrain, and easy-to-identify vegetation. The adoption of sites by particular groups or regularly scheduled weeding by neighborhood or community groups tends to be the most effective means of utilizing volunteers. If it is not possible to organize such groups, volunteers can be brought in if and when intensive weeding by hand is required for invasive-plant-removal “blitzes.”

Watering

During the establishment period, newly planted trees establish their root systems and adjust to their new growing conditions. Especially at this time, water is critical to their survival. Natural rainfall patterns often provide sufficient water, but during prolonged hot dry periods, supplemental watering may be necessary. Pay special attention to the most recently planted trees and trees growing in minimal organic matter. Trees planted in the spring tend to need more water than trees planted in the fall when they are entering dormancy. Fall planting also gives trees more time to establish roots prior to enduring the heat stress of the summer months. Trees planted on restoration sites with both adjacent trees to act as shelter and herbaceous ground cover and/or mulch to help retain moisture and moderate soil temperature frequently survive and establish despite limited watering.

At sites with available water sources, using a hose attached to a free-standing sprinkler is an effective watering method. Unfortunately, many reforestation sites are beyond hose-distance of a water source. At such locations, the only viable watering method is the use of watering trucks, or pickup trucks with spray rigs that require a worker to hold the hose and direct the water at each plant.

Public Engagement

Humans are also part of the ecosystems of new urban forests. Positive public perception and use of natural areas will be critical to the success of any restoration effort. These sites are often perceived as leftover or abandoned space because they do not exhibit the same characteristics as landscaped areas. Educating concerned members of the public can provide your project with potential future volunteers and stewards, and will expand the number of informed eyes on the site to protect plantings from disturbance. Whenever feasible, place explanatory signage at highly visible sites and include community outreach, education, and stewardship training as part of your management plan.

The best way to encourage positive responses from community members is to engage them in the early stages of design and planning, as well as through planting and management. New York City has many neighborhood groups that organize voluntary park stewardship programs. Parks provide significant recreational, psychological and physical health benefits that most residents value highly and care about protecting (Sherer, 2006).

NRG crew leader, teaching volunteers how to care for newly planted trees. (photo by Minona Heaviland)

ADAPTIVE MANAGEMENT AND RESEARCH

Adaptive Management

Managing natural systems necessarily entails confronting uncertainty. The variables influencing sites and systems are infinite and, while it may be impossible to predict a pest invasion or the failure of a particular species to thrive, you can nonetheless incorporate a responsiveness to change into forest restoration by engaging in adaptive management. Adaptive management is an iterative process of evaluating and refining applied strategies. This process provides managers with a mechanism for improving the effectiveness of their work through both the critical assessment of the outcomes of decisions and practices and the incorporation of knowledge gained through research into their plans. Adaptive management encourages practitioners to: clearly articulate goals; evaluate their success in achieving those goals through sound data collection; periodically adjust management plans based on observed results; and, during the process, deepen their understanding of the natural systems they are managing (Holling, 1978).

Experimentation and monitoring are central to the adaptive management model. Experimentation may focus on learning more about a particular natural system or on testing hypotheses about management practices. In the restoration context, monitoring is defined as the acquisition of information over time to assess the status and/or change in status of landscape qualities for the purpose of assessing and directing management activities (Maddox, 1999). This consistent capturing of data enables practitioners to effectively compare the actual versus the desired results of site interventions.

A Process for Adaptive Management

Adaptive management is comprised of a cycle of five overlapping and interacting stages:

1. Plan: Develop a management plan that addresses the project's goals and primary challenges, and identifies measures of success.

2. Act: Implement the management plans.

3. Monitor: Collect the previously identified information that will help measure progress towards project goals.

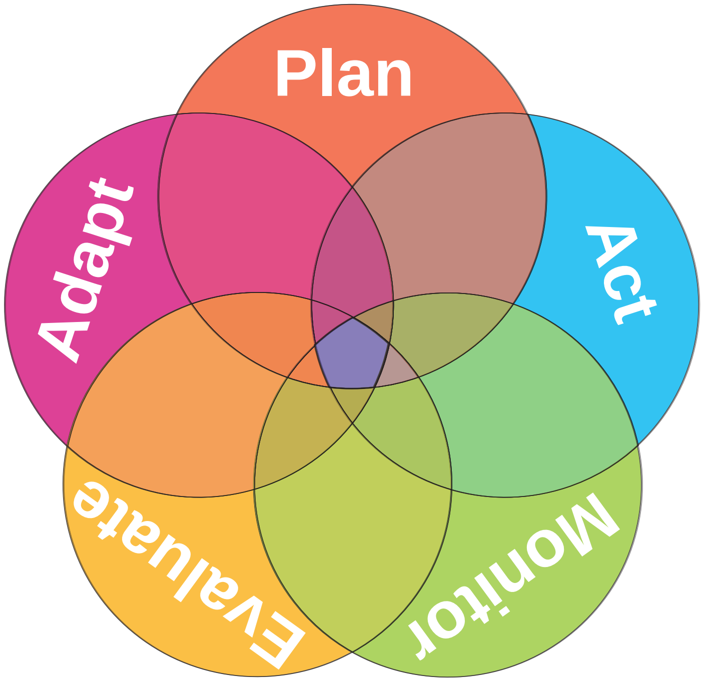
4. Evaluate: Analyze monitoring information and communicate the results to other team members.

5. Adapt/Adjust: Use the results of evaluation to adapt the plan to better achieve stated goals.

In forest restoration practice, adaptive management functions on two levels: site-specific management and restoration strategy. At an individual site, adaptive management facilitates real-time adjustment of strategies and timelines when field conditions change or potential failings of the original work plan are identified. For example, one goal of UFEP's work in Forest Park (Queens) was to manage the invasive cork tree (*Phellodendron amurense*) population. The team began this work by using the cut stump method. In the field, this method proved to be very time-consuming and no more effective than alternative methods. The team switched to basal bark applications, which allowed them to maintain their original goal, and improve productivity rates without sacrificing efficacy.

While in some instances one site may lead to an across-the-board change, more frequently it is the accumulation of observations over time across multiple sites that informs broader management modifications. For example, NRG's early work with bareroot and small containerized plant material ultimately dictated the setting of tree-sizing standards. NRG teams observed high mortality rates in bareroot plantings and high rates of rodent predation in 1-foot-tall container stock. After evaluating the success and failure of different plant stock and sizes over multiple projects, NRG set minimum plant size values accordingly, and has seen improved survival numbers as a result.

Figure 6.3: Adaptive Management Cycle



Monitoring

Active site monitoring supports the long-term improvement of restoration practices, as the above example demonstrates, while also facilitating the detection of disturbance, disease, drought, and other issues that can be addressed through site-level adaptive management. Before designing a monitoring program, make sure that you have established explicit goals related to conservation targets. If goals are numerous, you may need multiple monitoring programs in place to assess your progress. The three basic types of monitoring are:

1. Implementation monitoring: Did we complete the planned work?

2. Effectiveness monitoring: Did we achieve our objectives?

3. Validation monitoring: Were our assumptions correct? Was our intervention the most effective way to achieve our goals?

NYC Parks and USFS researchers laying down a plot in an invasive species area.

For example, imagine a park that is home to a rare amphibian species. Erosion, caused by vegetation loss, has negatively impacted the water quality of vernal pools that support the amphibian population. A restoration team creates a management plan to re-vegetate the buffer zones around the pools in order to control erosion and, ultimately, protect the amphibians by preserving water quality.

- An implementation monitoring question would be: “Were the buffers around the pools re-vegetated?”
- An effectiveness monitoring question would be: “Do the management actions improve water quality?”
- A validation monitoring question would be: “Does improving water quality actually help the amphibians?”

The three types of monitoring differ dramatically in the amount of effort they entail. Implementation monitoring tends to be relatively quick and easy. Is the re-vegetation project complete? The answer will be a simple ‘yes’ or ‘no.’ Effectiveness and validation monitoring, on the other hand, will require more legwork and careful study of a site. Did the improved water quality help the amphibians? The answer to this question may not be straightforward.

NRG’s Research Initiatives

Typically, NRG conducts implementation and effectiveness monitoring within restoration projects independently, but it often partners with academic investigators to embark on complex long-term research into urban forest restoration. Experimental urban forestry studies are few and most are less than 5 years in duration (Oldfield, et al., 2013). New York City, especially since its investment in PlaNYC, has great potential to support experimental research projects spanning long periods of time by taking advantage of NRG’s 30 years of forest restoration activity. In 2006, NYC Parks partnered with the US Forest Service (USFS) to create one of the nation’s pre-eminent urban field stations, the New York City Urban Field Station, which consists of both a physical laboratory and residential facility in Ft. Totten, Queens as well as a community of researchers. Through its joint management of the station and its partnership with researchers and practitioners throughout the region, NYC Parks is making New York City a primary locus for the study of urban ecology and restoration. The field station attracts researchers to New York City by defraying costs and simplifying the logistics of working with the USFS, a large government agency. Following are descriptions of some of NRG’s ongoing and recent research projects. Visit the New York City Urban Field Station web site at http://www.nrs.fs.fed.us/nyc/ to find regularly updated information on their work.

MONITORING AND NRG'S MillionTreesNYC SURVIVAL STUDY

In the summer of 2009, NRG developed and implemented a protocol for assessing the survival rates of trees planted as part of the MillionTreesNYC initiative. To estimate survival rates within planting areas citywide, and to identify factors associated with the variation observed across different sites, research teams established permanent 25 m^2 plots, randomly located within multiple planting areas. NRG has established plots in 53 parks citywide, installing each plot one year after the trees are planted. Along with survivorship, NRG records other health metrics, such as indicators of dieback, leaf condition, vandalism, and herbivory. Teams also assess ground area cover by herbaceous species for the entire 25 m^2 plot, using broad percent cover categories and identifying the three most abundant herbaceous species present.

The data NRG has collected over the last four years has shown an 88% survival rate for saplings in their first growing season (Fall to Fall) and, assessing those trees that survived the first year, a 90% survival rate for their second growing season. The data further shows that dieback was consistent between the two growing seasons, with a slightly higher survival rate in leader stem in the first growing season (73% in the first year and 69% in the second year). Trees planted in canopy gaps in mature forest demonstrated higher survival rates, while trees that experienced full sun, such as afforestation sites on the side of ballfields, demonstrated increased mortality. NRG introduced a soils component to the data collection set in 2011. NRG will collect final data during the summer of 2013 and will perform a full analysis of all the variables by 2014 (Simmons, B., n.d.).

Figure 6.4: MillionTreesNYC Citywide Survival of Forest Restoration Trees

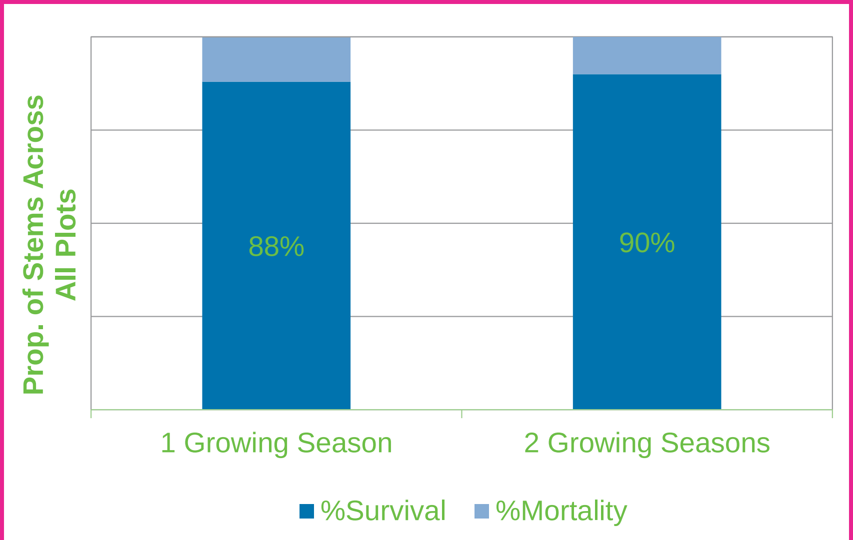
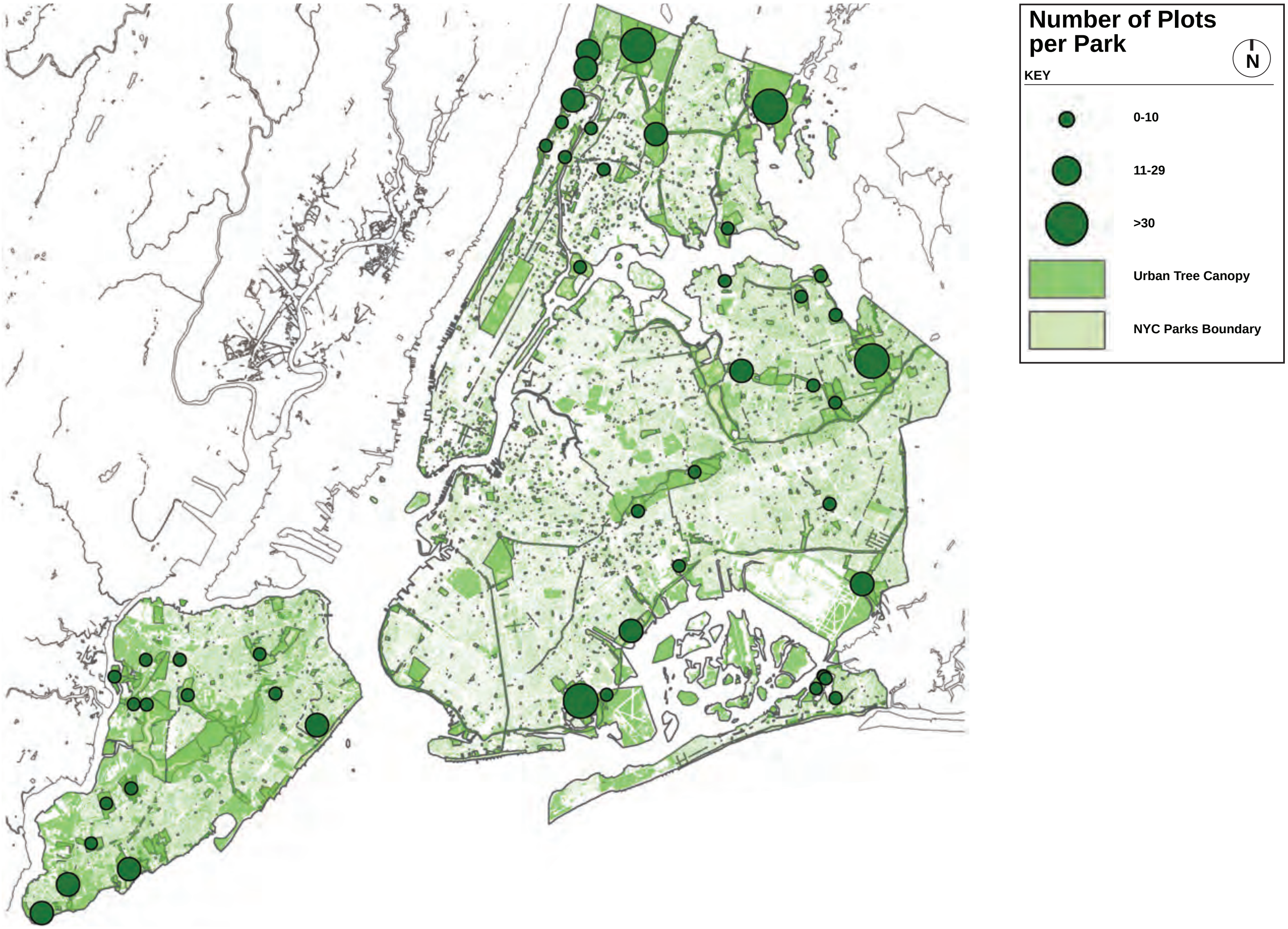


Figure 6.5: Citywide Location of Mortality Plots



Citywide locations of mortality plots correspond to the number of trees planted in forest restoration sites across the city.

UFEP researcher collecting vegetation data in one of the long-term plots established in the 1990s.

In 2006, a researcher from Rutgers University began collaborating with NRG to evaluate the long-term ecological effects of the restoration work that began under UFEP. The UFEP restorations examined were conducted in the early 1990s in woodlands heavily invaded by porcelainberry, multiflora rose and Oriental bittersweet. The restoration work included the removal of invasive non-native species by manual, chemical and mechanical means, followed by the planting of desired native tree species. UFEP established these plots and monitored tree survival and growth for 1-5 years following initial restoration. NRG recorded data on some post-treatment site conditions in 1998.

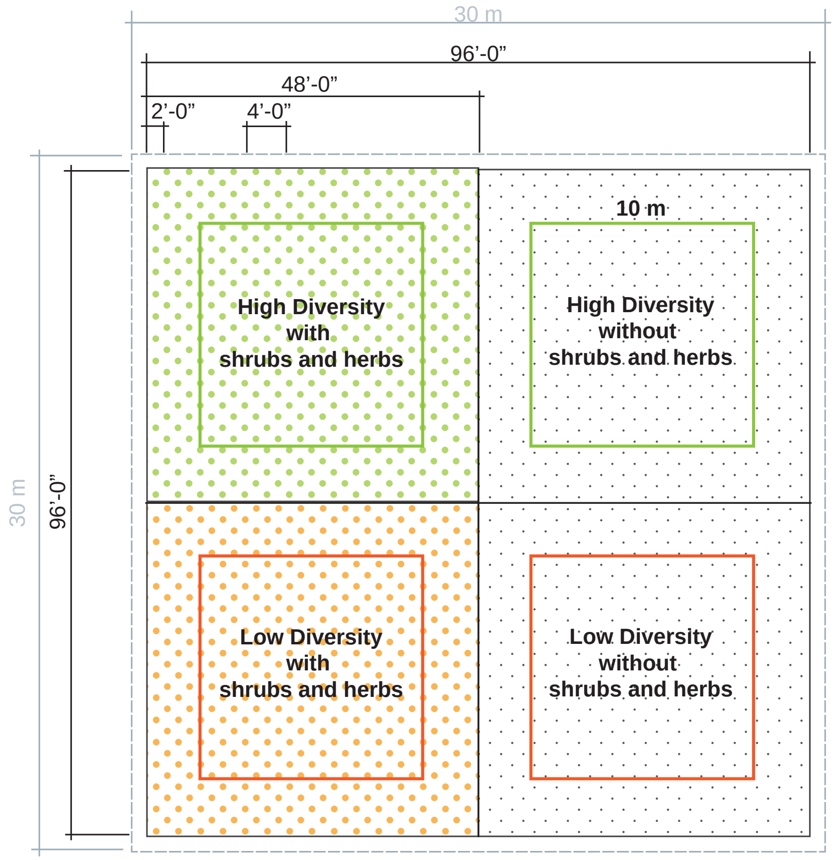
Recently completed analysis on a research project investigated three questions: the differences between restored and un-restored forest composition and architecture over time; the effects of management effort on the long-term ecological outcomes of restoration; and the relationship between urban soils and restoration outcomes.

Looking at 30 sites 15-20 years following their initial restoration, the differences in vegetation composition and structure found by this research indicates that invasive species removal followed by planting conducted by UFEP resulted in:

- persistent structural and compositional shifts
- greatly lowered invasive species abundance
- more complex forest structure
- greater native tree recruitment

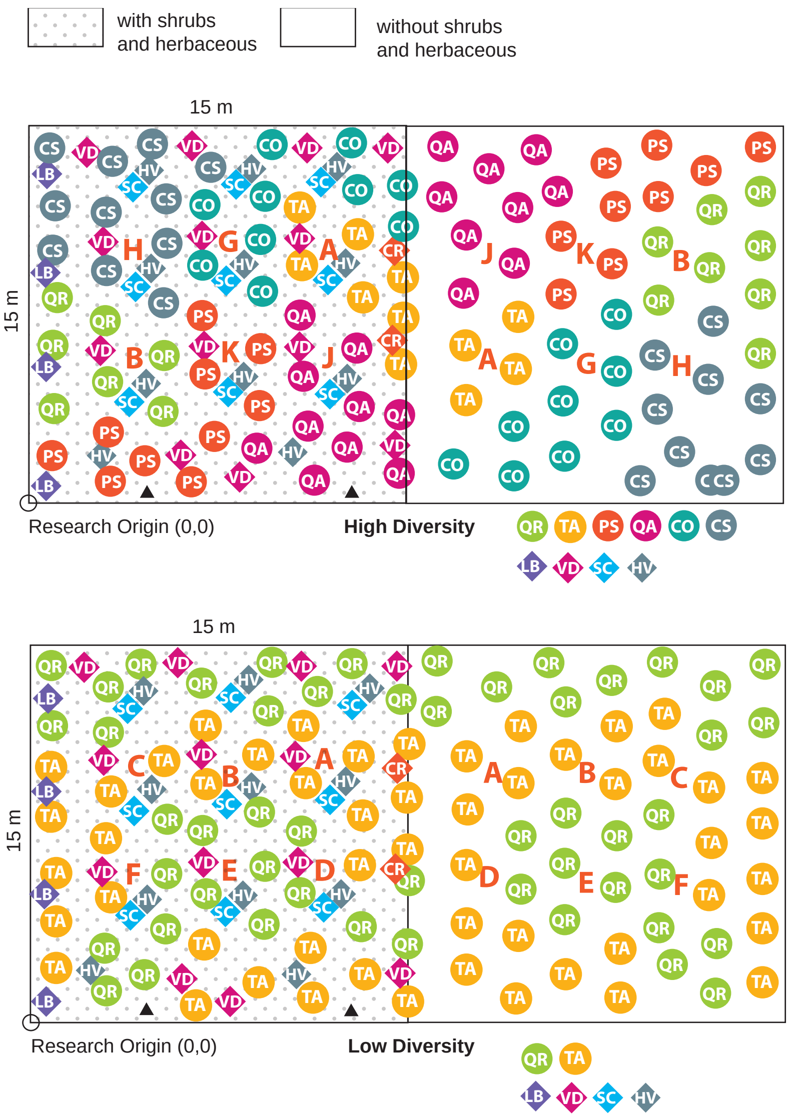
These research results also showed that the desired effects of restoration were greater in sites that were managed more frequently after the original plantings (Johnson, L.R., 2013).

Figure 6.6: Citywide Experimental Research Plot Design



Experimental Research Plot Design for volunteer plots citywide, showing 10m x 10m sampling plots within each 15m x 15m subplot for low and high species richness with and without stand complexity (four treatments total) in a factorial experimental design (McPhearson, 2011).

Figure 6.7: Kissena Park and Willow Lake Experimental Research Plot Design



Experimental research plot designs for Kissena Park and Willow Lake were planted by contractors. These projects utilize a split plot layout for low and high tree species richness, with and without stand completed (shrubs and herbs), with a total of eight treatments (Felson et al, 2013).

In 2009, NRG collaborated with researchers at Yale University, The New School, and Columbia University to establish long-term research plots in MillionTreesNYC restoration sites across the city. The goal of this research is to better understand how high- and low-diversity species combinations and the inclusion of mid- and understory plants influence: the abundance and distribution of native and invasive plant populations; the impact of urban soils on plantings; and the ecological succession of the sites over the long-term.

Though the designs vary, all the plots are fixed-area and include a buffer area between sampling plots to minimize edge effects from one treatment to another (see Figure 1a). All of the plots also utilize a standardized species palette developed by NRG and partners. This project required significant effort from both NRG's forest restoration staff and the collaborating researchers to coordinate site selection, data collection, site preparation work such as invasive species removal, as well as the supervision of plot installation on volunteer planting days (McPhearson et al., 2010).

Using these long-term research plots, the New York City Urban Field Station is now also collaborating with Yale University researchers to investigate the sustainability of constructed, native, urban forests and their resilience to invasive species. In order to do this researchers are tracking the growth and health of the planted trees along with the recruitment of native species and the proliferation of invasive plant species. Treatments of high and low diversity plantings and organic amendments will provide valuable information for future afforestation management decisions (Oldfield et al., 2013).

USFS, NYC Parks, and the Natural Areas Conservancy are collaborating on a research project investigating which tree species are best suited to urban soils of differing quality. The goal of the study is to quantify the performance of four commonly planted native tree species growing in typical urban soils collected from restoration sites in New York City. Using a multi-factorial design, the researchers planted seedlings of four native tree species into 13 soil types, including one custom-made greenhouse soil and twelve urban soils collected from four typical New York City soil categories (coal ash, urban fill, sandy clean fill, native till). In a common greenhouse environment, the researchers hypothesized that they would find that quantitative differences in the chemistry of the selected soils existed; that these differences would impact tree growth, health and survival; and that tree species would respond differently to the variable quality of the selected soils.

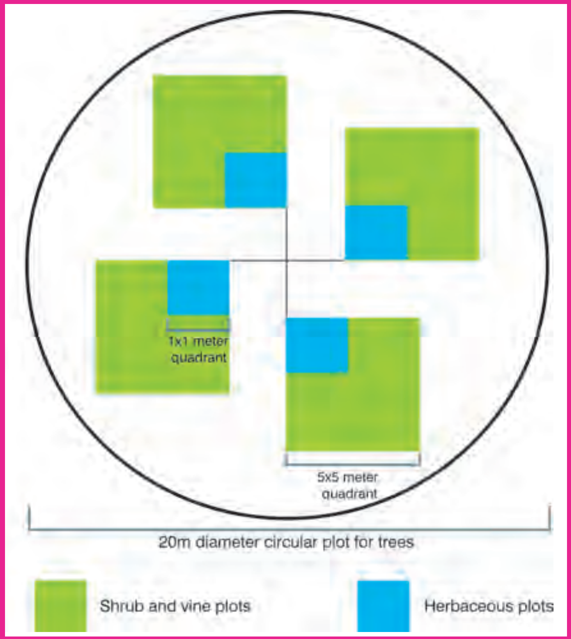
After one growing season, the project team found that tree height growth varied significantly among soil types, with the greatest growth occurring in coal ash and native till soil and the lowest growth occurring in urban fill and sandy clean fill. Soil type also had a significant effect on Fv/Fm, a measure of chlorophyll fluorescence used to assess plant stress. Researchers also found a significant relationship between species growth rates and soil types. Soil pH and total organic carbon could explain some of the variation in growth. In addition, overall tree health varied significantly across soil types by species. These results will inform future restoration efforts by allowing managers to select species that can best tolerate the specific limitations of the soils found on urban restoration sites (Pregitzer, 2014).

Through collaboration with the USFS, the New York City Urban Field Station, and our various academic partners, NYC Parks is continuing these and other long-term research projects to inform our best practices in forest restoration and management.

ASSESSING MANAGEMENT EFFICACY IN RESTORATION SITES IN PELHAM BAY PARK

As part of a National Science Foundation-funded Urban Long Term Research Area – exploratory grant project, NRG, in partnership with the USDA Forest Service Northern Research Station, collected plot-level data on the long-term outcomes of forest restoration in a section of Pelham Bay Park. From 1992 to 1995, UFEP chemically and mechanically cleared all species of exotic vegetation, and then planted several thousand native trees and shrubs throughout the site. According to NRG treatment records, the western section of the site was weeded on several occasions in 1995 by UFEP and then in 2000 and 2003 by the Pelham Bay Park Administrator's staff. The northern and southern portions of the site have received no weeding since 1996. NRG and Forest Service scientists are taking advantage of this differential weeding regime history to assess the influence of these treatments on the health of the resulting forest community.

Figure 6.8: Plot Design for Pelham Bay Park ULTRA-EX Research Project



Plot design for the ULTRA-EX project is a 20m diameter circular plot for trees with nested 5m x 5m shrub and vine plots, and 1m x 1m herbaceous plots.

The research team used a nested plot design to capture mature canopy trees along with shrub/vine and herbaceous species. Technicians recorded the diameter at breast height (DBH), height, and position of each tree in fifty-two plots in 20m-diameter circles. They captured stem counts and height data for the shrub and vine species in four 25-m^2 plots. Finally, they calculated percent cover categories to record the herbaceous species in four 1-m^2 plots.

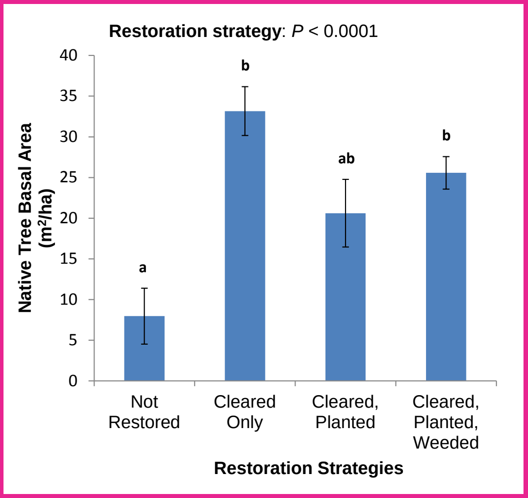
In addition to vegetation data, NRG used digital photos to measure canopy transparency to assess progress towards the ultimate goal of the restoration, a closed canopy forest. Since canopy transparency measurements do not distinguish whether canopy closure is due to native or invasive species, NRG utilized an additional camera technique to quantify the vertical structure of the forest and using a modified leaf area index to collect data on the native and invasive species present at different heights (Aber, 1979). In the spring of 2012, NRG also collected soil samples which they had tested for pH, organic content and basic micro- and macro-nutrients.

This plot-level study revealed that NRG's Pelham Bay Park forest restoration was effective and that there were variations in the effectiveness based on restoration strategy. In general, the restoration helped native trees establish and survive (Figure 1 – Native Tree Basal Area), created a more structurally complex forest (a more diverse distribution of vegetation from the forest floor to the forest canopy, known as Foliage Height Diversity), and closed the canopy. This study also demonstrated the added benefits of planting and weeding after clearing exotic vegetation: compared to clearing exotic vegetation alone, planting and weeding further increased tree diversity (Figure 2), canopy closure, and the abundance of native tree seedlings. In fact, periodic weeding increased the abundance of native tree seedlings to a greater extent than clearing and planting alone.

Despite this notable progress, restoration did not change the abundance of exotic vegetation or regeneration of exotic tree seedlings. Exotic vegetation continues to linger in the understory, even in plots that received weeding, although the type of exotic vegetation pre- and post-restoration has changed. Pre-restoration exotics were often vine species while post-restoration exotics were largely understory shrubs and herbaceous species. In addition, this study revealed that there was a positive correlation between high organic content in the soil and increases in the basal area of native trees and the Foliage Height Diversity. Overall, this study provides support for the benefits of planting and periodic weeding after clearing exotic vegetation from an urban forest (Simmons, et al, 2014).

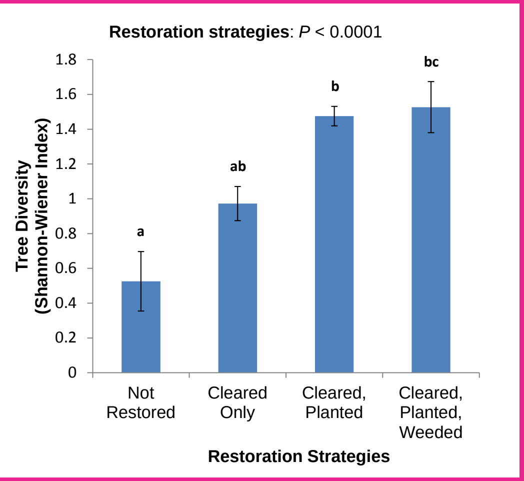
Researcher using a hypsometer to measure canopy transparency.

Figure 6.9: Basal Area of Native Trees in Plots



Letters A and B represent significant differences among the restoration strategies.

Figure 6.10: Tree Species Diversity in Plots



Letters A through C represent significant differences among the restoration strategies.

CASE STUDY: Incorporating Research into Reforestation Efforts at Givans Creek Woods

Duration: 1999-present

Site Location: Givans Creek Woods, Bronx, NY

Size and land type: 12-acre passive municipal parkland

Forest Type: Former estate and farmland, now invasive mugwort field

Soil Type: Construction and Demolition Urban fill

Givans Creek Woods restoration area dominated by mugwort, before planting in 1999. (photo by Tim Wenskus)

Pre-Restoration Site Conditions

Givans Creek Woods consists of twelve acres of natural areas located in the northeast Bronx, adjacent to Co-op City, the largest cooperative housing development in New York. In the eighteenth century, Robert Givan owned the land that now comprises the park and ran a watermill powered by the tidal run of the creek that bore his name. In the 1880s, the Givan family divided the property into lots to be sold, but with the exception of a few farms, the land remained largely undeveloped until the 1950s.

Constructed between 1968 and 1970, the Co-op City development covered Givans Creek and left the forest around it unevenly covered in C&D rubble. Remnants of native forest, including white and red oak, bitternut hickory, box elder, sassafras, red maple, and black walnut trees managed to survive on the compromised site, but many areas became dominated by aggressive invasive species, particularly mugwort. Thanks to the persistent efforts of community activists, in 1995, New York City designated the 12-acre parcel of woods as parkland to be preserved.

In 1999, NRG selected a two-acre site within Givans Creek Woods for targeted restoration with integrated research. The condition of this parcel of forest, with its degraded soils and dominant mugwort population, mirrors that of thousands of acres of reclaimed land in New York that present similar restoration challenges (King, K.L., 2012).

Restoration and Research Goals

- Restore native forest to an area filled with C&D debris and containing invasive weed species
- Understand reforestation dynamics on urban fill
- Evaluate the outcomes of multiple soil treatments

Givans Creek Woods planting in plot configuration in 1999. (photo by Tim Wenskus)

Methodology and Results

Total Trees Planted: 4,150
Total Acres Restored: 2

On one acre of the two-acre restoration site, NRG implemented typical restoration methods to establish closed-canopy forest. On the remaining acre, the restoration team established experimental plots planted and designed to determine which practices would be most successful at C&D sites characterized by high pH soil and dominant invasive species. The objectives of the study were twofold: 1. To determine which species would survive and thrive on landfill soil; and 2. To determine how soil amendments such as mycorrhizal root inoculation, mulch, or rooting medium would affect rates of survival or growth.

NRG installed two adjacent sets of sixteen replicate plots in the southwestern portion of Givans Creek Woods. One set was planted with four species of bareroot trees, the other set was planted with four species of container-grown trees (Figures 6.11 and 6.12). The trees were spaced at three-feet-on-center and grouped by species in two adjacent rows of five trees per plot. The researchers created four plot types based on different soil treatments:

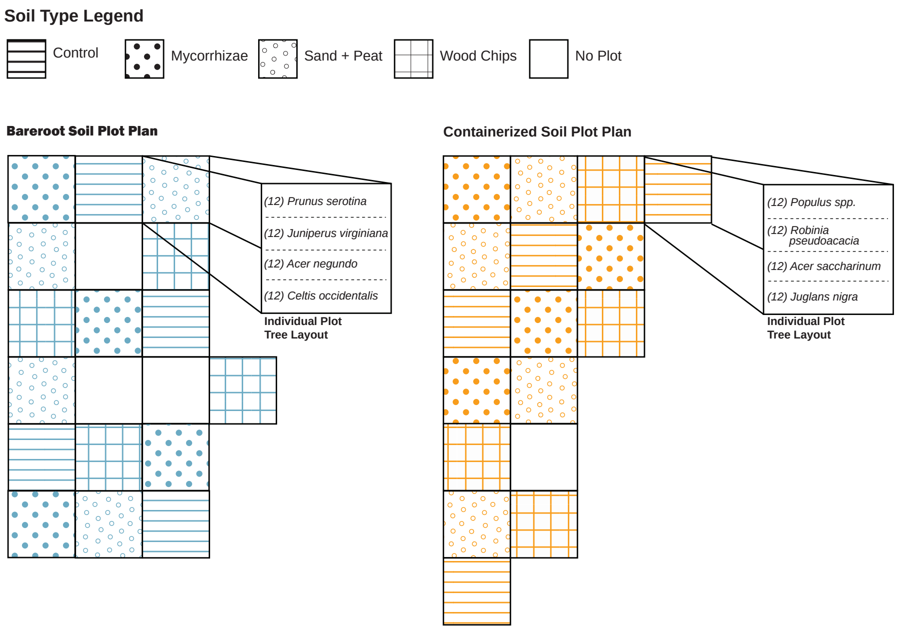
- Mycorrhizal Plot: Inoculation of mycorrhizal roots (Mycor Tree Saver) was conducted at each tree. For saplings grown in containers, a powder formulation was added to backfill. A root dip was used for bareroot species.
- Wood Chip Plot: A three-inch layer of wood chip mulch was spread in a twelve-inch radius around each tree.
- Soil Replacement Plot: A mixture of equal parts sand and peat moss was used to backfill each planting hole.
- Control Plot: Nothing was done to alter the existing soil conditions.

Figure 6.11: Givans Creek Woods Species Planting Plot Design

Bareroot Tree Species	**Containerized Tree Species**
Celtis occidentalis **Hackberry (CEOC)**	*Juglans nigra* **Black Walnut (JUNI)**
Acer negundo **Boxelder (ACNE)**	*Acer saccharinum* **Sugar Maple (ACSA)**
Juniperus virginiana **Eastern Red Cedar (JUVI)**	*Robinia pseudoacacia* **Black Locust (ROPS)**
Prunus serotina **Black Cherry (PRSE)**	*Populus spp.* **Cottonwood Hybrid (POPULUS)**

Plot design diagrams for bareroot (left) and containerized (right) experimental reforestation plots.

Figure 6.12: Givans Creek Woods Soil Treatment Plot



At the time of planting, after each growing season from 2000 to 2003, and again in June 2007, researchers measured tree height and collected mortality data. Over the course of the study, all plots exhibited similar tree survival rates. It is reasonable to speculate that much of the tree loss resulted from the severe drought of 2002. Two species, eastern red cedar (*Juniperus virginiana*) and black walnut (*Juglans nigra*), exhibited different total growth rates based on the soil treatments to which they had been exposed (Figure 6.13). The most significant differences in growth and survival rates, however, were found to correspond directly with tree species, rather than with soil treatments (Figure 6.14). It was not possible to draw a comparison between the bareroot and container-grown specimens because, due to the availability of plant material, no species was planted in both forms.

Black locust (*Robinia pseudoacacia*) and box elder (*Acer negundo*) grew taller than all other species, and box elder also exhibited a very high survival rate (93%), second only to hackberry (*Celtis occidentalis*) (95%). As of 2013, these two species, which are known to thrive in disturbed areas (Barnard, 2002), have created a closed canopy that potentially will shade-out mugwort and allow more desirable tree species to flourish.

That the different soil treatments appeared to have no influence on tree health suggests that the soil characteristics of the construction landfill were dominant enough to suppress the potential effects of the interventions. Some of the treatments, such as soil replacement, may need to be implemented at a larger scale, at a greater depth, and/or combined with other treatments in order to have a noticeable impact. Monitoring is ongoing and the long-term outcomes of this project have yet to be revealed.

Lessons Learned

For this research/restoration project, the data revealed that species was the most significant determinant of tree survival and growth, underscoring the importance of selecting appropriate species for a given site based on soil and hydrological conditions. Black locust proved to be the most successful planting, with box elder, black walnut, and hackberry also performing well. This initial research has provided a valuable dataset for the continuing assessment of the long-term outcomes of forest restoration on urban fill (King. K.L.,2012).

Givans Creek plantings in 2011.

Figure 6.13: Different Growth Rates Based on Soil Treatments

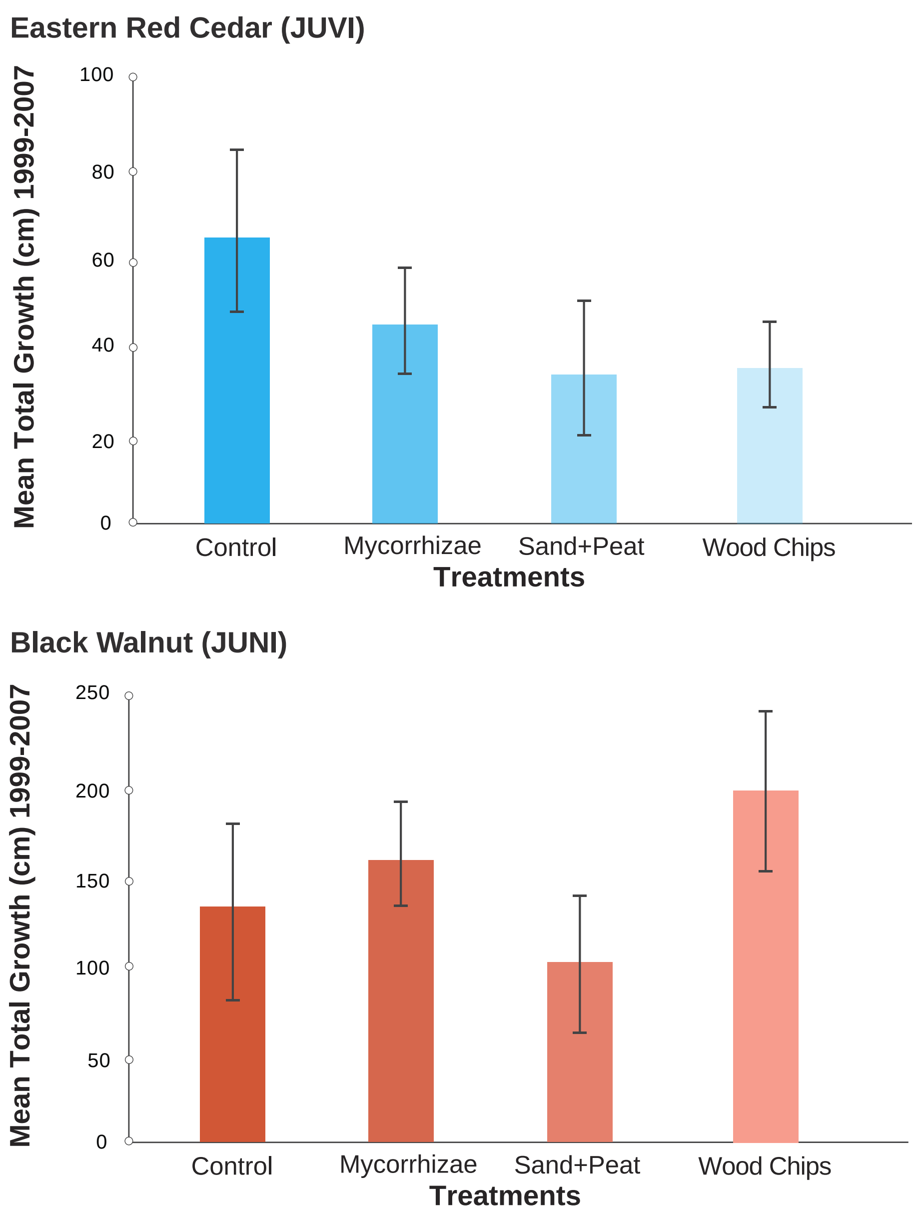
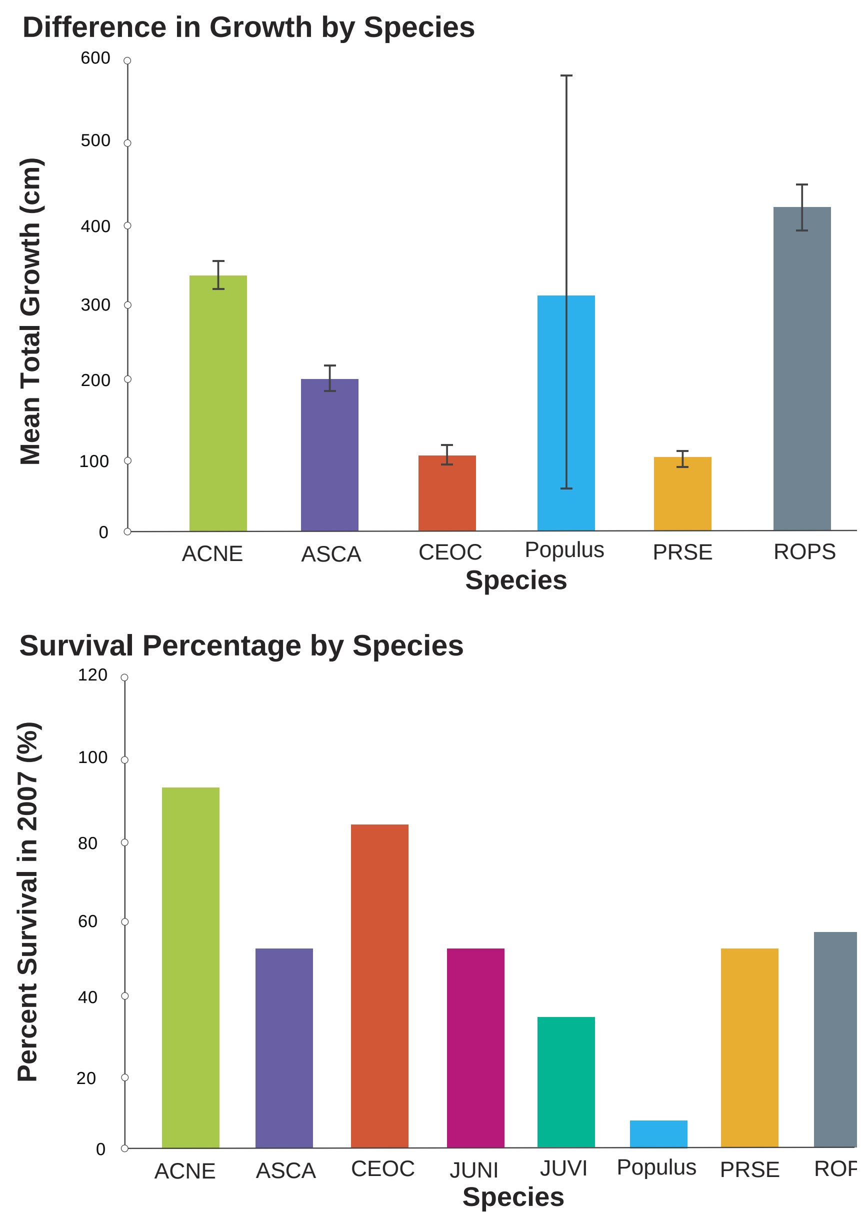


Figure 6.14: Different Growth Rates and Survival by Species



APPENDIX

Appendix Items:

APPENDIX 1: REGULATIONS

Federal, state and city regulations that may apply to forest restoration projects in New York City are summarized in this appendix. More details can be found on the website of each of the agencies listed.

U.S. Army Corps of Engineers (USACE) – New York District

- Section 404/Nationwide Permit (NWP) 27
  - Section 404 regulates the discharge of dredged or fill material into waters of the United States, including wetlands. Most forest restoration activities within Section 404 regulated wetlands will fall under NWP 27 - Stream and Wetland Restoration Activities.
  - If a Section 404 and a DEC tidal wetlands permit are both needed, there is a joint application process.

New York State Department of Environmental Conservation (NYSDEC)

- State Pollution Discharge Elimination System (SPDES) General Permit for Stormwater Discharges from Construction Activities GP-0-08-001: Required for a single project with soils disturbances greater than one (1) acre of land.
- An Erosion and Sediment Control Plan, including an inspection schedule that meets the requirements outlined in the construction stormwater permit, will need to be prepared.
- Section 401 Water Quality Certification: required for any discharge into the Waters of the United States and is generally limited to discharges of dredged or fill material regulated under Section 404 of the Clean Water Act. (See USACE permits above.)
- It is not likely that these activities will apply to forest restoration projects, but if designated water bodies or wetlands are present on the project site, NYSDEC should be consulted.
- Freshwater Wetlands Permit: Required for activities where freshwater wetlands exist on or within 100 feet adjacent to the project site.
- For many forest restorations, any impacts to freshwater wetlands will likely be small and may be considered “exempt” or “minor”, but this depends on the location and scale of disturbance to the site, so DEC should be consulted early in the site planning process.
- Tidal Wetlands Permit: Required for activities in tidal wetlands or within 150 feet of tidal wetlands and below the 10-foot contour.
- Any impacts to tidal wetlands due to forest restoration will likely be minor, but this depends on the location and scale of disturbance to the site, so DEC should be consulted early in the site planning process.
- Pesticide Applicator License: Pesticides must be applied under the supervision of a licensed applicator.
- All pesticide label procedures must be followed, and application records kept by the licensed applicator. Reports on pesticide use must be reported to the State DEC annually.
- Aquatic Pesticide Permit: Required for the application of pesticides in aquatic areas to manage invasive species.
- For pesticide applications in or within 100 ft of a wetland, an aquatic pesticide permit is required and must be applied for to NYSDEC by a New York State Certified Pesticide Applicator.
- Protected Native Plants Regulation (6 NYCRR 193.3):
  - This regulation establishes lists of endangered or rare plants, which are illegal to collect or destroy without the permission of the landowner. Native plants on a site should be inventoried and if there are listed plants a protection plan must be established before any site work commences.

New York State Department of State (NYSDOS) Division of Coastal Resources

Coastal Zone Consistency Assessment:

- NYC Waterfront Revitalization Program Consistency Assessment Form: Required for any forest restoration project that falls within the city's Coastal Zone (see the NYC Coastal Zone Boundary Maps at www.nyc.gov).
- Federal Consistency Assessment Form: Required for Federal coastal zones.
- NYC Waterfront Revitalization Program (WRP) Consistency Assessment Form: may cover both the Federal and State assessments.

New York's State Environmental Quality Review (SEQR)/ New York City Environmental Quality Review (CEQR)

- SEQR: Environmental impact assessment as prescribed by 6 NYCRR Part 617 State Environmental Quality Review (SEQR) Act. For forest restoration projects, if a State permit is required, an Environmental Assessment Form (EAF) is required to show that the project will not have significant adverse environmental impacts. Since the PlaNYC Reforestation Initiative does not result in any large impacts it will likely be classified as at Type II (minor) action. A determination of "no significance" (negative declaration) will then need to be prepared as part of the EAF. CEQR can be conducted in place of SEQR in NYC.
- CEQR: Identifies any potential adverse environmental effects of proposed actions, assesses their significance, and proposes measures to eliminate or mitigate significant impacts. Only certain minor actions identified by the state (known as Type II actions) are exempt from environmental review. Department of City Planning (DCP) may exempt the project from the CEQR process.
- Under CEQR the New York City Landmarks Preservation Commission (LPC) reviews areas of archaeological significance to ensure that if historical artifacts are discovered an archeological dig will be conducted to recover any artifacts of cultural significance. Forest restoration sites sometimes overlap with areas of suspected archaeological sensitivity. Review of these sites must be coordinated with LPC through the CEQR process.

New York City Local Laws

- Local Law 37 of 2005: encourages the reduction of pesticide use by City agencies by phasing out the use of certain pesticides, instituting new recordkeeping and reporting procedures, and providing prior notice to the public before many pesticide applications.
    - Forest restoration sites need to have signage postage prior to pesticide application to notify the public of the application.
- Local Law 3 of 2010: encourages the protection and retention of city-owned trees by requiring basal area replacement of any city-owned trees that are damaged or removed by any party.

APPENDIX 2: COMMON FOREST COMMUNITIES OF NEW YORK CITY AND SURROUNDINGS

The following lists of forest types provide models of what successful restorations could become or resemble over time. They are end-point targets rather than assemblages of starting species. Almost all restoration sites begin as disturbed sites, newly planted, with maximum available light, and minimal soil organic matter and food webs for cycling organic matter. Among the greatest challenges in designing a restoration site is choosing the plant species that will stabilize the site quickly, intercept sunlight, and build soil and complex food webs – in other words, jump start a successional process that sets a disturbed site on a trajectory that will enable it to ravel into a resilient, robust, and resistant closed-canopy forest.

Not all species in the following list of plant communities facilitates this process to the same extent. Restoration managers should chose species that grow fast, tolerate full sunlight and shade, exhibit fecundity, and encourage the recruitment of additional native species while discouraging the recruitment of non-native, especially invasive, species.

Floodplain Forest

Floodplain forests are hardwood forests that occur on mineral soils in the lowlands of river floodplains and river deltas. These sites are characterized by their flood regimes; low areas are flooded each spring and high areas are flooded only irregularly.

Floodplain forests feature plant species including stinging nettle, smooth nettle, clearweed, lesser celandine, jumpseed, and skunk cabbage. Wood duck, red-bellied woodpecker, blue-winged warbler, and tufted titmouse are common denizens of floodplain forests.

In New York City, flood plain forests are found in the following locations: Bronx River Corridor, Bronx Park (Bronx); the Ambergill, Prospect Park (Brooklyn); the Ravine, Udalls Park Preserve (Queens); Tibett's Brook, Van Cortlandt Park (Bronx).

Trees > 5m

boxelder (*Acer negundo*)

red maple (*Acer rubrum*)

silver maple (*Acer saccharinum*)

sugar maple (*Acer saccharum*)

green ash (*Fraxinus pennsylvanica*)

American sycamore (*Platanus occidentalis*)

eastern cottonwood (*Populus deltoides*)

American elm (*Ulmus americana*)

Shrubs

speckled alder (*Alnus incana ssp. rugosa*)

American hornbeam (*Carpinus caroliniana*)

spicebush (*Lindera benzoin*)

Herbaceous Plants

false nettle (*Boehmeria cylindrica*)

spotted jewelweed (*Impatiens capensis*)

wood nettle (*Laportea canadensis*)

creeping jenny (*Lysimachia nummularia*)

ostrich fern (*Matteuccia struthiopteris*)

sensitive fern (*Onoclea sensibilis*)

jumpseed (*Persicaria virginiana*)

giant goldenrod (*Solidago gigantea*)

Appendix Oak-Hickory Forest

Appalachian oak-hickory forests are hardwood forest that occur at well-drained sites, usually on ridge tops, upper slopes, and slopes facing south and west. The soils of Appalachian oak-hickory forests are usually loams or sandy loams. Northern red, black, and white oaks, or their hybrids, are dominant. Northern red oak grows on moist soils at the bottom of slopes, black oak on mid-slopes, and white oak on drier ridge tops. American beech may be co-dominant in moist sites. Shagbark, bitternut, and mockernut hickories are often prominent canopy trees in Appalachian oak-hickory forests. Ground layer forbs include blue-stemmed goldenrod, wild sarsaparilla, black snakeroot, bloodroot, tall meadow rue, rattlesnake root, toothworts, and trout-lily. In sites containing sufficient forest interior, typical breeding birds may include great crested flycatcher, white-eyed and red-eyed vireos, American redstart, ovenbird, and woodthrush. Eastern grey squirrel may be conspicuous in Appalachian oak-hickory forests; northern flying squirrel and white-footed mouse may also be present but are much less common.

In New York City, Appalachian oak-hickory forests can be found at: Forest Park (Queens); the Ravine, Prospect Park (Brooklyn); High Rock, Greenbelt (Staten Island); and Seton Falls Park (Bronx).

Trees > 5m

red maple (*Acer rubrum*)

sugar maple (*Acer saccharum*)

bitternut hickory (*Carya cordiformis*)

shagbark hickory (*Carya ovata*)

white ash (*Fraxinus americana*)

hophornbeam (*Ostrya virginiana*)

white oak (*Quercus alba*)

chestnut oak (*Quercus montana*)

northern red oak (*Quercus rubra*)

black oak (*Quercus velutina*)

scarlet oak (*Quercus coccinea*)

Shrubs

flowering dogwood (*Cornus florida*)

American witch-hazel (*Hamamelis virginiana*)

beaked hazelnut (*Corylus cornuta*)

early lowbush blueberry (*Vaccinium pallidum*)

mapleleaf viburnum (*Viburnum acerifolium*)

Herbaceous Plants

wild sarsaparilla (*Aralia nudicaulis*)

Pennsylvania sedge (*Carex pensylvanica*)

Appalachian sedge (*Carex appalachica*)

blue cohosh (*Caulophyllum thalictroides*)

black snakeroot (*Cimicifuga racemosa*)

ground pine (*Dendrolycopodium obscurum*)

eastern hay-scented fern (*Dennstaedtia punctilobula*)

evergreen wood fern (*Dryopteris intermedia*)

white wood-aster (*Eurybia divaricata*)

Indian-pipe (*Monotropa uniflora*)

common Solomon's-seal (*Polygonatum biflorum*)

Christmas fern (*Polystichum acrostichoides*)

northern starflower (*Trientalis borealis*)

roundleaf violet (*Viola rotundifolia*)

Red Maple Hardwood Swamp

Red maple hardwood swamps occur in poorly drained depressions, usually on mineral soils, including permanently flooded forests and upland forests that are flooded only a few weeks of the year. Varying mixes of red maple, sweetgum, pin oak, and tupelo dominate these sites. Skunk cabbage may be prominent among the ground cover.

In New York City, red maple hardwood swamps are found at: The Great Swamp, Greenbelt (Staten Island); Wolfe's Pond Park (Staten Island); Van Cortlandt Park (Bronx); Lily Pond, Alley Pond Park (Queens).

Trees > 5m

boxelder (*Acer negundo*)

red maple (*Acer rubrum*)

silver maple (*Acer saccharinum*)

sugar maple (*Acer saccharum*)

green ash (*Fraxinus pennsylvanica*)

sweetgum (*Liquidambar styraciflua*)

American sycamore (*Platanus occidentalis*)

eastern cottonwood (*Populus deltoides*)

American elm (*Ulmus americana*)

Shrubs

speckled alder (*Alnus incana ssp. rugosa*)

American hornbeam (*Carpinus caroliniana*)

spicebush (*Lindera benzoin*)

Herbaceous Plants

false nettle (*Boehmeria cylindrica*)

spotted jewelweed (*Impatiens capensis*)

wood nettle (*Laportea canadensis*)

creeping Jennie (*Lysimachia nummularia*)

ostrich fern (*Matteuccias truthiopteris*)

sensitive fern (*Onoclea sensibilis*)

jumpseed (*Persicaria virginiana*)

giant goldenrod (*Solidago gigantea*)

Rich Mesophytic Forest

A rich mesophytic forest is a hardwood or mixed forest community that occurs on rich, moist, well-drained soils favorable to the dominance of a wide variety of tree species. There are a number of types of rich mesophysic forest in which only a few species co-dominate. Oak-Tulip stands are dominated by tuliptree, red maple, and red and black oaks. Beech-Maple forest stands are dominated by sugar maple and American beech, and tend to occur on acidic soils.

The use in the New York City region of the category “Rich Mesophytic Forest” is a departure from the nomenclature of the government of New York, which reserves this term for forest type for western New York State. NRG uses the term to describe forests that differ from Red Maple hardwood swamps by growing on deeper, moister soil, sometimes due to being situated on lower slopes or more gradual grades. Wildlife in rich mesophysic forests is essentially the same as the Appalachian oak-hickory forests. In rich mesophysic forests, redbacked salamanders thrive on the uniformly moist forest floor.

In New York City, examples of rich mesophysic forests are found in the following locations: Van Cortlandt Park (Bronx); Bloodroot Valley, Greenbelt (Staten Island); the Midwood, Prospect Park (Brooklyn).

Trees > 5m

red maple (*Acer rubrum*)

sugar maple (*Acer saccharum*)

sweet birch (*Betula lenta*)

American beech (*Fagus grandifolia*)

white ash (*Fraxinus americana*)

tuliptree (*Liriodendron tulipifera*)

cucumber magnolia (*Magnolia acuminata*)

wild black cherry (*Prunus serotina*)

northern red oak (*Quercus rubra*)

American hornbeam (*Carpinus caroliniana*)

American chestnut (*Castanea dentata*)

Shrubs

beaked hazelnut (*Corylus cornuta*)

American witch-hazel (*Hamamelis virginiana*)

red elderberry (*Sambucus racemosa*)

Allegheny blackberry (*Rubus allegheniensis*)

Herbaceous Plants

white snakeroot (*Ageratina altissima var. altissima*)

small white leek (*Allium tricoccum*)

Successional Mixed Hardwoods

The successional hardwood or mixed forest community occurs on sites that have been cleared or otherwise disturbed. A characteristic feature of successional forests is the lack of reproduction of the canopy species. Most of the tree seedlings and saplings in a successional forest are species that are more shade-tolerant than canopy ones. Shrub and ground layer dominants may include species characteristic of species that occurred on or near the site prior to disturbance.

Successional forests - or discrete patches of successional forests - are often dominated by species that arrived first. As a result, there may grow side-by-side patchwork-patterns of stands of saplings of similar ages but different species, such as a stand of black cherry next to one of black locust or a sassafras stand abutting poplar and sweet gum stands. Often, successional forests occur in highly dissected landscapes mosaics. Species typical of adjacent meadow and shrubland may also be present. Wildlife in early successional forests include eastern cottontail, white footed mouse, catbird, mockingbird, northern cardinal, willow flycatcher, rufous-sided towhee, and warbling vireo.

In New York City, early successional forests can be found in Blue Heron Park (Staten Island), Pelham Bay Park (Bronx), and Northern Cunningham Park (Queens).

Trees > 5m

silver maple (*Acer saccharinum*)

black birch (*Betula lenta*)

gray birch (*Betula populifolia*)

common hackberry (*Celtis occidentalis*)

eastern red cedar (*Juniperus virginiana*)

black cherry (*Prunus serotina*)

common sassafras (*Sassafras albidum*)

Shrubs

shadblow (*Amelanchier canadensis*)

red-panicled dogwood (*Cornus racemosa*)

spicebush (*Lindera benzoin*)

elderberry (*Sambucus canadensis*)

arrowwood (*Viburnum dentatum*)

lowbush blueberry (*Vaccinium angustifolium*)

Herbaceous Plants

sensitive fern (*Onoclea sensibilis*)

little bluestem (*Schizachyrium scoparium*)

Indian grass (*Sorghastrum nutans*)

white boneset (*Eupatorium rugosum*)

wild bergamot (*Monarda fistulosa*)

white beardtongue (*Penstemon digitalis*)

Coastal/Marine Forest

Coastal/Marine forests grow on the dry, rolling outwash plains and moraines of the Atlantic coastal plain. Coastal/Marine forests are subject to salt spray and offshore winds, and are thus dominated by low shrubs or stunted trees. Poison ivy and Virginia creeper are two prominent components of maritime shrublands. In autumn they supply dazzling crimson foliage. Myrtle warblers congregate in maritime shrublands during winter and eat bayberry fruit.

In New York City, examples of Coastal/Marine forest can be found along the Belt Parkway Bike Path (Brooklyn-Queens), West Shore Parkway Bike Path (Staten Island), Dubos Point Sanctuary (Queens), and Idlewild Park (Queens).

Trees > 5m

serviceberry (*Amelanchier arborea*)

American holly (*Ilex opaca*)

eastern redcedar (*Juniperus virginiana*)

pitch pine (*Pinus rigida*)

black cherry (*Prunus serotina*)

sasafrass (*Sassafras albidum*)

Shrubs 2-5m

red chokeberry (*Aronia arbutifolia*)

northern bayberry (*Myrica pensylvanica*)

shadblow (*Amelanchier canadensis*)

shining sumac (*Rhus copallinum*)

elderberry (*Sambucus canadensis*)

arrowwood (*Viburnum dentatum*)

beach plum (*Prunus maritime*)

lowbush blueberry (*Vaccinium angustifolium*)

Herbaceous Plants

beachgrass (*Ammophila breviligulata*)

broomsedge (*Andropogon virginicus*)

little bluestem (*Schizachyrium scoparium*)

butterflyweed (*Asclepias tuberosa*)

heath aster (*Aster ericoides*)

New York aster (*Aster novi-belgii*)

purple Joe-Pye weed (*Eupatorium purpureum*)

horsemint (*Monarda punctata*)

seaside goldenrod (*Solidago sempervirens*)

APPENDIX 3: TECHNIQUES FOR CONTROL OF INVASIVE PLANTS

Mechanical Control

Trees and shrubs

Removing invasive trees reduces the possibility of the re-colonization of prepared sites, but avoid clear-cutting, as the deep shade trees provide is often the sole force keeping the seed bank in check.

Unskilled staff or volunteers can usually uproot smaller trees and shrubs. Because some species will re-sprout from small amounts of root left in the ground, removal should include as many of the roots out as possible. There are many tools on the market to help remove root systems, such as weed wrenches, weed hooks and the honeysuckle popper.

Larger trees and shrubs can be felled, using either a handsaw or chainsaw. Care should be taken to avoid damage to desirable trees and vegetation nearby. If the species being removed is prone to developing stump or root-sprouts, the stump should be treated with herbicide (see cut-stump treatment under herbicide below for a full length description of this technique).

Another option for large trees is girdling. Removing a continuous band of cambium from around the lower trunk of the tree, at least one inch in width, will eliminate the flow of nutrients and kill the tree. An effectively girdled tree has the added benefit of offering habitat in the form of standing deadwood excellent for certain cavity nesting birds. Standing deadwood, however, is not appropriate in proximity to roads, paths, and benches. Take care that only well-rooted species with dense wood, such as white mulberry, are left as standing deadwood. Trees that are less well-rooted, have a narrow girth, or less dense wood, such as ailanthus, may easily blow down, thus providing little habitat value and possibly hazardous conditions for staff and volunteers.

Vines

Vines can be the most difficult of all invasive plants to remove. They have extremely fast growth rates, large underground nutrient storage capacities, fragile root systems that easily fragment when pulled, and large seed crops that can spread aggressively. Their foliage is also often difficult to distinguish from surrounding canopy leaves. Manual control of vines is similar to the control of small trees and shrubs described above. It is extremely important to remove as many roots as possible, as early as possible. Because of the persistence of vines, management of seed sources should be a priority. If full root removal is not possible, cut stems or branches prior to maturation of the seed crop, to prevent another year of seed dispersal. Even after you take control measures, vines are likely to return. If a site is extremely sunny, and/or the restoration plan will result in an open canopy in future years, it is wise to remove unnecessary structural elements (i.e. brush and standing deadwood) that could be used by vines as trellises for climbing to sunlight and expanding their potential seeding range.

Herbs

Some perennial and annual herbaceous species are nearly impossible to fully eradicate. Annual herbs have short life cycles and produce large amounts of seed. It is difficult to pull them without leaving parts of their root systems in the ground. If roots remain, herbaceous plants will re-sprout vigorously and attempt to produce seed before senescing. If seeds have been set or they are active in the soil seed bank, invasive plants will grow anew. Minimizing disturbance and amendments to soil are also important; recurrence of many types of invasive herbs is closely associated with soil disturbance. The preferred option for manual control of herbs is hand pulling at the appropriate time of year over multiple years. This has been found to be an effective control for herbs such as garlic mustard (*Alliaria petiolata*) and saplings of Norway maples (*Acer plantanoides*).

Chemical Control

Herbicide applications must be performed in accordance with the law and administered by someone with proper credentials and certification from applicable legal bodies such as the New York State Department of Environmental Conservation. New York City has passed even more restrictive regulations (Local Law 37) concerning pesticide use.

NRG makes extensive use of systemic herbicides that are applied to parts of plants (foliar, basal or dormant stem) and translocated through the plant’s vascular system to the roots, killing the entire plant. This approach to chemical control may call for multiple treatments of existing invasive species and additional follow-up treatments for new recruits and persistent mature rootstock.

Foliar Spray Method

Herbicide is sprayed on as much of the photosynthetic surface of the target vegetation as possible. This usually involves only the leaves, and must be done in spring or summer. For species such as multiflora rose, however, this can also involve the stems, treatment of which can be performed year-round. Foliar spray is most effective when applied while the plant is actively photosynthesizing and translocating nutrients to roots. Inclusion of an adjuvant, such as an oil or soap, in the tank mix with some systemic herbicides can increase their efficacy by penetrating the cuticle of waxy-leaved plants. An adjuvant holds the herbicide to the foliage for a longer time, thereby increasing the absorption of the herbicide by the plant. Foliar treatments are often followed by cutting and removal of above ground portion of plants, both to improve access to the site and to make follow-up treatments more effective.

Basal Bark Method

Basal bark treatment involves spraying a mixture of herbicide and basal oil on the woody parts of a plant. The oil carries the product through the bark and into the plant's vascular system. Basal bark treatments can be performed in the winter when other work is not possible; this can allow for a smoother sequencing of site preparation. Herbicide treatment done during the winter is beneficial because plants that are leafed out during the growing season are dormant, thus limiting damage from herbicide drifting to actively growing herbaceous plants.

Foliar and basal bark treatments can be done in combination during the growing season. Combined treatment is often the most effective option for initial treatment of dense areas of mixed invasive vines with or without other types of invasive plant species. Very dense tangles of vines that have received basal bark treatment often need to be cleared in order to provide access for follow-up treatments and eventual planting.

Cut Stump Method

This method combines mechanical and chemical treatments and is one of the least disruptive methods of application. In the first step, shrubs, trees, or vines are cut close to the ground. Then, the remaining stump is treated with concentrated herbicide. For vines, large nodes and as much of the root structure that can be accessed should be removed when feasible and herbicide should be applied to all small diameter roots that cannot be extracted without breaking. For vines such as porcelainberry, large nodes and root structures can potentially filter out herbicides, so their mechanical removal will help limit the number of repeat treatments required. Proper timing of cut stump treatments is essential. Do not perform this treatment in the spring when the sap is flowing because plants will push out the herbicide rather than translocating it throughout its vascular tissue. With the cut stump method, the likelihood of resprouts is relatively low. Thus, it is useful when a quick timeline is desired in the treatment of a relatively small site. The cut stump method is also useful for targeted treatment of persistent mature rootstock within larger work sites and for precise removal of individual shrubs or trees without disturbing other plants.

Direct Application

In some cases, NRG has found that direct application to an individual target plant, whether by hand-wiping or injection, has been the most effective and least harmful to non-target organisms. Hand-wiping and injection can only be performed on a very small scale, but are valuable tools in sensitive ecosystems. It is especially useful in a site with many sensitive desirable plants and a very limited number of stems of the invasive target.

Hand wiping, or "bloody glove" treatments are done with a relatively high concentration of herbicide, typically around 30%, and directly applied to the inflorescence or photosynthetic surfaces of the target plant. The applicator wears a long protective glove, with the opening cuffed to prevent dripping onto skin, with a thin cotton glove over the top. The herbicide solution is either sprayed onto the cotton glove, or the cotton glove is dunked into the solution, and then used to directly wipe the herbicide onto the target surface.

Injection can be done with an awl and squirt bottle, or with specialized injector guns. A hole is made either by the awl or gun into the stem between the second and third node. The hollow inside the stem is then filled with a high concentration, typically 100%, of herbicide.

Combining Mechanical and Chemical Treatments

As described in Chapter 5, mowing, pulling, and spraying can be used in a variety of combinations. Mowing before spraying can be helpful when treating species that require active or new growth for herbicide to be most effective. For example, NRG has found that mowing hardy plants such as multiflora rose or mugwort first, and then spraying the new growth that emerges, is the most effective sequence for removal. Conversely, mowing after herbicide has been sprayed can be an effective strategy for controlling vine species because vines grow in long mats, making it difficult to see the origin of the root. To use this method, first, spray herbicide to kill the tangled stems, wait 4-6 weeks for die-back, and then mow the dead stems. This will allow you to target the new growth that appears from the root directly.

While using mowing and spraying methods together may require a more complex schedule than simply mowing or spraying alone, it is effective and often the preferred approach for invasive plant control. Choosing the best sequence will depend on the traits and growth strategies of the invasive plant.

APPENDIX 4: MORTALITY DATASHEET

Date: Personnel – Full Names:
Park: Plot Number:
Plot moved from original position: Yes / No Lat: Long:
Comments:

SAPLING MORTALITY

Write clearly and fill in all boxes. Draw a diagonal line through all unused boxes.

Tree #	Species - Common or Scientific Name	Survival 1 for Live, 0 for Dead	If Dead ⇨	Cause of Death	If Alive ⇨	Diameter cm*	Height of Leader (cm)	Condition	Vines Present on Tree 1 for Yes, 0 for No	Leader Stem 1 for Live, 0 for Dead	If Leader DEAD
1				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
2				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
3				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
4				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
5				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
6				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
7				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
8				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
9				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
10				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
11				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
12				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
13				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
14				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
15				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
16				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
17				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
18				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
19				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead
20				UR BS MD				LD LC SD			Less 1/2 Dead More 1/2Dead

Cause of Death Codes - UR: Plant Uprooted **BS**: Broken Stem **MD**: Mammal Damage

Leader Stem Damage Codes - **LD**: > ½ of Leaves Damaged **LC**: > ½ of Leaves discolored **SD**: Any part of stem(s) chewed or bitten off

*Diameter – take measurement 6" or so above ground (avoid root flare) and use large jaws of calipers

Dominant Non-Tree Plant Cover

List the 3 non-tree plant species in the plot that cover the greatest area, and estimate percent cover in 25% increments. Please indicate bare ground. Do not leave blank spaces.

Species – Common or scientific name	Native (Yes or No)	Estimated percent cover – circle one	Height
		0-25 25-50 50-75 75-100	< 1ft. 1-5ft >5ft
		0-25 25-50 50-75 75-100	< 1ft. 1-5ft >5ft
		0-25 25-50 50-75 75-100	< 1ft. 1-5ft >5ft

Comments and General Description (use back of sheet if more space is needed)

APPENDIX 5: WEB RESOURCES

GIS and Spatial Data

- NYC Open Data: https://data.cityofnewyork.us/
- Landcover Raster Data (2010): High resolution land cover data set for New York City: https://data.cityofnewyork.us/Environment/Landcover-Raster-Data-2010-/9auy-76zt

Native and Invasive Plant Species

General Species Reference

- USDA NRCS Plants Database: http://plants.usda.gov/

Native Species Reference

- Greenbelt Native Plant Center: http://www.greenbeltnativeplantcenter.org

Invasive Species Reference

- Long Island Invasive Species Management Area: http://www.nyis.info/
- The Partnerships for Regional Invasive Species Management: http://www.nyis.info/?action=prism_partners
- Asian Longhorn Beetle (ALB) Host species: http://www.na.fs.fed.us/fhp/alb/general/hostlist.shtm
- Plant Invaders of Mid-Atlantic Natural Areas at: http://www.nps.gov/plants/alien/pubs/midatlantic

Invasive Species Control Reference

- JK Injection Systems: http://www.jkinjectiontools.com/
- Local Law 37: https://a816-healthpsi.nyc.gov/ll37/

Tools for invasive species control:

- Weed wrench: http://www.weedwrench.com/
- Honeysuckle Popper: http://www.misterhoneysuckle.com/
- Assorted Brush Grubber products: http://www.brushgrubber.com/products.html

Forest Restoration Planting Design

- Coder, K.D. 1996. Number of Trees per Acre by Spacing. The University of Georgia: http://warnell.forestry.uga.edu/service/library/for96-054/for96-054.html

Soils

General information on soils

- Brady, NC, RR Weil. 2009. Elements of the Nature and Properties of Soils. 3rd Ed. Prentice Hall.
- USDA Natural Resources Conservation Service, USDA Agricultural Research Service, University of Illinois Urbana-Champaign. “Soil Quality for Environmental Health.” <http://soilquality.org/>.

General information on soil testing

- Horneck, DA, DM Sullivan, JS Owen, JM Hart. 2011. “Soil Test Interpretation Guide.” Oregon State University Extension Service, EC 1478. <http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/22023/ec1478.pdf>.
- USDA Forest Service. 2001. “Soil Quality Test Kit Guide.” <http://soils.usda.gov/sqi/assessment/files/test_kit_complete.pdf>.

Heavy metals in soils

- USDA Natural Resources Conservation Service. 2000. “Heavy Metal Soil Contamination.” Soil Quality – Urban Technical Note No. 3. <http://soils.usda.gov/sqi/management/files/sq_utn_3.pdf>.

Soil organic matter content

- Cornell University Cooperative Extension. “Soil Organic Matter.” Agronomy Fact Sheet 41. <http://nmsp.cals.cornell.edu/publications/factsheets/factsheet41.pdf>.

Soil nutrient content

- Whiting, D, A Card, C Wilson. 2011. “Plant Nutrition.” Colorado State University Extension, Colorado Master Gardener Program, CMG GardenNotes #231. <http://cmg.colostate.edu/gardennotes/231.pdf>.

Soil pH

- Murphy, S. “Soil pH and Lime Requirement for Home Grounds Plantings.” <http://njaes.rutgers.edu/soiltestinglab/pdfs/ph-Lime-req.pdf>.

Soil salinity

- Cardon, GE, JG Davis, TA Bauder, RM Waskom. “Managing Saline Soils.” Colorado State University Extension Fact Sheet No. 0503. <http://www.ext.colostate.edu/pubs/crops/00503.pdf>.

- Provin, T, JL Pitt. “Managing Soil Salinity.” Texas Agricultural Extension Service E-60. <http://publications.tamu.edu/SOIL_CONSERVATION_NUTRIENTS/PUB_soil_Managing%20Soil%20Salinity.pdf>.

Soil texture

- Cornell University Cooperative Extension. “Soil Texture.” Agronomy Fact Sheet 29. <http://water.rutgers.edu/Rain_Gardens/factsheet29.pdf>.

Adaptive Management, Monitoring and Research

- Adaptive Management Services Enterprise Team (AMSET): http://www.fs.fed.us/adaptivemanagement/

- Bureau of Land Management’s report on “Measuring and Monitoring Plant Populations”: http://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf

- Challenges for adaptive management in coastal and riparian ecosystems: http://www.ecologyandsociety.org/vol1/iss2/art1/

- Collaborative Adaptive Management Network (CAMNet): http://www.adaptivemanagement.net/

- Fish and Wildlife Service report on “Adaptive management and the regulation of waterfowl harvests”: http://www.fws.gov/migratorybirds/currentbirdissues/management/ahm/ahm2.html

- Foundations of Success documents and discussion of AM: http://www.fosonline.org/resources_categories/1-overview-am

- Landscope America: A Conservation Guide to America’s Natural Places: http://www.landscope.org/

- Sierra Nevada Adaptive Management Project: http://snamp.cnr.berkeley.edu/

- Taylor et al review of “Adaptive management of forests in British Columbia”: http://www.for.gov.bc.ca/hfd/pubs/docs/sil/sil426.htm

- US Forest Service New York City Urban Field Station: http://www.nrs.fs.fed.us/nyc/

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