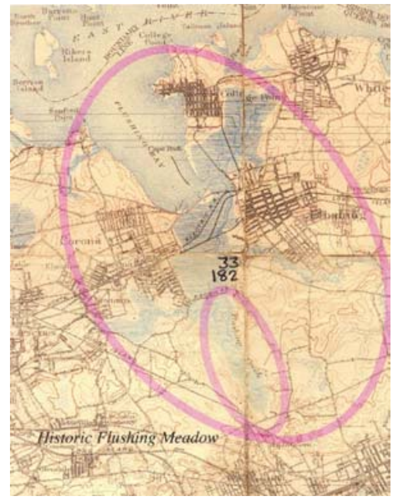
Ecological Engineering and Restoration Study
Flushing Meadows Lakes and Watershed

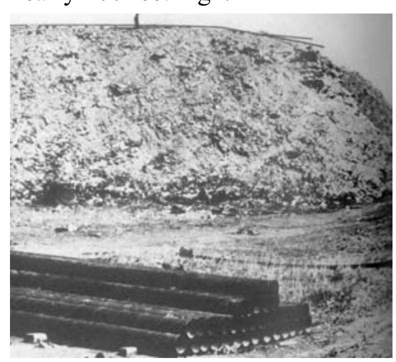
THE GAIA INSTITUTE
June 2002

EXECUTIVE SUMMARY

Meadow and Willow Lakes today are the product of human intervention in the natural environment. Sculpted by glaciers thousands of years ago, Flushing Meadows has been substantially altered over the last hundred years – first by its use as a city dump and then by Robert Moses as part of an aggressive park and highway building campaign. The resulting landscape reflects the predominant construction and design philosophies of the early 20th century, not a process of natural development.



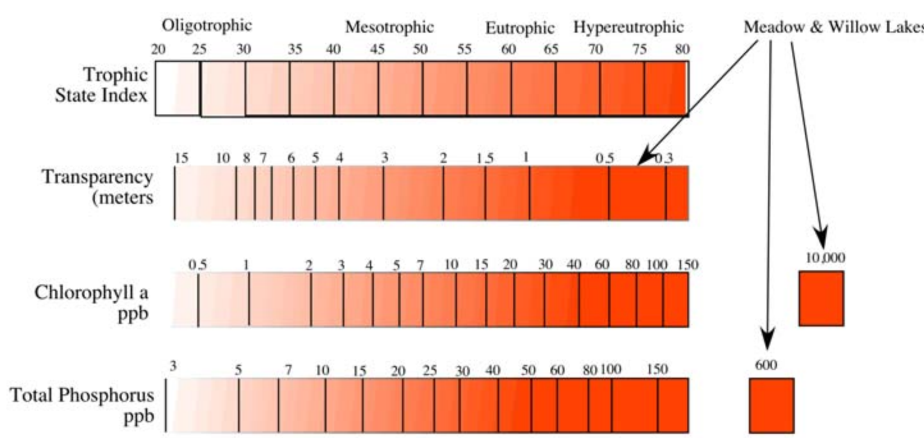
The tidal marsh in Flushing Meadow (above) became one of the largest garbage dumps in New York City (below). Mount Corona, as photographed in the 1900's, was nearly 100 feet high.



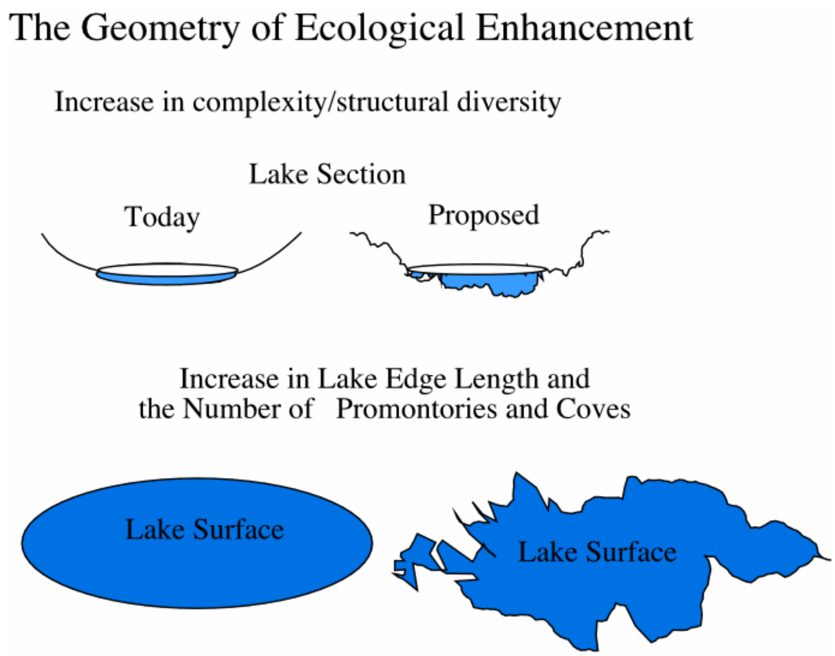
The twin lakes were conceived as a stormwater retention basin and ornamental centerpiece for the 1939 World's Fair. As a result, the topography and contours are a byproduct of the bulldozer, not the forces of nature. Driven by aesthetic rather than environmental concerns, the physical structure of the lakes works against the emergence of a diverse ecological system, and towards one of monoculture and dominance by invasive species.

The lakes further suffer from pollution that is, ironically, a result of their very creation. For thousands of years, Flushing Meadows was a tidal marsh drained twice a day by the natural action of the tides, which served to keep nutrient levels in balance. Damming Flushing Creek to create the lakes has eliminated tidal action, and the resulting unchecked release of phosphorus from the former marsh bed has caused the lakes to become "eutrophic" – or super-saturated with algae in warm weather. Eutrophication is not only unpleasant – causing bad odors and pea-green water – but is also destructive to natural habitats and to fish, which are killed in large numbers in summer by the depletion of oxygen in the water.

The Trophic State Index is a measure of the "health" of lakes. As can be seen, measures of Meadow and Willow Lakes, reported in the Lawler, Matusky & Skelly Report, indicate values far into the hypereutrophic, or polluted, zone (from Carlson's Trophic State Index, modified from the Lake and Reservoir Restoration Guidance Manual, 1990).



Only human intervention can remedy this situation. Without it, the lakes are likely to look and function as they do today for the next several hundred years. The smooth curves and even depths of the lakes do not provide the varied habitats needed for biodiversity. The graphic at right represents the form of the lakes today compared to the more varied lake edge and bottom structures needed to sustain a more varied ecological system.



This uniform structure has led to a virtual monoculture of the invasive reed *Phragmites*. This aggressive plant has invaded almost the entire perimeter of Willow Lake, occupying and eliminating this habitat for almost all other species. In fact, the Gaia Institute has noted only about 37 species around Willow Lake – an area which could support an estimated 300 to 400 species. This limited plant diversity is mirrored in limited aquatic life, with only six species of fish counted in the waters of the two lakes – whereas water bodies of this size should be capable of sustaining twice this number.

The common reed, *Phragmites* has dominated the edges of Willow Lake, as can be seen in the photograph at left.

No plan has emerged – prior to the NYC2012 proposal – for the comprehensive ecological restoration and enhancement necessary to make the lakes truly healthy for human and non-human use. With the proper techniques, the NYC2012 proposal "... could provide the integration of infrastructure and natural systems essential for the improvement of the lake environment and the protection of human and ecological health." In fact, not only is this an environmental enhancement opportunity, but from the Olympic point of view, it is a necessity. Clean water, a healthy landscape, and improved facilities are all prerequisites for Olympic use, and through major modifications by the Gaia Institute, the plan now incorporates systems that will provide a permanent, largely self-sustaining lake and upland environment by 2012 and for centuries beyond.

The 2,000-meter rowing course proposed for the 2012 Olympic Games has been ecologically engineered by the Gaia Institute to more than quadruple the acreage of productive wetlands and dramatically expand natural habitats. In order to be used for competition, the lakes must also be deepened below the racing lanes to a depth of 3.5 meters, and the necessary dredging will remove many if not all of the phosphorus-rich sediments that contribute to the poor water quality of the lakes today.

The techniques recommended are neither new nor untested. The Gaia Institute, as well as City, state, and federal agencies, and a number of engineering and construction companies have successfully implemented similar measures at many other locations throughout New York City and the surrounding metropolitan region. Post construction monitoring indicates that where these techniques are properly designed and carried out, they have substantial environmental benefit at relatively modest cost. Furthermore, these systems are largely self-sustaining, eliminating the need for costly mechanical systems, chemicals, infrastructure, or on-going maintenance crews. Among the most important steps proposed by the Gaia Institute and included in the Olympic rowing program are the following:

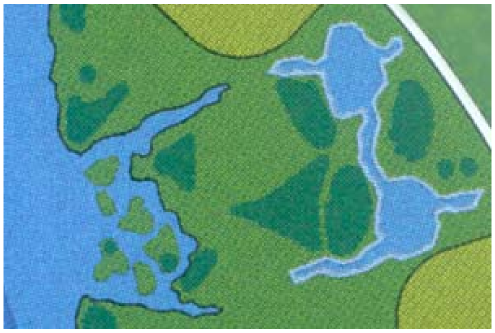
- **Dredging the lake bottom** is one of the most important steps to improving water quality, and one that has been advocated by the Parks Department at the recommendation of its consultants for decades. Only by removing the deep, nutrient-rich peat and sediment layers left over from the historic salt marsh will the lakes be able to sustain a diverse and healthy fish and invertebrate populations. Today, only six species of fish populate

Meadow and Willow Lakes, compared to twice this number seen in water bodies of similar size. Dredging the lakes to at least 12 feet deep in the middle is required for Olympic rowing. Preliminary coring samples suggest that a harder, low phosphorus sandy layer may underlie the top two meters of soft sediments.

Core samples taken by the Gaia Institute in 2001 show a nutrient-rich peat layer at least 2 meters deep, which is an ongoing source of pollutants in Meadow and Willow Lakes.

Two separate cores are pictured at left. The brown peat layer is the top of each core, and the bottom segment of the core is to the left. The cores are approximately 21/2 inches in diameter.

- **"Daylighting" of stormwater**, recreating streams and creeks by removing pipes which now discharge highway runoff into the lakes without any natural filtration by sun or soil, would help remove the heavy metals and suspended solids that now accumulate on the lake bottom. Replacing these underground culverts with open wetland holding ponds would further aid the natural filtration process and provide beautiful landscape features around the lakes. The NYC2012 proposal would daylight all of the stormwater pipes around the lakes while maintaining continuous pedestrian access and all existing playing areas.



The Olympic Rowing proposal includes daylighting of stormwater pipes (above), much like the enhancements being implemented in Conference House Park, Staten Island (right).

- **Reintroduction of native wetland plant species** is essential to recreating a balanced ecosystem. The invasive, common reed *Phragmites* has virtually taken over the entire perimeter of Willow Lake. While providing habitat for certain birds and other organisms, the contribution of this narrow wetland filter is limited. A more diverse and expanded native shrub and herbaceous wetland plant community would provide habitat for a much greater number of birds, fish, and invertebrates, while providing more filtration capacity because of the increased area of the enhanced wetland surrounding the lake edges. The NYC2012 plan proposes large-scale reintroduction of native plant communities well in advance of the 2012 Games. The lead time is necessary to ensure sufficient time for the growth and development of the biomass required to power the natural filtration which will bring water quality up to Olympic standards.

The difference between urban runoff problems and habitat lies in sustainable natural structures. A mallard and her ducklings can just be seen in the photo at left, well hidden in the dark right center of the picture, under a grassy overhang. Eighteen months ago, this wetland was a blacktopped path. Constructed by the Gaia Institute, this former asphalt surface now contains a coverage of 22 native species, with about 300 individual shoots and 170 colonies.

- **Wetlands in series** – or a terraced sequence of wetlands and uplands – would exponentially increase the natural filtration ability uplands and wetlands taken separately. Studies indicate that efficiency goes up dramatically when water alternatively moves through wetland pools, soil buffers, wetland pools, soils, and so on. By creating as many as four wetlands in series, it would be possible to virtually eliminate pollutant inputs and bring the water quality to swimable – theoretically even to drinkable – levels. The NYC2012 plan proposes installation of wetlands in series around the entire perimeter of Willow Lake, as both a natural filter and an environmental education asset.

The enhanced wetland, island, and soil buffer system pictured at right would dramatically improve biodiversity and water treatment capacity in the twin lakes. By filtering stormwater through an alternating series of soils-wetlands-soils-wetlands, the removal capacity of these systems is increased exponentially. Water passing through a single wetland prior to entering lakes and ponds removes approximately 50 –90% of nitrogen, heavy metals, and pathogens, whereas the wetland series proposed in the NYC2012 plan would remove approximately 90 to 99% of nitrogen, phosphorus, heavy metals, and pathogens.

- **Expanding wetland acreage to match runoff inputs** is also critical. To meet water quality goals, the area of wetlands must be sized to handle the volume of water flowing from impervious surfaces in the surrounding watershed. Today, the two lakes are rimmed by about 15 acres of low-diversity wetland, which is inadequate given an estimated watershed area of 4-6 square miles. The NYC2012 plan calls for approximately 90 acres of diverse, high-productivity wetlands – an increase of ~500% in wetland acreage. This area would be sufficient to handle runoff from 1,250 acres of paved surface – an area equal to at least 50% of the entire watershed.

Increasing wetland area six-fold, the 90 acres of wetland proposed in the NYC2012 plan, as pictured at left, would be sufficient to filter runoff from 1,250 acres of paved surface, approximately 50% of the entire Flushing Meadows watershed.

By adding an 18” rich humus layer over construction and demolition debris and urban landfill, as can be seen in the photographs above and at left, transformed a ragweed-covered, abandoned lot in Brooklyn into a stormwater capture park. Presently covered with blueberries and other native plants, natural infiltration processes have been restored and enhanced by the action of plant roots, worms, and burrowing insects.

- **Improving the water infiltration rate of existing soil** is also critical, not only to natural filtration processes but also to eliminating flooding. The substratum beneath the park is composed of cinder ash, which can become compacted, thus behaving like a paved surface. Adding a fresh, humic soil layer 12” to 18” deep will dramatically enhance the ability of the land to absorb rain – eliminating “ponding,” making it possible to maintain healthy turf, and reducing damage to park infrastructure caused by the freeze-thaw cycle. Past studies by the Gaia Institute have shown that the addition of such a layer increases infiltration rates up to as much as 1 to 2 feet per hour of water – an amount equal to or greater than the total rainfall dropped by Hurricane Floyd. The NYC2012 proposal includes a plan to regrade the lakes area with at least 12” of humus-rich topsoil, the essential prerequisite for the growth and development of diverse and aesthetically appealing plant communities.

- **Ongoing public access and education** is perhaps most important of all to the success of these efforts. Experience at State and National parks has shown that people are most willing to protect and promote landscapes that they can experience and enjoy. The NYC2012 plan proposes a nature sanctuary around Willow Lake which features an elevated boardwalk which passes along the periphery of the wetlands, allowing for bird watching, strolling, and contemplation, while preventing direct access to fragile, natural habitats by people.

The Olympic rowing proposal would incorporate six new boathouses for recreational use by the public, high schools, colleges and universities. At the same time, the natural areas to the south will be accessible only by a raised boardwalk, allowing public access, while limiting disturbance to wildlife.

Public appreciation of natural areas through direct experience is becoming the new approach to conservation at the Department of the Interior. To deepen public appreciation of the protected watershed in Government Canyon, the formerly off-limits park land will be opened for recreational use.

Conclusion

Given the intrinsic aim of producing an ecologically sustainable, low nutrient water body surrounded by a mosaic of native plant communities, soil buffers, and biologically diverse, productive wetlands, there is no essential conflict between the goals of NYC2012 and environmental quality. In fact, given the history of the landfill and ash dumping together with the high phosphorus sediments of the lake bottom left from thousands of years of marsh growth, environmental quality improvements without the restoration and enhancement steps described here are not possible. Increases in biological diversity and ecosystem services are only likely to occur with the kinds of investment necessary for developing the park for Olympic use.

I. THE ECOLOGICAL CONTEXT OF FLUSHING MEADOWS

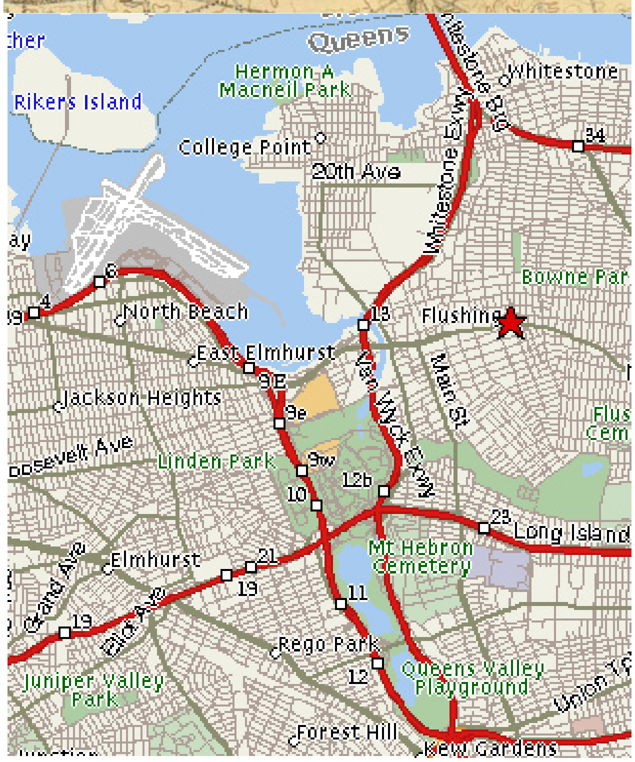
In the recent course of history, from the arrival of Dutch and English settlers in what is now New York City, Flushing Meadows and its surroundings was transformed from a high quality habitat for native plants and animals and a powerful biogeochemical water filter to an ash dump with negligible ecological productivity. The resulting blight on the landscape was dramatized in the early 20th century by F. Scott Fitzgerald in *The Great Gatsby*:

> *About half way between West Egg and New York the motor road hastily joins the railroad and runs beside it for a quarter of a mile, so as to shrink away from a certain desolate area of land. This is a valley of ashes – a fantastic farm where ashes grow like wheat into ridges and hills and grotesque gardens; where ashes take the forms of houses and chimneys and rising smoke, and finally, with a transcendent effort, of ash-gray men who move dimly and already crumbling through the powdery air.*

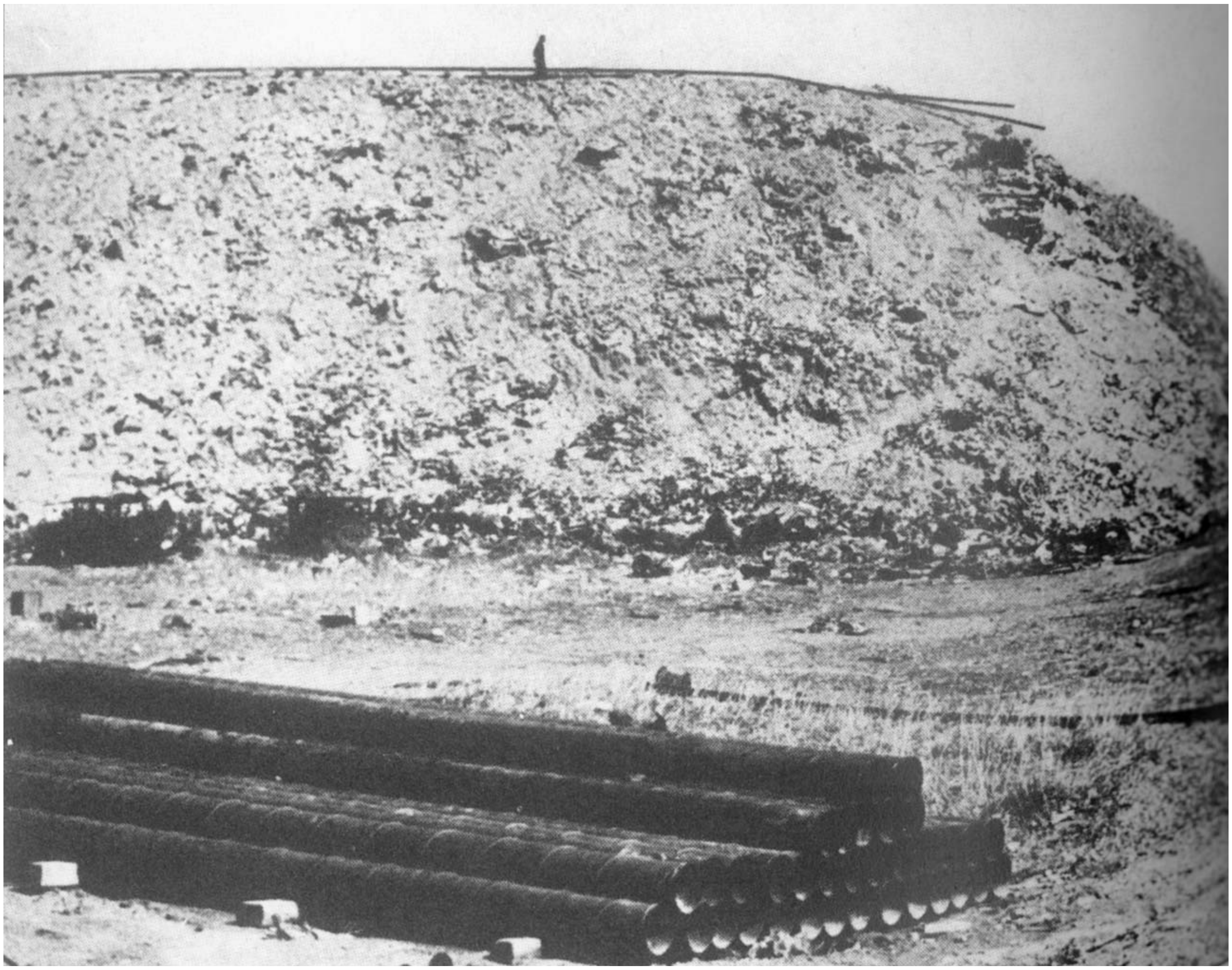
By his own account, this situation was "rectified" by the late Robert Moses, the most prodigious builder of parks and highway infrastructure the City of New York has ever known. By building the Whitestone Bridge, the Queens-Midtown Tunnel, the Grand Central Parkway and Van Wyck Expressway, Flushing Meadows became a central node on the transportation grid connecting the region. Who and whatever moved from New England and the Bronx to Brooklyn, Nassau, and Suffolk Counties, or from Long Island to Manhattan and New Jersey had to pass within minutes of Flushing Meadows. While all boroughs were to some degree fragmented by the Moses highway program, Queens may be the most divided by speeding cars and trucks.

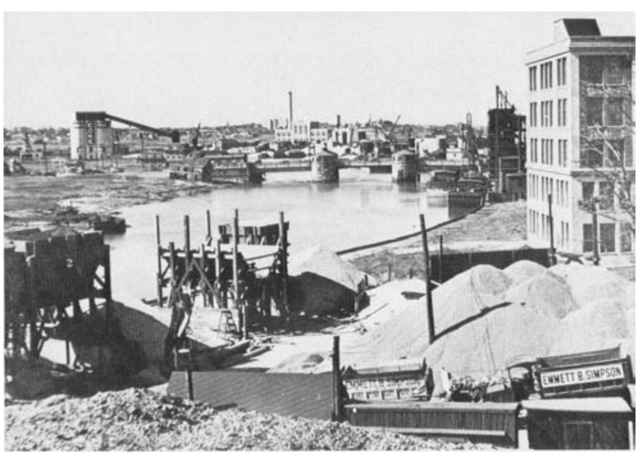
Amidst these hard roadbeds of infrastructure, Moses also created "public amenities" in Flushing Meadows-Corona Park. By fixing the water level in the former wetland complex with a tide gate near the high tide mark, two water features – Willow and Meadow Lakes – were formed. These provided the World's Fairs of 1939 and 1964 with an aesthetic centerpiece. From the onset, however, they were designed to capture stormwater runoff from the miles of surrounding roadway. While little attention was probably given at the time to pollutants in the runoff from thirty-plus acres of highway, the fact that water was detained for weeks to months in these lakes was itself an early version of "stormwater treatment", even if unintended. While the lakes were probably eutrophic (nutrient rich, oxygen depleted) from the time of their creation because of the high nutrient sediments, the long residence time would nonetheless have removed hydrocarbons, metals and sediment from the water before it entered Flushing Bay.

Although the park landscaping has undergone many changes over the years, the focus on lawns and specimen trees has allowed for limited ecological development. Whatever diversity of plantings may have occurred, the creation of uniform lake edges on landfill together with a lack of maintenance provided an extensive habitat for the invasive common reed (*Phragmites communis*), which has since the late 1980's surrounded Willow Lake. So while the construction of the World's Fair infrastructure may be credited with cleaning up the ash dump, it also established the landscape features that limit the biodiversity, growth and development of the ecological systems in Flushing Meadows. The landscape principally serves the original aim of construction, i.e., to support an infrastructure for moving people through the area. Other aims, such as enhancing biodiversity and creating natural filters, were not part of the plan.



The above map dates from 1897 and shows Flushing Meadows and environs with the tidal marsh as it existed before substantial human intervention. The image below is current road map of the area (courtesy of MapQuest).





The Corona Ash Dump (above), run by Fishhooks McCarthy from the beginning of the 1900's through the 1930's, was famous for its grotesque presence on the landscape. The so-called "Mount Corona" was a mountain of garbage that reached nearly 100 feet high. Less infamous is the industrial pollution that tainted Flushing Creek (left) during this same period of time. By his own account, both were cleaned up by the late Robert Moses in preparation for the 1937 World's Fair.

The entire perimeter of Meadow Lake was used as the primary parking field for the 1964 World's Fair (above). So closely tied to the culture of the automobile was Meadow Lake that it was the site of daily demonstrations of the "***amphicar – the car that swims***" in the amusement area (left).

Today, the landscape of Flushing Meadow principally serves the original aim of construction, i.e., to support an infrastructure for moving people through the area. Other aims, such as enhancing biodiversity and creating natural filters, were not part of the plan.

The surface areas of Willow and Meadow Lakes are 47 and 93 acres, respectively. These water bodies, together with surrounding watershed area in Flushing Meadows, however, may provide the single largest opportunity for ecological restoration of shrublands, meadows, lake-edge, and wetland habitat in the City of New York. Given the presently low plant biodiversity, a tenfold increase in native plant species (an order of magnitude change) in the area is probably within reach.

Flushing Meadows offers opportunities for conservation and enhancement. The landscape as it now exists supports coverage by the common reed *Phragmites* around much of Willow Lake, as well as turf grass lawn and specimen trees around Meadow Lake. Differences in urban fill at the lake edges and a few variations of depth at specific points on the lake margins support a patchwork of wetland plants in a number of habitats. However, widely distributed fill and stresses caused by nutrient-poor cinder-ash subsoil has led to habitat uniformity in much of the surrounding landscape. Uniformly poor, stressful environments support uniform plant coverage, a virtual monoculture in some areas. Changing these two parameters – landscape diversity and soil structure – would lead to greatly increased biodiversity.

The ecology of the twin lakes appears to be largely driven by pollutant loads, and may be

The common reed *Phragmites* has achieved near domination of the entire edge of Willow Lake, leaving no room for other species to establish themselves in this invasive monoculture.

described as at the last stages of "eutrophication" – the over-production of algae followed by the total depletion of oxygen in the water.

An experiment in eutrophication - this textbook example demonstrates the effect of increased phosphorus on lake ecology: the upper lake partition received added phosphorus, the bottom half did not. Meadow and Willow Lakes will most probably behave like the upper lake in this photograph indefinitely unless the phosphate-rich sediments are removed by dredging or otherwise covered with an inert material (taken from Environmental Ecology, 2nd Ed., by Bill Freeman, Academic Press, NY, 1995 p. 199).

The high density of algae in the water column, the blooms which make the twin lakes appear green or brown, indicate high levels of productivity, and eutrophic quality. While nutrients are the cause, in this case, much of the nutrient input is not caused directly by human input, but rather, by a human caused change in conditions. The lakes were created on intertidal marsh, a natural sink for sediments. The creation of the lakes created conditions that release the nutrients, especially phosphorus, from sediments stored during the long history of the marsh. The hypereutrophic conditions stem from man-made causes, i.e., the creation of the lakes over marshes, even though the sediments are derived from the natural behavior of the marsh.

The natural food chain from algae to zooplankton to planktiverous fish to fish eating fish stabilizes the flow of nutrients. At Meadow and Willow lakes this food chain apparently has never developed. Thus there is a build up of plankton, followed by a subsequent periodic die-off of life in the ponds. A smoother flow of materials through the lakes would require lower nutrient inputs, as well as fish species to fill all the necessary roles, from planktivore to piscivore.

Willow and Meadow Lakes are presently used by migratory neotropical birds and waterfowl. Present plant community coverage of the surrounding landscape probably supports a fraction of the native avifauna that formerly nested and migrated through. Increasing landscape diversity and habitat structure will increase habitat types, and hence provide more opportunities for plants and animals.

Limited habitat diversity also limits fish species – only six have been identified in surveys of the twin lakes. The reason for this relatively small number, which includes three saltwater species that probably come in under the tide gate from Flushing Bay, is the all too frequent fish kills during warm weather. Removing nutrient-rich sediments from the bottom should allow for both more diversity and greater numbers of fish in these water bodies.

Goals of the Study

This report provides a framework to inform decisions made for the purpose of improving environmental quality and ecological growth in the urban landscape in and around Flushing Meadows. Basic questions orient this investigation:

- What have human beings accomplished with, and done to, the landscape in terms of the ecological services in the Flushing Meadows watershed?
- What are the capabilities of the landscape and area in terms of providing habitat for a diverse assemblage of organisms in this region?
- What have and can these natural systems provide in terms of biological diversity, stormwater treatment, air filtration, and human health protection, and how can these ecosystem services be enhanced?

This report addresses potentials which could, or perhaps even should be realized through developments coupled with the aims and requirements of the Olympic Rowing proposal, but it also identifies goals which may be pursued independently of such future uses of Flushing Meadows and its associated lakes, natural landscapes, and human built infrastructure. This report will:

- Review existing conditions and identify problems.
- Describe how the geologic past, and recent development, has shaped Flushing Meadows, physically, ecologically and functionally.
- Describe principles and methods for enhancing “ecosystem services” i.e., natural, ecologically based solutions to environmental problems.
- Compare impacts, environmental and ecological costs, and mitigation plans for lake and shoreline edge modifications, as compared to a no-build option.
- Provide a framework for decision makers to choose amongst park development scenarios in order to achieve environmental quality goals in and around Flushing Meadows.
- Discuss potential effects and opportunities associated with building the Olympic Rowing course, for achieving ecological enhancement goals in Flushing Meadows-Corona Park.

II. EXISTING CONDITIONS AND PROBLEMS

Good water is the life-blood of natural systems. Three structural features of the twin lakes in Flushing Meadows negatively impact the quality and quantity of water:

1. **The area is ringed by roadways** that discharge pollutants into the lakes and cause significant habitat disruption.

2. **Large quantities of stormwater are diverted out** of the watershed, reducing the flow of the "life's blood" of all natural systems. Less water flowing in means a reduced flushing rate in terms of throughput, as well as less water to support plant communities.

3. **High nutrient content in the underlying sediments** from the historic salt marsh is compounded in Meadow Lake by the grassy water's edge, which attracts geese that deposit droppings, adding yet more nutrients to the water.

The ring of roadways: pollutant deposition & habitat disruption

The simple problem with Flushing Meadows-Corona Park is that it is cut off from the surrounding area by roadway infrastructure. As can be seen in the 1969 aerial photograph of the twin lakes in Flushing Meadows, major highways ring the entire circumference of the park. More than five miles of highway effectively surround the park with a nearly continuous "fence" of high-speed vehicles. This moving barrier deposits a continuous stream of hydrocarbons, nitrate, and metals on the roadway, portions of which are washed directly into the twin lakes.

Pollutants deposited per acre of major highway have been quantified. By these generally accepted measures, each acre of the Van Wyck and Grand Central can be estimated to annually discharge some 20 pounds each of hydrocarbons and nitrate, a half pound each of lead, zinc and copper, and two tons of suspended solids into receiving waters.

In total, the thirty-plus acres of roadway each year contribute a quarter ton of hydrocarbons and nitrogen, tens of pounds of heavy metals, and tens of tons of suspended solids. While precise solutions to these loads in terms of wetland uptake is premature without more accurate measures of wetlands and highway area and runoff, such quantities are certainly well within the range of wetland removal capacities reported in scientific and engineering literatures.[1]

Quantity of pollutants per roadway mile

mg/l	NOx	TKN	TP	Cu (µg/l)	Cd (µg/l)	Cr (µg/l)	Pb (µg/l)	Ni (µg/l)
max	13.37	2.45	1.54	53.5		20	56	17
	6.47	2.42	0.81	52		13	30	14
mean	2.25	1.42	0.43	24.2		8.1	21	8.1
kg/ha/yr								
german rd			1.6	0.62	0.04	0.06	1.33	
Charl NC			3.5	0.22	0.22	0.03	0.2	0.09

Wu,J.S., C.J. Allan, W.L.Saunders. J.B. Evett. 1998. Characterization and Pollutant Loading Estimation for Urban and Rural Highway Runoff. Journal of Environmental Engineering. Vol. 124 (7): 584-592.

Reintroduction of native animal and plant species through migration from one side of the highway to the other is severely limited by this high-speed traffic. While birds can fly across the road, there is often roadside evidence of others that do not make it. Toads, frogs, salamanders, turtles, snakes, squirrels, chipmunks, foxes, muskrat, and even smaller animals such as insects have limited opportunities to immigrate from surrounding landscapes, therefore isolating the park from nearby natural areas, in part, by eliminating migrants with a deadly barrier. By reintroducing these species into enhanced, engineered habitats, a diverse ecosystem can be re-established in Flushing Meadows-Corona Park.

1969 aerial photograph of Flushing Meadows showing the surrounding highways, which limit the natural reintroduction of native animal and plant species.

Disrupted hydrology: Stormwater shed, seeps, and puddles

The twin lakes are literally surrounded by impermeable infrastructure: expressways, parkways, boulevards, parking lots, railways, sidewalks, and paths. Each and all are paved or compacted and so made impermeable to precipitation, thus maximizing runoff. On the other hand, the existing open land, especially on the hills around the lakes, is most probably highly porous because of the high sand and gravel composition of the glacial subsoil, so water entering the unpaved areas probably migrates relatively quickly to groundwater that flows into the twin lakes.

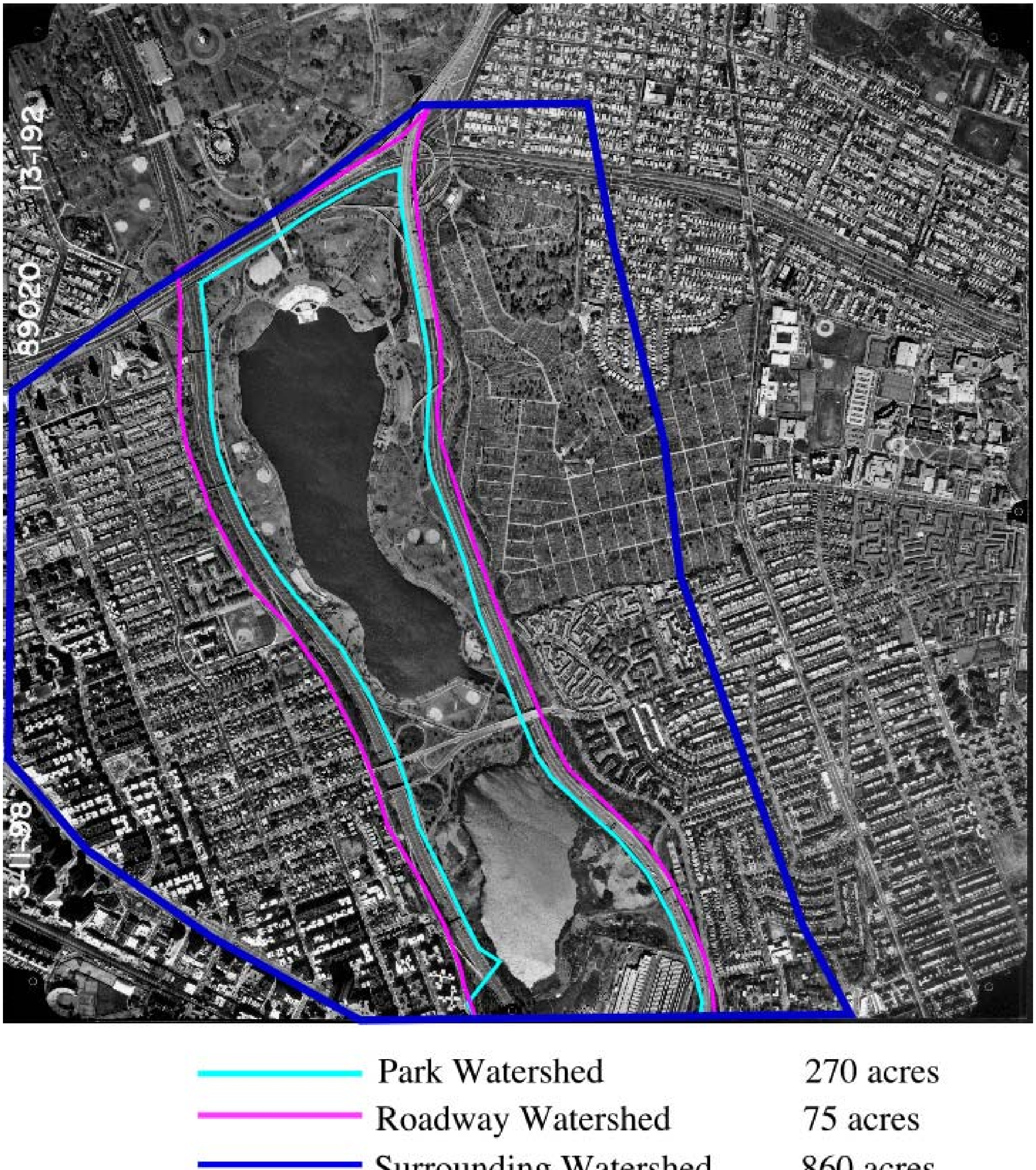
The terrace-like behavior of the infrastructure ringing the twin lakes can be seen adjacent to the highways, parking lots, and pathways, where seeps and upwelling of underground water sources are visible during wet periods or freeze-thaw cycles. The water blockage from these structures causes water to puddle and pool, increasing physical damage caused by freeze-thaw cycles and also increasing potential liability due to accident and injury. One manifestation of this ongoing problem may be seen in the seepages that emerge along the western edge of Meadow Lake following rain events, from the upslope water table that intersects the ground surface and runs across pathways and roads.

In a number of cases, failed pumps, or modified water tables emerge next to or over infrastructure, created more or less permanent wetland features – havens for mosquitoes in summer and ice hazards in winter.

Stormwater runoff and erosion

More than five miles of highway around the twin lakes and Flushing Meadows-Corona Park generate, from an inch of runoff, some two hundred thousand cubic feet of water. This runoff has created dozens of erosion gullies around both Willow and Meadow Lakes. The absence of fine-grained materials at the mouths of pipes and along roadway, parking lot and pathway edges indicates that runoff rates of a foot per second or greater has scoured away any clay, silts, and fine grained sands. This high velocity water carries fine sediments and nutrients into the lakes, at once disturbing the landscape and polluting the water with nitrate from acid precipitation, as well as metals, suspended solids, and hydrocarbons from the road surfaces.

Runoff discharge causes erosion gullies and creates mosquito breeding habitat.



The size of the watershed surrounding the twin lakes is a minimum of 1,200 acres, and probably closer to double that figure. Additional geographic analysis will be necessary to determine the precise boundaries.

Fragmented watershed: the diversion of stormwater

Less water flows through Flushing Meadows today than in the past. Ground water inputs have been compromised by the removal of vegetation and soil, and compaction. A major fraction of the four to six square mile watershed of the twin lakes has been built over, paved, and channeled into stormwater pipes. The immediate area of the park is between 200 and 300 acres, diminished from more than 2,000 acres of the historic watershed. While groundwater recharge from those upland areas is probably lower than the period preceding disturbance, it is still substantial because of the cemetery and other green space on the slopes around the lakes, which is not diverted by storm drains and related stormwater infrastructure.

According to the 1990 Department of Parks & Recreation study, approximately 70 million cubic meters of groundwater flows into the twin lakes each year, or over 100 million cubic feet per annum. While we do not, at present, have precise determinations of watershed scale, were it four square miles, this would mean that, on average, each square foot of landscape is capturing between one and two cubic feet of water. This is higher than expected, even with very efficient infiltration, so it is likely that the effective watershed is substantially larger, probably closer to six or even eight square miles. If the majority of runoff from this large watershed was redirected to creeks and wetlands around the restored edges of twin lakes, water quality of the lakes and Flushing Bay could be improved.

Low flushing rate

Since inputs must equal outputs, one approach to characterize water flow is to measure how much water flows out of the lakes, and then to use this quantity to infer what must enter the lakes from the watershed. In the NYCDPR Lake Restoration and Management Plan, the output at the tide gates has been reported to be 130 million cubic feet of water per year[2]. If the watershed is six square miles, the annual infiltration rate would have to be about two thirds of a cubic foot of water (0.65) for each square foot of land surface each year. This relationship is shown in the table below, which gives the water holding capacities of each lake:

	Willow Lake	Meadow Lake	Total
Mean Depth (feet)	4.3	4.9	
Area (acres)	46.9	93.4	140.4
Volume (cubic feet)	8,722,515	20,022,940	28,745,455.2
Groundwater input flow (cu. ft./year)	37,786,467	70,982,054	108,768,521
Groundwater+ surface input flow (cu. ft./year)	45,000,000	85,000,000	
Flush rate groundwater only (yrs.)	0.23	0.28	
Flush rate groundwater + surface (yrs.)	0.19	0.15	

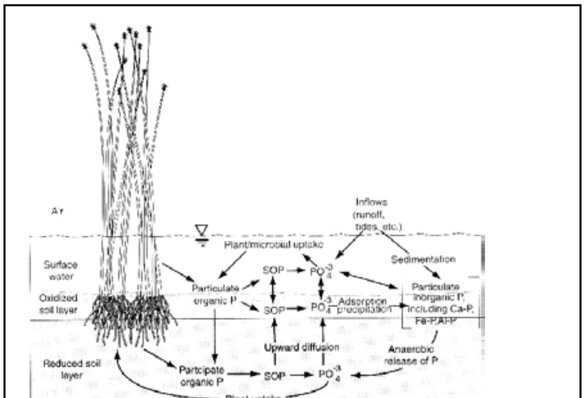
As can be seen in the table, the holding time, or hydraulic residence, time is equal to the volume (8.7 million cubic feet) divided by the flow rate (45 million cubic feet per year), yielding a residence time of .19 years in Willow Lake. One way to think of this is that if no water were to enter the lake from its surroundings, Willow Lake would empty in 70 days. For Meadow Lake, the timeframe is approximately 55 days. In both cases, the relatively long residence time provides ample opportunity for phosphorus to enter the water column from sediment. The only way to increase flushing rates is to increase water inputs by redirecting stormwater within the watershed to enhanced wetland features, plant communities, and soil buffers around Flushing Meadows.

Pollutants and eutrophication

Two primary pollutants in the twin lakes cause "eutrophication" – the superabundant nutrient levels which lead to uncontrolled algal production followed by massive dieoffs from the subsequent depletion of oxygen:

1. **Phosphorus**, captured through thousands of years of sediment deposition in the former tidal marsh, is released under anoxic conditions (where oxygen is not present). Overproduction of algae removes oxygen from the lake bottom, establishing the anoxic conditions which make phosphate soluble, which in turn cause an increase in phosphorus release leading to more algal production.

2. **Nitrogen,** in the form of NO_3 and related compounds, is constantly emitted from internal combustion engines. It falls as particulates and in rain and snow on the land and flows into streams, ponds, lakes and rivers. It also leaches into the groundwater from highly fertilized residential lawns and cemeteries. Nitrate, NO_3, is a nutrient that, in superabundance, becomes a serious pollutant that causes water bodies to become "pea green" and overgrown with weedy species of algae.



The phosphorous cycle (above) produces superabundance of algae when concentrations are high, leading to the production of ammonia, which kills fish in large numbers. The nitrogen cycle (below) contributes to the problem as well.

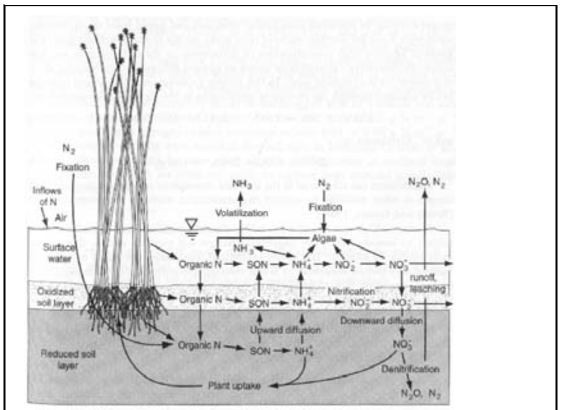
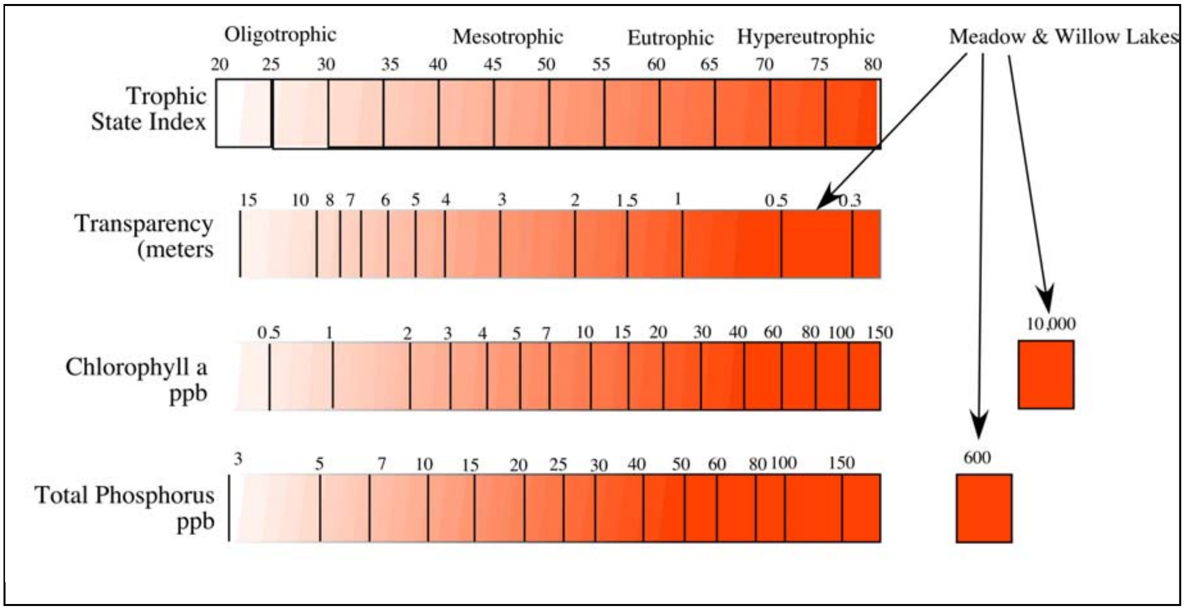


Figure 6-11 Nitrogen transformations in wetlands. SON indicates soluble organic nitrogen.

Simplified wetland nitrogen cycle. From Wetlands, by W.C. Mitsch & J.G. Gosselink, 3rd ed. p 171.

At a critical stage, phosphorus and nitrogen together produce extraordinary numbers of algal cells. This contributes to their own demise, since at night, when they cannot produce it, their own requirement for oxygen is not met by their surroundings. The death of algal cells from these and other causes leads to a burst of growth of the bacteria that use them as food, further depleting oxygen in the lake, and, periodically, leading to large fish kills, which may be directly caused by high concentrations of the fish toxin ammonia.

This cycle of phosphorus and nitrogen addition results in increased algal growth, decreased oxygen levels, algal death, fish kills, and further decreases in oxygen, which appears to be at work in both Willow and Meadow Lakes.



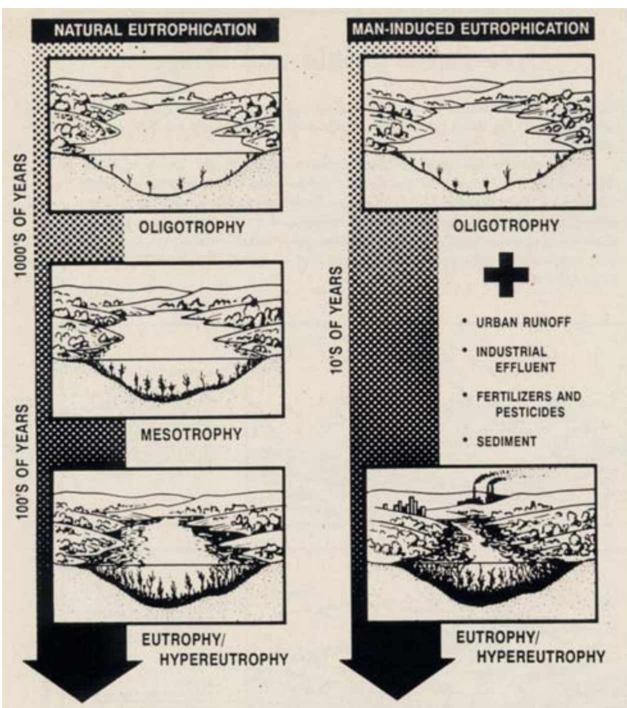


Figure 2-12.— *(left column)* The progression of natural lake aging or eutrophication through nutrient-poor (oligotrophy) to nutrient-rich (eutrophy) sites. Hypereutrophy represents extreme productivity characterized by algal blooms or dense macrophyte populations (or both) plus a high level of sedimentation. The diagram depicts the natural process of gradual nutrient enrichment and basin filling over a long period of time (e.g., thousands of years).

(right column) Man-induced or cultural eutrophication in which lake aging is greatly accelerated (e.g., tens of years) by increased inputs of nutrients and sediments into a lake, as a result of watershed disturbance by humans.

The Trophic State Index (top) is a measure of the "health" of lakes. As can be seen, measures of Meadow and Willow Lakes, reported in the Lawler, Matusky & Skelly Report, indicate values far into the hypereutrophic, or polluted, zone (from Carlson's Trophic State Index, modified from the Lake and Reservoir Restoration Guidance Manual, 1990). This manifests itself as the "pea soup" often seen in Meadow Lake (above).

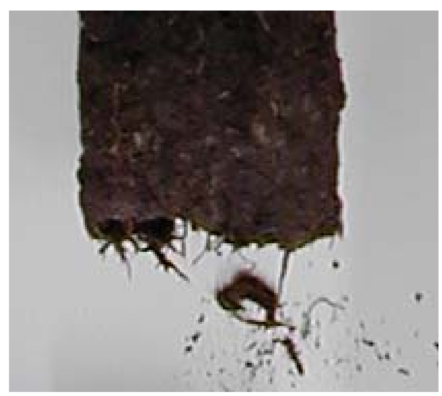
The EPA Manual (left) illustrates how human intervention speeds up the natural eutrophication process.

High nutrient sediments

Landfill and lake building on the original marsh area changed patterns of sediment deposition. By eliminating marsh habitat and tidal flows, the creation of the twin lakes at Flushing Meadows reversed physical and biogeochemical processes, removing oxygen and releasing nutrients instead of storing them.

When marshes are growing and developing, capturing sediments and adding biomass each year over the area of their distribution, nutrients are captured and stored. In plant biomass and in the oxidized area around the roots of marsh plants, phosphorus is taken up as a plant nutrient, and captured in oxidized iron, aluminum, or peat layers. With each large storm that causes upslope erosion, with each spring thaw, sediments are captured and phosphorus is stored by marsh plants. With each year of growth and autumn dieback, layers of peat, mats of intertwined plant roots and biomass at various stages of breakdown, intermingle with these sediments, creating an increasingly thick layer of rich sedimentary material. The presence of mussels and oysters can add to this storage capacity, by filtering up to millions of gallons of water per acre each day, and depositing their nutrient-rich wastes in the accumulating mass of peat and sediment.

Cutting off sediment sources by encasing creeks, diverting stormwater through pipes, and removing most of the tidal input with the tide gate used to create the lakes, has dramatically decreased sediment input rates. This has left nutrient-rich sediments exposed at the bottom of the lakes. Without the former exposure at low tide, and without the marsh grasses to move oxygen into these sediments, they have become anaerobic, as bacteria use up available oxygen. When oxygen disappears, phosphate is released into the water, providing nutrients for algae that create thick, green "blooms." This source of nutrients, where cores have been taken of the lake bottom, appears to be about two meters thick.



Cores taken in Willow Lake by the Gaia Institute indicate the presence of partly degraded plant material and fibers, which can be seen in the photos above and at left. The fibers, broken down plant parts and sediments comprise a deep peat layer, which may be as deep as two meters.

As long as these sediments remain, it is likely that the twin lakes will remain eutrophic, providing an abundant supply of the phosphorous that supports algae growth. When the algae become superabundant, as they appear to do each year, they die and provide biomass that is utilized by bacteria, depleting oxygen and releasing ammonia that is toxic to fish. This process is the probable cause of the yearly fish kills at Willow and Meadow Lakes. It is likely to continue as long as the sediments contribute nutrients to the water column.

Uniform lake edges and shoreline

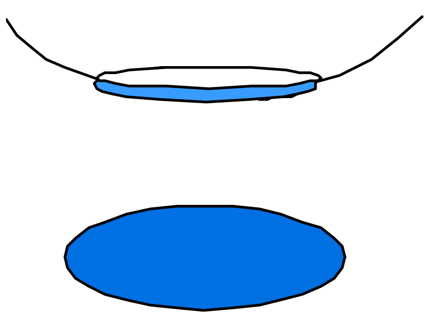
Habitat is enriched where different kinds of structures intersect. For example, increased biodiversity and/or ecological productivity may be expected where the landscape rises or falls sharply, where creeks or streams enter or leave larger bodies of water, or where bedrock or sediment types change abruptly, providing different chemical, physical, and mass and energy flow conditions.

Lake edges around Willow and Meadow Lakes are generally uniform in section. The bowl-like contour of the immediate watershed of the park and lake bottom shows relatively little change in relief – the topography of the basin is smooth and flat. In plan view, an analogous problem exists – the lake edge is comprised of smooth curves, with few peninsulas or promontories.

These two concepts are illustrated below: The left side shows relative uniformity in section and in plan, while the right side indicates more “fractalized” shapes, with changes in elevation, depth, and variegated edges.

Typical profile of twin lakes

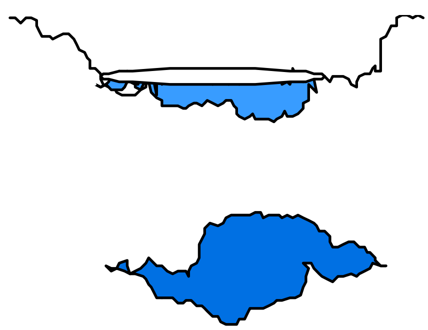
Cross-section



Plan

Typical profile of natural lakes

Cross-section



Plan

The top graphic shows the watershed geometry features and lake in section, while the bottom graphic indicates the plan view of lake shoreline, with greatly increased habitat diversity on the right side of the graphic.

Habitat for invasive weeds and "weedy animals"

Uniform habitats, such as farm fields, lawns, and the straight edges of infrastructure often provide opportunities for one or a few organisms to dominate. Existing conditions around Willow Lake fit this description, since the lake edge is largely filled with the common reed *Phragmites*, to the exclusion of most other plants.

In a similar manner, the smooth banks, grassy landscape, and lack of shrub cover or dense edge vegetation makes for easy "goose walks," or an ideal habitat that attracts these animals to congregate at the water's edge. Their presence creates a nuisance in terms of droppings on lawns and walkways, added eutrophication from nitrogen and phosphorus, and increased fecal coliform bacterial counts in the lakes.

The reach of lawn-turf grass cover down to the water's edge provides an entry and invitation to geese. Tens to hundreds of these can distribute droppings over an extensive landscape – adding yet more nutrients to an already overloaded system.

Low quality soils: ash fill

While a few large willows and sweet gums populate the edges of the twin lakes, trees and shrubs are in a minority in terms of coverage compared to grasses and herbaceous plants in Flushing Meadows. This is partly caused by the fact that trees were not planted widely in the original landscaping for the Worlds Fair. It also reflects the likelihood that there was no substantial native seed source on-site or in the imported soils and landfill used to cover the historic marsh.

Grassy edges are readily eroded (above right). One scenario is that Nor'easters drive waves across the lake, which then undermine the shallow-rooted turf. Another is that sheet flow from lawns and walkways scour the edges while raindrops erode bare soil.

A rip-rapped or rock-lined shoreline (at right) protects against wave-driven erosion and provides some aquatic habitat, but is unproductive ecologically.

The low quality of the landfill materials is also indicated by the relative sparseness of the vegetation in many places, especially on the ash fill at the south end of Willow Lake. Vegetation is also spare in terms of species composition, with much of the edge of Willow Lake filled with a monoculture of the common reed *Phragmites*, and other areas of fill dominated by ragweed. Beyond the human health impacts of hay fever and asthma, ragweed dominance is indicative of a lack of competition from other plants and nutrient-poor soil.

The configuration of the lake edges and the low quality of the fill around the twin lakes is the cause of three ecologically detrimental effects:

1. **The low water holding capacity of the landfill material** has led to a poorly developed soil horizon, which means many kinds of plants cannot survive in these areas. By contrast, organic soil, which develops because of plant growth, captures and holds water.

2. **The lack of organics in the soil together with compaction** has led to low biodiversity and poorly developed root systems of plants. The resulting lack of soil structure has led to erosion, especially on the western sides of Willow and Meadow Lakes.

3. **The near-complete dominance of common reed** has led to the elimination of any opportunity for growth and development of diverse plant communities. This is especially true for Willow Lake, where nutrients from sediments and runoff are relatively high and water is abundant in low areas around the edges.

The lack of native plant communities leads inevitably to an additional problem – a lack of native seed sources. At the same time, the open, sparsely vegetated areas facilitate the dominance of the wind blown seeds of the non-native, invasive ragweed.

Open environments and edges have been readily invaded by porcelain berry, multiflora rose and hops, as well as the aggressive native grass, *Phragmites*, the common reed. While the southern edge of Willow Lake looks green, the invasive vine porcelain berry is at work killing the half-century-old trees on the site between Willow and Meadow Lakes, adjacent to Jewel Avenue.

While it appears green, the invasive vine porcelain berry is in the process of covering and killing the trees pictured above, adjacent to Willow Lake.

Low biodiversity

The numbers of different plant, animal and fish species present in and around the twin lakes today are significantly lower than healthy environments of comparable size. The bad news for Flushing Meadows comes in two forms:

- Ecosystem services, the capacities of natural systems to clean air and water, are not well distributed around Flushing Meadows to protect environmental quality and human health.
- Biodiversity is not a prevailing feature of Flushing Meadows.

The number of species in an area are, in general, maintained by immigration and extinction[4]. Populations of a species in a given area may disappear, but if "immigrants" in the form of individuals, seeds, or spores move in from neighboring areas, populations are restored and biodiversity maintained. The ring of roadways prevents this process from occurring naturally. Furthermore, the structure of the lake edges and bottom makes it difficult if not impossible for many species to take hold.

Fish biomass in the Twin Lakes is probably dominated by the non-native carp or goldfish, pictured above. Clean water plus the presence of predators such as the large mouth bass and eastern chain pickerel could help regulate carp populations, and increase biodiversity and overall productivity of the lakes.

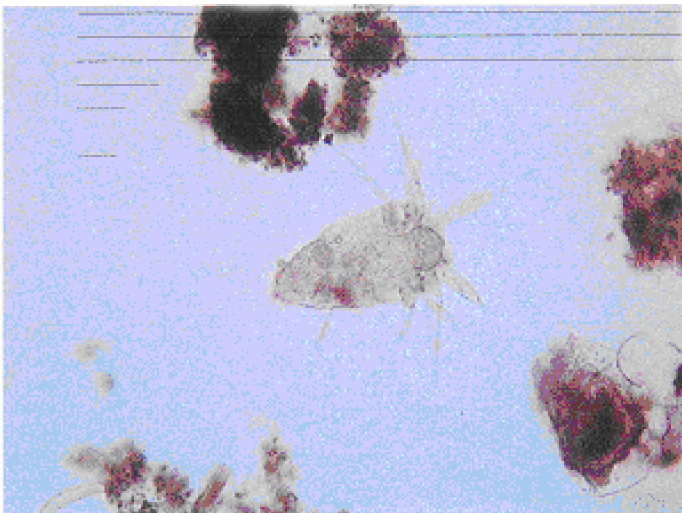
Fish: Surveys by the NYC Department of Parks show that only six different species of fish survive in the lakes today. These include pumpkinseed and bluegill sunfish, carp, white perch, Atlantic silverside, and banded killifish[5]. Comparatively sized water bodies in this area can have more than twice this number.

The bridge to the nature trails around Willow Lake have been closed by a chain link fence, providing no open view of the reaches of Flushing Meadows. The overgrown ball fields (visible in the 1969 aerial photograph, which can be seen on page 16) support few plant species. The extensive *Phragmites* community can be seen in the distance.

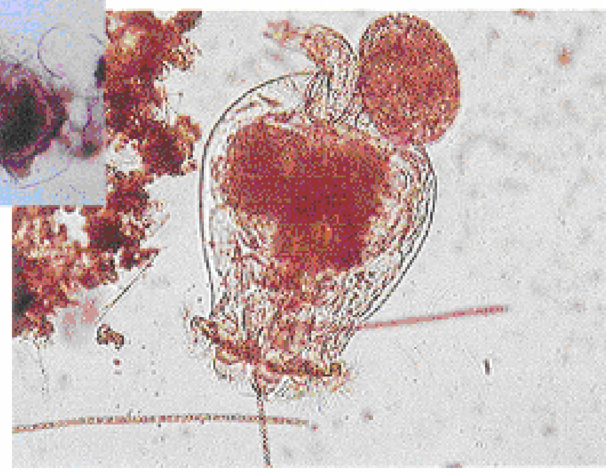
Plants: Similarly, only about 37 species of different plants have been identified in an area that should support anywhere from 300 to 400. For example, the eastern expanse of open space adjacent to Willow Lake is quite beautiful, but totally lacking in diversity. Grasses are sparsely colonized with sapling trees ten to twenty years of age. A few groups of non-native willows occur along the lake edges.

Birds: While bird census activity has been more intense at Jamaica Bay, Pelham Bay Park, and Central Park in New York City, in the list covering the years preceding February 1984, parks naturalists counted 160 species in the area, with 21 of these nesting or assumed to be nesting. In the period ending in April 1984, 318 species of bird were sighted at Jamaica Bay, with approximately 67 of these nesting in the area.[6] Thus about twice as many birds were seen in and around Jamaica Bay, with about three times as many nesting in the more diverse habitat of Gateway National Recreation Area, which includes trees, shrubs and meadow, in addition to *Phragmites.*

A Plankton Sample of Willow Lake

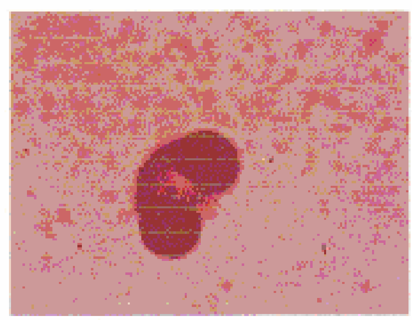


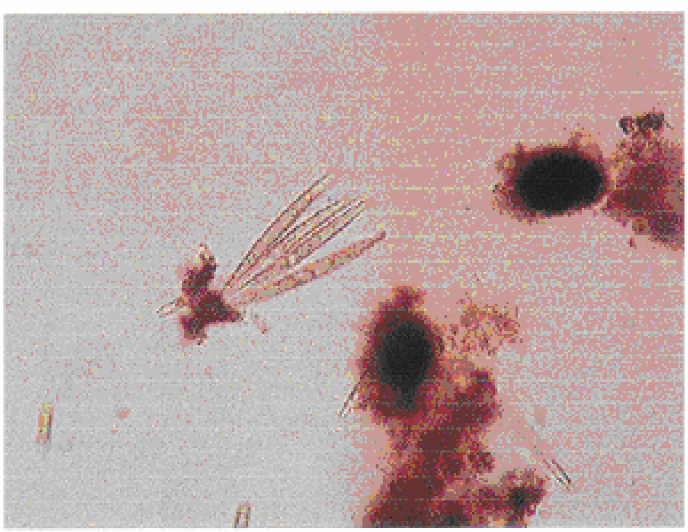
The rotifer pictured below feeds on bacteria and other single celled organisms. The presence and abundance of specific rotifer types can be used to characterize water quality.



The copepod pictured above is a member of the zooplankton, small animals that live in the water column, feeding on yet smaller organisms, and food for larger invertebrates and small fish. Abundance, distribution, and diversity of copepods depends on the kinds of habitat present, available food sources, and predation by dominant predators.

Creating different habitat types while conserving those already present in the lakes should increase the biodiversity of plankton as well as larger plants and animals.





Diatoms, pictured at left, are one of the most important algal groups in the primary productivity of the biosphere. The glassy, silica shells of these organisms can be seen in sediments from hundreds of millions of years ago. These shells or tests may be useful in characterizing changes in Meadow and Willow Lakes, and the history of the sediments beneath them. The pollen grain pictured above can also provide an indication of the ecological history of Flushing Meadow.

[1] Kadlek, R.H., & R.L. Knight:. 1996. Treatment Wetlands, CRC Press, Lewis Publishers, Boca Raton, FL.
[2] Flushing Meadows-Corona Park Lake Restoration and Management Plan. Prepared for NYC Department of Parks & Recreation, Olmstead Center, Flushing Meadows-Corona Park, Flushing, NY 11368. Prepared by Abel, Bainnson & Butz & Coastal Environmental Services, Inc. April 1990 Flushing Meadows-Corona Park Lake Restoration and Management Plan, cited above.
[4] MacArthur, R.H. & E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press
[5] Flushing Meadows-Corona Park Lake Restoration and Management Plan, cited above. Figure 6.7.
[6] These figures were taken from the Pamphlet from Gateway: "Birds of the Jamaica Bay Wildlife Refuge," Compiled by Thomas H. Davis, U.S. Department of the Interior. National Park Service. Gateway National Recreation Area.

III. THE PAST AND FUTURE LANDSCAPE OF FLUSHING MEADOWS

Extending more than a hundred miles from the western edge of Brooklyn to the eastern tip of Montauk, the gritty, gravelly fragments of the continent to the north provide the structural basis of Long Island. Now a metropolitan center never far from the beach, this same glacial landmass was, a geologically short time ago, a richly forested and vegetated landscape.

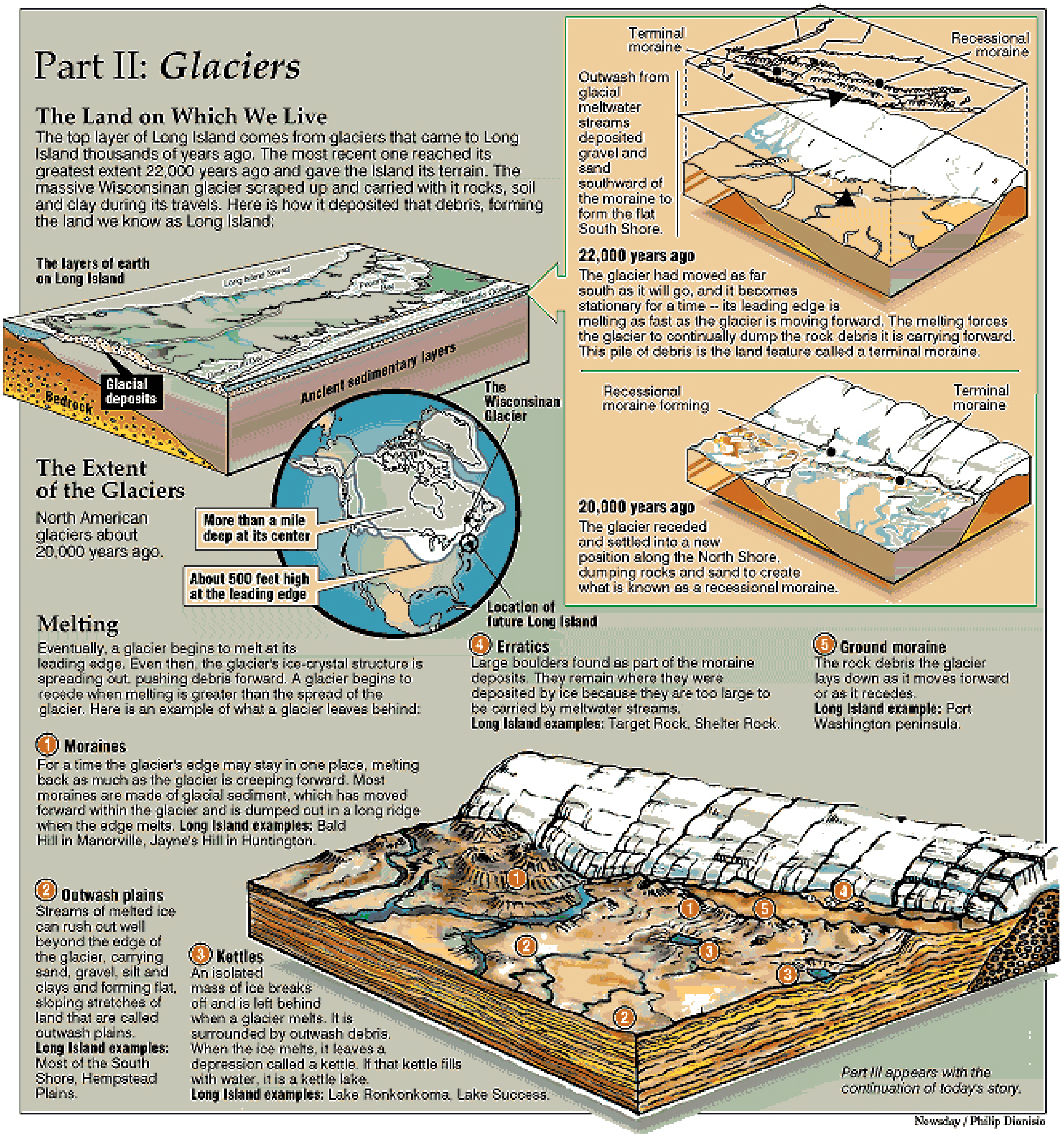
Far geologic past

Hundreds of millions of years ago, the North American and African plates collided with the tectonic body that now carries Western Europe. In some of the remnants of this collision, the Silurian origins of land plants may be found, in rock more than 400 million years old. One product of such impacts, the Manhattan formation, literally set in stone the bedrock features which form the western and northern horizon around Flushing Meadows. While bedrock more than a half billion years old guides the flow of the Hudson and Connecticut rivers towards the Atlantic and Long Island Sound from the north, a much more recent geologic event occurring only thousands, not millions, of years ago, formed Flushing Meadows from ice and the water which flowed from it as it melted away.

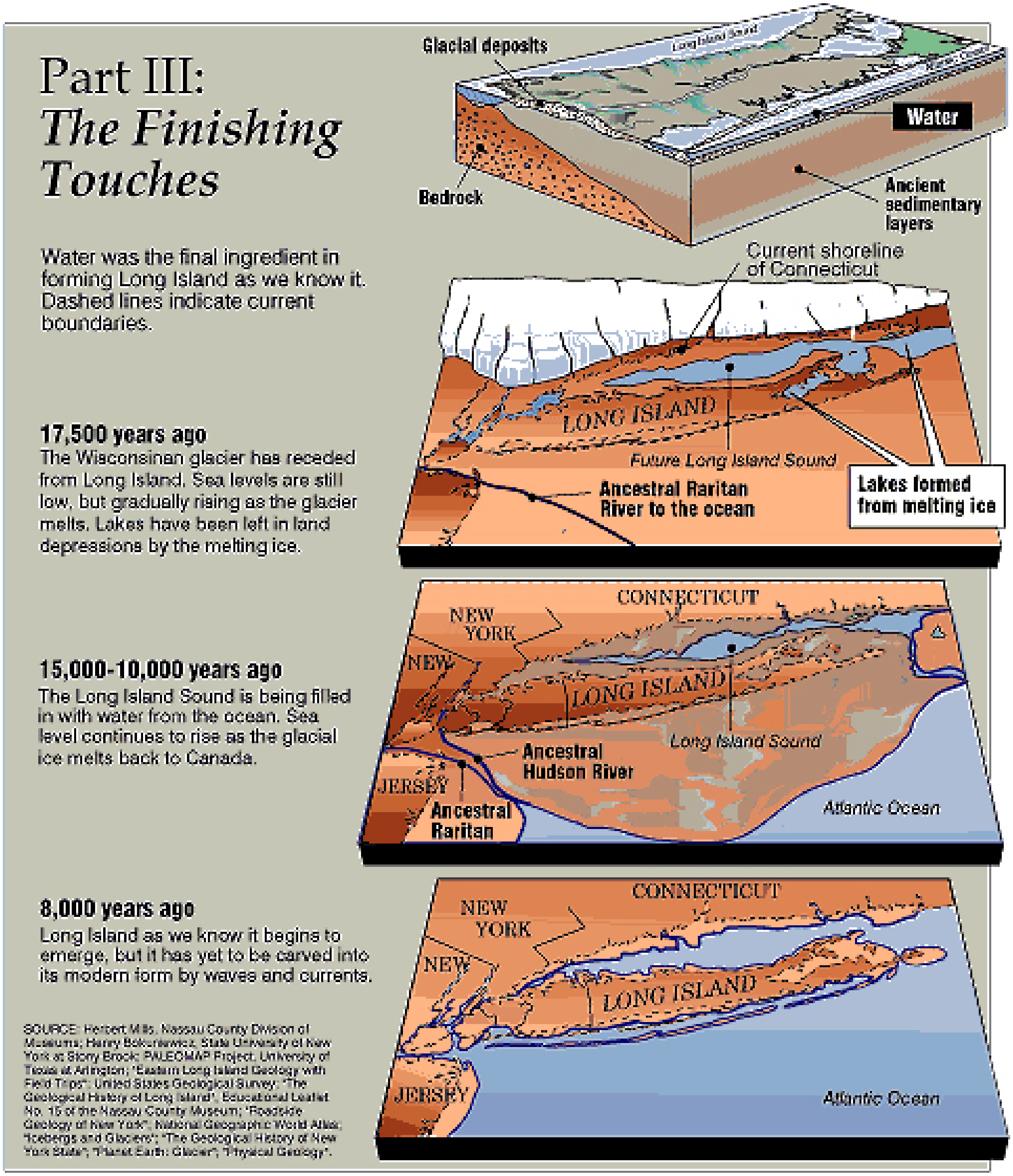
Glacial history

A number of glaciers advanced and retreated over the past million years until finally, about 12,000 years ago, the last of these mountains of ice retreated, leaving an effective hundred mile dam and berm, known as the terminal moraine- the ridge of sand and gravel that marks the backbone of Long Island. As the glacier receded to the north, a large lake filled the hollow south of the rocky Connecticut and Westchester coastlines, well situated to receive melt water rivers running off the continental shelf. The landscape of this period had a form similar to what we would recognize today, but the earliest plant communities were northern bog and sedge. As the glacier retreated and opened up the land, the terrestrial landscape became covered with plants – spruce, fir, and tamarack forests. Over millennia, these generated peats and soils that increased the rates of weathering of rock, adding more minerals to the thickening organic layers in the river valleys, from the Hudson to the Housatonic to the Connecticut.

The "clean slate" left 12,000 years ago after the Wisconsin glacier swept away all vegetation north of the terminal moraine is analogous to certain aspects of modern development. Just as the glacier scoured the landscape clean of plant life, clear cutting, industrialization, ash dumping, highways and urban infrastructure have had similar effects in reducing both biodiversity as well as ecological productivity. These two indices of integrity reached minima immediately following the glaciers as they have again under human influence. The analogy stops there, however, since glaciers supply nutrients in the form of powdered and dissolving minerals, as well as water, while urban development with its pavement, storm drains and pipes, eliminates these.



This illustration depicts the process which formed the "terminal moraine" of Long Island. As the glacier stopped its southern advance and began to melt, its debris-filled edge left the slopes of the north shore, and the finer-grained materials washed out to form the flat, smooth south shore. The last glacier in this region reached its most southern extent 22,000 years ago. Thereafter, it receded northwards, towards its present coverage of the artic north today.



As the glacier melted, it not only created the flat outwash plain of the south shore, but it provided an abundant source of fresh water to support plant and animal communities.

In sum, the landmass configuration in Flushing Meadows was set by the last glacier and fine-tuned by water and wind. Thereafter, the long east-west running terminal moraine became the divide for watersheds of the north and south shores of Long Island. Every square mile of watershed could produce flow in streams and creeks of about a cubic foot per second (and such estimates from historic behavior will be used below to develop aims for water capture in the watershed of the present). Cool north facing slopes were sculpted by water, as precipitation eroded and smoothed down the steep grades, and then seeped into the moraine, bursting out to the surface as streams and creeks in bottomlands near the shore. Tidal activity modified the edge of the meadow twice daily, once sea level had risen to replace the lake level behind the glacially deposited moraine, 8,000 to 10,000 years ago.

The future of the Flushing Meadows landscape now depends on how the land and water features will be structured to provide for ecosystem development. Simply stated, what we see in and around the twin lakes of Flushing Meadows is largely the result of human impact on water, seed sources, soils, and sediments organized into the ecological communities that cover the landscape and water bodies. Spare or missing soils, erosion, seed sources of invasive weeds, stormwater infrastructure piping water off the land – each of these limit the biodiversity of the region, and the lack of humus, water and plant diversity together inhibit ecosystem development, measured by the total amount of carbon captured by plants, as well as the length and diversity of food chains and food webs.

To bring life back to urban deserts, water, minerals, humus, and diverse communities must be restored by integrating water sources, plant species, soil depth and richness, and the shape, scale, area and volume of wetlands and lake environments. In this way, the future of the area around Flushing Meadows could be made more like the past in terms of biological diversity and environmental quality. This cannot and will not happen without commitment to a major effort, as described below.

Post-glacial settlement

As glaciers retreated northward, warming climates became locally hospitable for northern hardwoods, beeches and maples, oaks and hickories. These forests then became home to Native American peoples who had made their way from the west. By their practices, these peoples apparently came to live in a manner that sustained and even increased biological diversity, by opening the forest understory with fire, shifting agriculture, and hunting practices[1]. These immense stands of wood became one of the first resources for export when discovered by the colonists, more than three hundred years ago.

Farming and landfill impacts

The clearing of the land reversed the soil creation process, opening up land to farming, but also to erosion from water and wind. As the settlement in Manhattan grew, more extensive lands were cleared for farming in the hinterlands to support the growing villages and towns. While the Dutch began filling wetlands from their arrival early in the sixteen hundreds, as they had in their homeland for millennia, the large open marsh at Flushing Meadows appears to have escaped this fate. Not until the waste products of the industrializing landscape rolled out of Brooklyn in the early 20th century in the form of a vast ash dump were the meadows permanently altered[2].

Landfill for a higher purpose – transportation infrastructure and two World's Fairs

By the time the Grand Central Parkway was under construction in the 1930's, landfill on and around the thousands of acres of Flushing Meadows had created hillocks reaching heights of nearly a hundred feet, creating a landscape topography of city garbage and trash (as seen on page 1), covered with layers of ash and cinders. As the Parkway was in the planning stages, however, the idea of a World's Fair provided the interest – and resources – necessary to acquire and rebuild the whole area. As Robert Moses relates in his own history of the area, the layers of fill over the old marsh were themselves covered by:

> *"... the manufacture of topsoil out of earth, peat moss and mulch, planting of large trees, grass and shrubs on the basis of final landscape design..."*[3]

The northern part of the meadow was filled, and on the southern portion, two lakes were constructed. Still more infrastructure was added starting in 1960 (including the Van Wyck Expressway), for the second World's Fair in 1964. This fixed the present day circumference of Flushing Meadows and the twin lakes.

Future enhancement requires intervention

While this fill and construction has left an invaluable urban parkland in the geographic center of the City, plant and animal communities have developed about as far as the soil, water, size, shape and aspect of the waterways, seed sources and biogeochemical resources of the former dump site will allow. The future landscape will not improve, i.e., it will not differ significantly in terms of biodiversity or ecological productivity in coming generations[4], unless additional resources are brought in specifically for the purpose of the creation of more diversified habitat. The quality of the future landscape will thus depend on human investment in the creation of aquatic, wetland, and terrestrial habitat. This will require plant material, seed sources, and biomass additions in the form of humus.

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[1] Changes in the Land- Get Citation

[2] Moses, Robert. April 11, 1966. "The Saga of Flushing Meadow" describes the history of Flushing Meadows and the building of the infrastructure for the Worlds Fairs. This article can be found at: http://ww.nywf64.com/saga01.html.

[3] Moses, Robert. April 11, 1966. "The Saga of Flushing Meadow" describes the history of Flushing Meadows and the building of the infrastructure for the Worlds Fairs. This article can be found at: http://ww.nywf64.com/saga01.html.

[4] The likely timeframe for any significant change by natural means is on the order of hundreds of years. As we write,fields of hops with a few sweet gums are being covered by porcelain berry, and *Phragmites* is continuing its spread to remaining moist edges, but there are no great immigrations of native plants, and humus is building up relatively slowly in most portions of the park. These two "missing ingredients", biomass in the form of humus, and biodiversity in the form of plants and propagules, cannot come back in the near term without human intervention in the form of ecological restoration.

IV. PRINCIPLES OF ECOLOGICAL ENGINEERING AND RESTORATION

The design of human society in concert with the natural environment for their mutual benefit defines the goal of ecological engineering.[i] Ecological restoration is more difficult to define, since it may have historically informed goals, including the diversity of the original flora and fauna as well as functional components. For Flushing Meadows, ecological restoration may be defined as the reestablishment and support of biologically diverse plant and animal communities native to, and historically found in and around, north central Queens.

Plants modify and transform the landscape. En mass, they capture carbon, release oxygen, regulate the local and regional water table, and turn sunlight into living structures on the land and in the water. In short, the energy and material embodied in plants supports and sustains the local and global biosphere. In concert with the millions to billions of microbes under each square inch of land, plant and animal communities create soils and increase the overall fertility of the land.

Organisms are active agents of landscape and water transformation, not merely passive passengers on the planet. The flora and fauna literally "engineer" the landscape to capture water, prevent erosion, and increase the biomass that sustains food chains and webs. By growing tens to hundreds of feet tall, plants structure a boundary layer, a kind of membrane over the landscape, within which the speed of wind is diminished, solar radiation loads are regulated, and the forces of moving water are controlled, making the environment generally more equitable for life. A forested landscape or grassy meadow produces, in its canopy, an area cooler in summer and less windy in winter because of the coverage of plant life and the thermoregulatory properties of water. Plant life itself, in turn, regulates water on the land.

The Appalachian Mountains are softened and made inhabitable by tree and shrub cover in summer, with soils protected and renewed through leaf fall in autumn and winter.

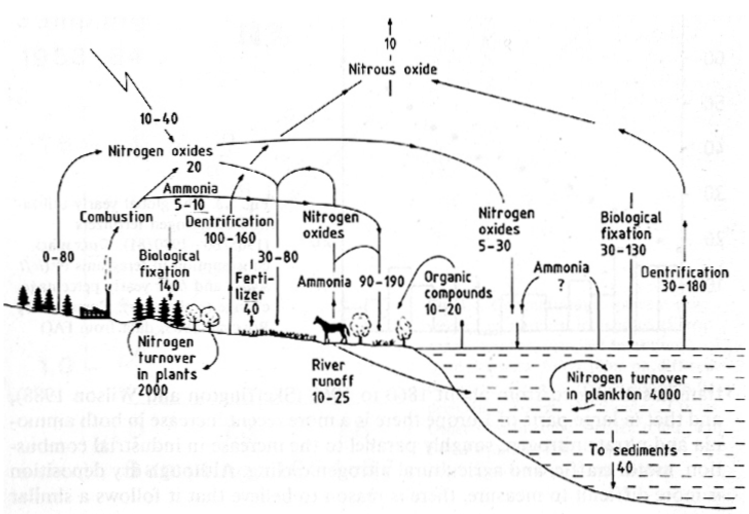
This 19th century engraving of Lake Erie evokes the interdependent cycle of water, plants, and animals. *In:* Kerner von Marilaun, A., The Natural History of Plants, translated by F.W. Oliver, Blackie & Sons, Ltd. 1896.

Flows of materials and energy: enhancing fundamental ecosystem processes

Natural systems are organized around the flow of matter and energy. Geological processes structure and shape the flow of water, the distribution of north, south, east and west facing slopes, the availability of minerals, and even the catastrophic destruction of the vegetation under glacial advance, landslides, volcanoes, earthquakes and the like. Analogous activities shape the urban environment in that blasting, heavy earth moving equipment, and huge quantities of fill are transported, destroying native plant communities in the process. Human activity has greatly changed the way these energy and material flows occur in cities, but the analogy breaks down in terms of life support systems. The landscape has, in many places, essentially been engineered such that urban areas cannot support life. This is opposite to the effect of the last glacier, which, to be sure, removed vast quantities of vegetation, but then supplied the developing landscapes downstream with cold water freshets and "glacial milk" – the turbid icy waters filled with minerals ground into fine particulates by the scour of huge masses of ice.

Native plant communities of the New York region cannot grow without water. So where water is piped off the land, plant growth is diminished or eliminated. This further affects the natural filters in the landscape, since soils or wetlands cannot develop without water and plants. Water cannot be scrubbed of nutrients, sediments and pathogens without soils or wetlands, and animals cannot live without the food and habitat plants create in partnership with water. Many standard engineering approaches have compromised or eliminated ecological development, even as stormwater drains, pipes, and other structures have met their intended purpose of removing water from roadways and other impervious structures. The reason here is simple: moving water more efficiently off the land creates a more thorough means of bringing ecological processes to an end, since water is the prime mover of life.

Energy inputs to Flushing Meadows have remained relatively stable over the past ten millennia. Solar inputs here, near 40°N latitude, are between a third of a day of sun in winter and two thirds of a day at the summer Solstice, with average energy values for mid-latitude areas being about 17 MJ per square meter per day[ii]. Paved areas transform virtually all of the energy into heat, with none moving into plants and ecological productivity. While lawns capture some solar energy, these turf grass systems often need to be subsidized with water, fertilizer, and systematic competitor removal (mowing & herbicides), and are still much less capable of capturing energy than the multi-layer leaves of forests, meadows or wetlands.



This graphic illustrates the global flow of nitrogen from the air, the land, and the water and back. Note that nitrogen turnover in land plants and plankton is more than ten times higher than any inputs, suggesting that these processes, and denitrification, may be able to regulate the movement of this potential pollutant, where plant communities, soils, and wetlands are large enough to make a difference.

From: Mitsch, WJ & JG Goselink. 2000. Wetlands. 3rd ed. Wiley and Sons.

Principles informing ecological enhancement

Water and air quality may be enhanced around Flushing Meadows by increasing the structural diversity, area, and mass of natural systems that come into contact with the water and air in this watershed. Therefore, three steps towards the enhancement of ecosystem services are possible:

1. ***Structural diversity***. Filtration capacity depends not only on surface area, but also on filter surface complexity. From cotton to fiberglass to activated carbon, all good filters have complicated surfaces. Different kinds and shapes of trees, shrubs, herbs and grasses acting in concert are a better filter than any one type of structure by itself. Similar structural diversity below ground increases the infiltration rate and filtration capacity of the zone where thousands of root hairs, humus and minerals in the soil create the rhizosphere. Together, these living and non-living components are a much more powerful water and air purifying matrix than either kind on its own.

2. ***Filter area***. The footprint of a forest, meadow, and wetland must be increased in order to favorably impact water quality.

3. ***Hydroperiod***. Holding water for a greater time in contact with natural (biogeochemical) filters increases their effectiveness removing nutrients, hydrocarbons, pathogens, and heavy metals.

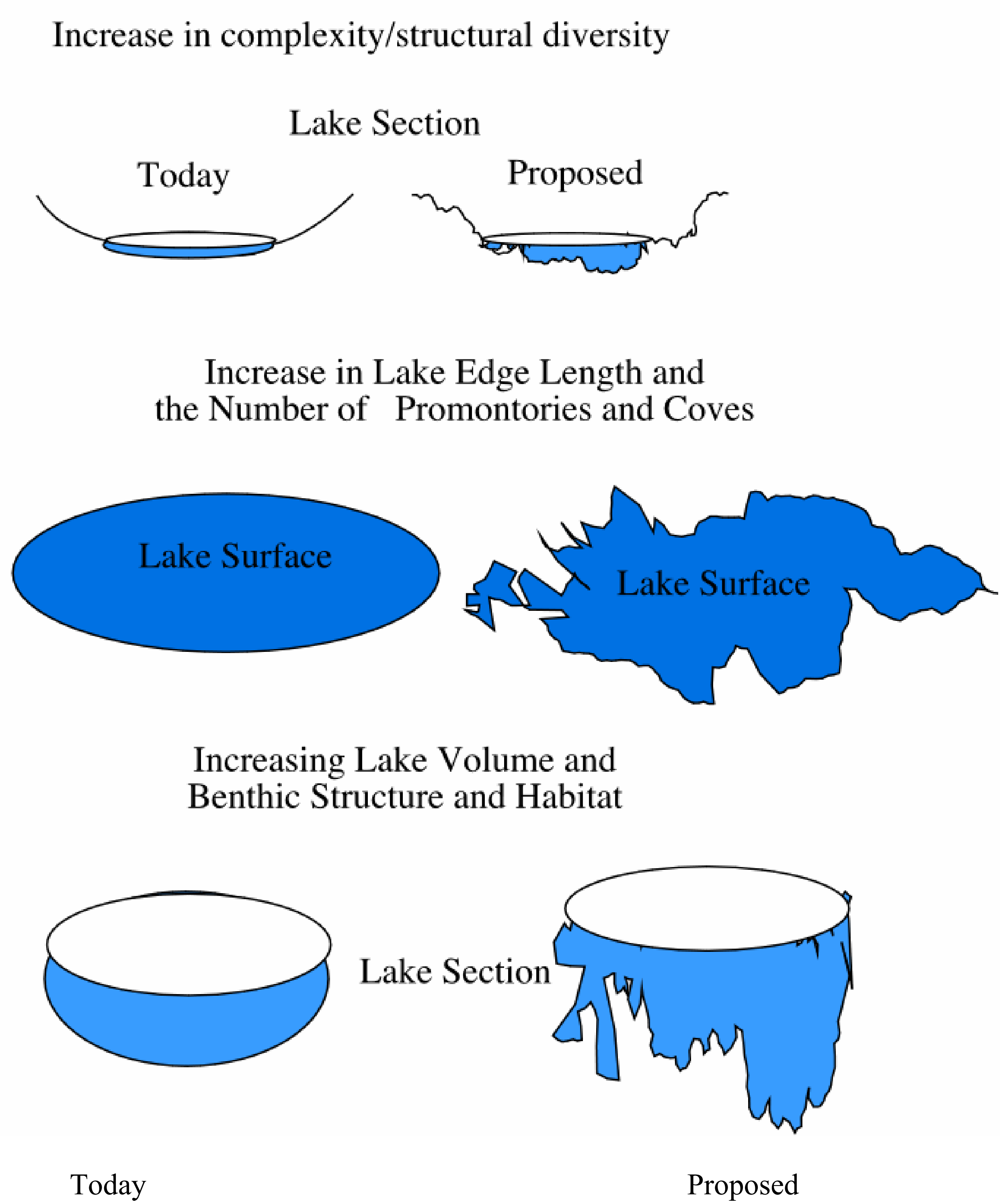
Strategies to enhance ecosystem services would require the increase of structural complexity of the land, an increase of the areas where the land is "complicated" instead of "simple" (i.e., native plant communities instead of lawns), and increase water holding capacity. This provides straightforward directives for any ecological development in and around Flushing Meadows.

Techniques to increase ecosystem services and biodiversity require the creation of variegations in the landscape: berms, wetland hollows, terraces, wet meadow water storage areas, and deep organic soils amongst tree and shrub plantings. Individually, these structures need not be large, but together must be scaled to capture, store, and treat storm runoff for each watershed section.

Incorporating ecosystem services in future plans

Ecosystems support a diversity of organisms. As landscape features, green areas often increase the value of real estate. Natural areas offer what is called "passive recreation," a catchword for the deep, often profound aesthetic and empathetic connections with other beings and Nature, writ large. Beyond these contributions, natural systems also clean air and water and protect human health. Because there are always costs associated with human technologies aimed at similar ends, these latter behaviors are now termed "ecosystem services," since they embody value for all of us, yet their primary maintenance cost is the adequate provision of those resources necessary for plant growth and development.

The Geometry of Ecological Enhancement



Each tree leaf, rootlet, and soil crumb in and around Flushing Meadows literally filters the air and water of toxic chemicals, pathogens, and particulate matter. Present human health protection by the natural systems in Flushing Meadows is real, and, in a number of areas, measurable. However, the extent of such natural capacities is limited by the area, structural diversity, and mass of the natural systems themselves[iii], much as the capacities of our lungs, kidneys, and livers are constrained by their surface area, structure, and size. For future development of Flushing Meadows, the question that must be asked is, "what level of health protection is the Flushing Meadows watershed capable of providing for surrounding human communities under alternative scenarios of development that incorporate ecological communities?" Plans that incorporate the largest and most diverse natural systems are likely to produce the greatest human health benefits.


The variegated structure of the kidney is analogous to that of natural soil and plant filters. At one scale, the branching, tubular filters of the kidney are analogous to trees, branching into the atmosphere. At another, the repeated bifurcations look like the multiple branching of fine roots and rootlets, which capture and filter water at and below the soil surface.

Structuring habitat for biodiversity

Each plant or animal has a habitat, a place where it lives, which supports and sustains its life cycle. In the City of New York, and perhaps most especially in Queens County, natural systems are fragmented, especially by roadways, where many if not most of the populations of native plants are 'islands', relics of past distributions or relatively recent plantings. To maintain or enhance the diversity of organisms, as well as the ecosystem services they provide, requires human insight, participation, and various levels of intervention. The good news for Flushing Meadows is that the New York City region is quite rich in species, and there is probably more than enough area for ecological systems to have a major impact on pollutants here.

Ecosystem services are also based on complexity, area, and volume of water-holding habitat. Added to the equation for these contributions, however, is biomass itself, since the quantity or mass of organisms on a site provides the material which houses and supports the sophisticated biogeochemical process chain which breaks down toxins, utilizes nutrients, and sustains the growth of surfaces which sequester metals and capture and destroy pathogens. Ecosystem services are maximized in large, deep, complicated habitats powered by solar energy and stored biomass.

In the landscape fragment that makes up Flushing Meadows-Corona Park, it will be necessary to construct, enlarge and enhance habitat, and restore plant communities, since the area was scraped clean of virtually all plants, animals, and soils in the course of its use as a garbage and ash dump.

Holding stormwater on a mixed-use landscape

Centralization, channelization and acceleration of runoff to pipes and into receiving waters have been at the core of stormwater policy and infrastructure to date. In simple terms, the land has been made impervious, and the laws of gravity have been used to get stormwater off the land as quickly as possible. But channeling stormwater into pipes has greatly diminished or eliminated its movement into groundwater. In most natural systems, other forces are at work, where the surface tension of water pulls this essential fluid into the thousands of pores in each square inch of soil. Gravity works here too, but in a way that improves water quality by moving water into the depths of soil and filtering it along complicated paths tens to hundreds of miles long through earth before it moves as groundwater just a few hundred feet in linear distance into streams and lakes.

Structuring the landscape around Flushing Meadows such that increasing quantities of water are pulled into the soil and held on the land will increase biogeochemical filtration, and enhance water quality in the lakes. Such soil infiltration galleries also sustain the primary medium of plant growth and development: moist soil. By creating different habitat types with this medium, biodiversity can be increased using composted organic materials diverted from the city's waste stream on site. Reestablishing the ecological feedback loop that recycles waste – both organics and stormwater – into resources is, in itself, a strong indication of the sustainability of this program. These impacts can be quantified, both in terms of the influence of organics on water-holding capacity and moisture content of soil, and in the effect of these on plant growth and biogeochemical activity.

Pollutant sinks

Pollutants can be removed by a variety of "sinks" or filters:

1. **Plants** take up quantities of phosphorus, using it as part of the backbone of all DNA molecules, and central to energy use in all cells. Terrestrial plants also remove nitrogen, a building block of all proteins. In wetlands, nitrate is, through a number of steps, turned into harmless nitrogen gas, and bubbled back into the atmosphere.

2. **Soils** rich in oxygen remove much greater quantities of phosphorus than wetlands. In order for soil to work effectively as a filter, however, it must be porous enough not to generate sheet runoff.

The problem to solve is to remove sources and/or create sinks for these nutrients, which, in super abundance, have become pollutants, such that a dynamic equilibrium is reached which can sustain biodiversity and environmental quality goals. Such aims were not considered in the original construction of these water bodies, so their development has been hampered by the lack of humus-rich soils and biologically diverse communities to populate the surrounding areas. Nevertheless, the soil buffers and wetlands that have developed around Willow and Meadow Lakes provide some local biogeochemical filtration of air and water. The landscape and water retention modifications that supported this development clearly led to a substantial increase in ecological productivity and habitat development, compared to the historic ash dump period. But by the measure of the eutrophic quality of the lakes, and often yearly fish kills, their pollutant removal capacity is not large enough to match the inputs.

Along the Willow Lake shoreline, a narrow, dense reed bed has developed probably since the late 1980's, interspersed with trees and shrubs, surrounded by grassy meadows. It is likely that this naturalized area provides substantial nitrogen removal capacity, estimated to be approximately a ton of nitrate removed each year[iv]. Even without a well thought out treatment scenario, the act of capturing stormwater from the roadways and groundwater increased the life support system for terrestrial and aquatic plants. This in turn increased the potential for wildlife habitat, and, to a limited but probably measurable degree, increased the biogeochemical filtration of storm and ground water. However, the relative lack of soil and nutrients in these upland environments has reduced ecosystem growth and development on the surface of this disposal area. The simple addition of humus, plus a diversity of native plantings, offers very high potentials for increasing ecological value by augmenting the structure and function of these natural systems.

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[i] Ecological Engineering: An Introduction to Ecotechnology. 1989. Ed. By W.J. Mitsch & S.E.Jørgensen. John Wiley, & Sons. New York. p 4.

[ii] While there are decades of research on solar inputs into ecological systems, a good, technical compendium of how it all works together is Physicochemical and Environmental Plant Physiology by Park S. Nobel, 1991. Academic Press, San Diego, CA.

[iii] Mankiewicz, PS. 1997. Biological Surfaces, Metabolic Capacitance, Growth and Differentiation: A Theoretical Exploration of Thermodynamic, Economic, and Material Efficiencies in Fluid Purification Systems. *In* Ecological Engineering for Wastewater Treatment, 2nd ed., ed. by C. Etnier & B. Guterstam. 1997. CRC Press, Lewis Publishers, Boca Raton, FL.

[iv] The following studies indicate that between a half a ton and a ton and a half of nitrate can be removed by each acre of above or below ground ecological systems each year. It is estimated that Willow Lake is surrounded by between one and two acres of reed bed, assuming a circumference of approximately 2500 feet, with a reed bed average width of 20 feet. Documentation of capacities of natural systems may be found in the following: Christ, M, Y. Zhang, G.E. Likens, & C.T. Driscoll. 1995. Nitrogen retention capacity of a northern hardwood forests under ammonium sulfate additions. Ecological Applications. 5(3) 1995. pp. 802-812; Groffman, PM, G. Howard, AJ. Gold, & WM. Nelson. 1996. Microbial nitrate processing in shallow groundwater in a riparian forest. Journal of Environmental Quality. 25: 1309-1316 (1996); Starr, JL., AM. Sadeghi, TB. Parkin, & JJ. Meisinger. 1996. Wetlands and Aquatic Processes: A tracer test to determine the fate of nitrate in shallow groundwater. Journal of Environmental Quality. 25:917-923 (1996).

V. STRATEGIES AND TECHNIQUES FOR ENHANCEMENT

Like an English Garden, which is planned to be a place of beauty as it develops over the years through various stages in the life cycles of the plants in the landscape, all strategies that aim to incorporate ecological systems must encourage and plan for their growth and change through time. Rich soils are one necessary component to such planning, but we must also recognize that soils may need to be periodically enriched to support increasing or changing needs of the plant and animal communities they support.

In a world where open space, passive recreation, sports and playgrounds are packed into one park, means need to be found to make sure that parkland can still act as the "lungs of the city" while allowing space for exercise, enjoyment and solitude. The methods and means for integrating different park uses to mutual benefit through the techniques of ecological restoration and engineering are given below.

Ecosystem growth and development

The plant communities in and around the twin lakes have developed to their present state largely over the past three decades. Nutrient, water holding, and seed source limitations are probably the main inhibitors of further growth and development on the land. This leaves a large number of landscaping opportunities to enhance biodiversity and ecosystem services along virtually every linear foot of roadway, degraded soil system, turf grass, and lake edges.

Today, the structure of the natural systems reflects the uniformity of the lakes. This is especially so since the plant communities were reduced to minimal diversity through the period of clearing and building, and then left to develop, on their own, so to speak, without any systematic reintroductions from neighboring areas. Beyond wind blown and bird-distributed seed inputs, little has been done to restore the original species composition or native plant communities on the site.

In general, where there are no immigrations of plants to a site, marginal populations will disappear, displaced by invasive weeds, with seeds continually entering the site from surrounding weed populations. Nor have there been any large imports of biomass in the form of organic matter, compost[i], which would increase the scale of the biogeochemical filter and primary water holding capacitor: the humus that supports plant and ecosystem growth and development.

The future plans for Flushing Meadows-Corona Park should incorporate the methods described below if the park environment is to be substantially improved. These can be implemented one at a time or as part of a master plan, but each will begin to have a positive impact on the park itself.

Wetlands in series

Wetlands have measured capacities to remove toxins and pollutants[ii]. Typical, well-documented removal capacities for single wetlands are given in the table below.

Summary of North American Wetland Treatment Systems
Operational Performance: Surface Flow

	Concentration (mg/l)			*Mass (kg/ha/d) b*		
Parameter	**In**	**Out**	**Eff.%**	**Load**	**Rem**	**Eff.%**
BOD (5 day)	30.3	8	74	7.2	5.1	71
TSS (total suspended solids)	45.6	13.5	70	10.4	7	63
NH4-N	4.88	2.23	54	0.93	0.35	38
No2+NO3-N	5.56	2.15	61	0.8	0.4	51
Organic nitrogen	3.45	1.85	46	0.9	0.51	56
TKN- (Tot kjeldahl nitrogen)	7.6	4.31	43	2.2	1.03	47
TN- (Total nitrogen)	9.03	4.27	53	1.94	1.06	55
ORTHO-P	1.75	1.11	37	0.29	0.12	41
Total P	3.78	1.62	57	0.5	0.17	34

Kadlek and Knight: Treatment Wetlands, CRC Press, p 731 .

These values are for single wetlands. Coupled wetlands, and wetland plus soil buffer systems act to multiply removal efficiencies. In most cases, these capacities are described in terms of quantities of pollutants removed per area of wetland per unit time, and in terms of the ratio or percentage of removal, input concentration divided by output concentration.

The opportunities offered at Flushing Meadows allow a dual approach to utilizing these pollution removal abilities:

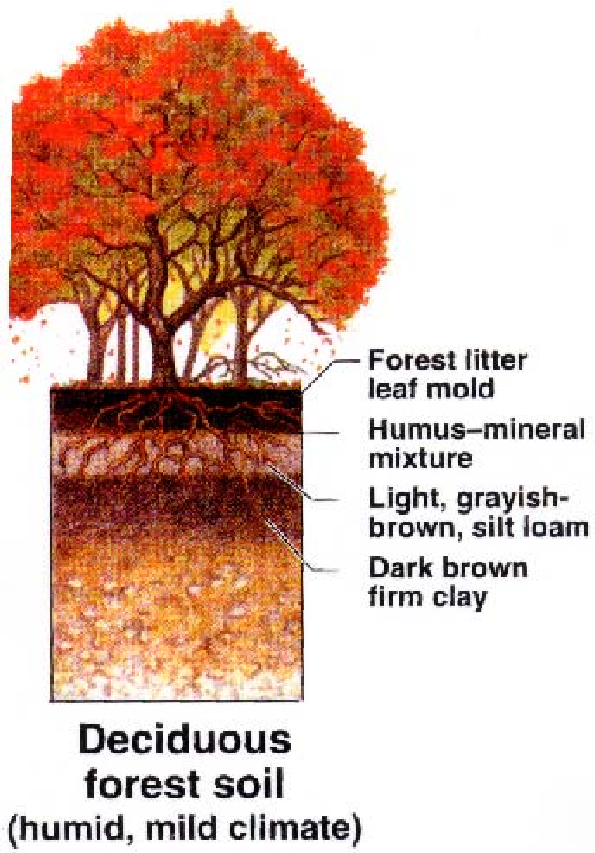
1. By measuring loads or input quantities around the twin lakes, it becomes possible to use potential loadings to specify the area and configuration of wetlands required to remove 50%, 90%, or 99% of these inputs.

2. By taking the known values for lake eutrophication, it is possible to determine how large a wetland (and soil buffer) complex would be needed to remove specific quantities of pollutants and sustain water quality in the lakes.

In practice, integrating both of these approaches will make it possible to create a testable, verifiable framework for ecological engineering of natural systems to meet water quality goals in Flushing Meadows.

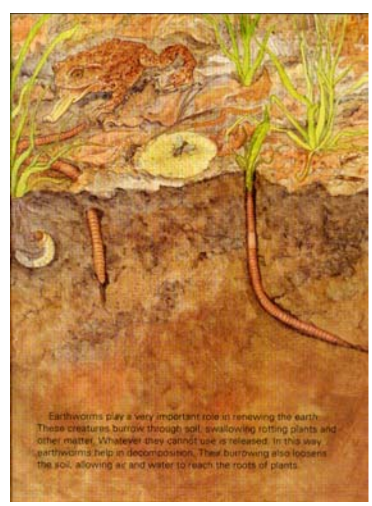
Increasing biomass to improve soil quality

As moist surfaces, plant leaves filter particulates from the air. Below ground, plants are even more active. Beneath a dense coverage of forest vegetation, a “rhizosphere,” or root zone, literally weaves itself together. More than two linear miles of fine roots can be found beneath every square yard of forest soil, along with billions to trillions of microbes associated with these plant roots and the physical-chemical environment of the soil[iii].



Tree roots, worms, and burrowing animals all keep the soil porous, rich, and supportive of life through maintenance of an organic layer.
Schmid, E. 1994. The Living Earth. North-South Books. (above)
Miller, J.E. 2000. Living in the Environment. 11th ed. Brooks/Cole.

Macro-pores are created in soil by roots and burrowing animals. Root hairs and microbes together elaborate an immense surface area of some ten square feet of biological surface beneath a single square foot of landscape[iv]. The porous, air-filled sponge-like soil so created below the forest floor is ecologically engineered by the activities of organisms to support their further growth and development. These same features positioned around human built infrastructure can purify water and air, and incorporate runoff in groundwater and nutrient-rich sediments in soils and plants so as to increase local ecological productivity and biodiversity.



Controlling Erosion

One year ago, the cover of *BioCycle: Journal of Composting and Organics Recycling* read: "Controlling erosion: Why compost and composted mulch are winning the battle to stem erosion and revegetate even the toughest of scarred slopes"[v]. The reason for the optimism regarding the seemingly intractable problem of increasing erosion around impacted landscape lies in results of more than five years of testing composted organics as a cost-effective means to bring highways into compliance with water quality regulations. While Flushing Meadows faces exactly this difficulty, it is seriously compounded by thousands of visitors and multiple land use, disturbance, and compaction problems within the park. All of this has translated into erosion and runoff, increased sedimentation in the lakes and decreased water-holding capacity on the land. While pathways, desire lines, connections between park entry, parking zones and use destinations will need to be integrated into any soil rebuilding and revegetation program, the key element to restoring ecological systems in the park is integrating park use with the addition of organic matter, humus, which can be cost effectively incorporated to increase biomass and biodiversity by diminishing or eliminating erosion and compaction.

Compaction and subsequent erosion prevent the establishment of permanent, healthy ground cover.

Increasing biomass to improve infiltration

Potentials for ecological engineering are set by local and regional hydrology and geology, together with land use and modifications of these by human activity. In Flushing Meadows, of glacially deposited materials provide a highly porous subsurface environment allowing for high stormwater infiltration rates. Urban fill covering the meadow, by contrast, has, in many areas, become compacted. Prior work of the Gaia Institute suggests that infiltration rates into urban fill can be multiplied by adding thick compost with shrub plantings, which can greatly increase water flow into the subsoil and groundwater.

For example, a community of blueberries and other shrubs planted on a foot and a half of compost over construction and demolition debris, increased infiltration rates of an inch or less per hour to between one and two feet per hour – more than enough to absorb the rate of rainfall produced by Hurricane Floyd.

Plantings on compacted soil next to a foundation with negligible infiltration have come to support vines twenty to thirty feet long. Through ongoing mulching with compost and wood chips, a strong organic horizon has developed, with multiple worm burrows (≥50 per square foot) and infiltration rates of several inches per hour.

Such relatively simple ecological engineering steps could transform infiltration and water holding capacity in and around Flushing Meadows. The addition of a new soil layer will start the natural processes of incorporating the compacted ash and cinder substrate back into the cycle of water and nutrient flows.

Within months, this 18" thick topsoil layer (pictured above) had produced a healthy rhizosphere on top of heavily compacted construction debris. The infiltration rate of the soil was also increased dramatically. This project, by the Gaia Institute, continues to be monitored for its on-going effectiveness. The photograph at left shows the macropores which formed at the edge of the boulder, in the left corner, which was rolled back to take this 'snapshot' of below ground activity. The quarter placed at center left for scale shows that roots and worm borrows have reached a scale of 1/8" to 1/4", providing for rapid infiltration, and the dark humus in the picture providing high water holding and moisture retention capacity.

Ecologically engineered surfaces

Ecologically engineered surface and subsurface features, from wetlands, ponds and creeks to porous gravel or wood chip paths and parking lot foundations, are needed to connect upslope water sources with water holding and conducting areas to bypass and eliminate overland seeps and erosion rills and gullies. This can be accomplished by integrating water conveyance and water holding landscape features to diminish wetness around road and path foundations, which should also decrease damage to park infrastructure and reduce potential liability.

The difference between urban runoff problems and habitat lies in sustainable natural structures. A mallard and her ducklings can just be seen in the dark shade at center right in the photo at right, under the grassy overhang. Eighteen months ago, this wetland was a blacktopped path. Constructed largely by school children, interns, and community members working with the Gaia Institute and the NYC Parks Department, this former asphalt surface now contains a coverage of 22 native species, with about 300 individuals shoots and 170 colonies.

Design can turn a runoff and erosion problem into a valuable landscape feature, as in the wetland (below) constructed by the Gaia Institue and NYC Parks, which increases biodiversity while enhancing environmental quality.

One method for creating stormwater treatment and edge stabilization is with timbers for terracing and eastern white cedar plantings (below right).

Coupling recreational areas with natural filters

The single most important area for water purification may be directly adjacent to infrastructure, since impervious surfaces are sources of stormwater runoff, and often, of air pollution. Parking lot, path, and road edges can be designed to capture and biogeochemically filter stormwater, an approach that has documented success at an increasing number of sites[vi]. As the robustness of scientific backing grows, together with pressures to capture stormwater and surface pollutants, municipalities and agencies responsible for the impacts of infrastructure around the country and the world are turning towards vegetated soil buffers and wetlands to capture precipitation before it creates erosion and pollution problems. By treating water near where it falls, this approach has the added advantage of minimizing runoff, and, therefore, the size of detention basins such as the $300 million sewage tank under construction in Flushing. If several linear miles of roadway edges had been coupled with water capturing green buffers, this project might have been scaled down or made unnecessary. In any case, diverting as much stormwater as possible from the treatment plant will greatly increase its efficiency in removing pollutants from Flushing Bay.
A critical element in improving ecosystem services in Flushing Meadows-Corona Park is the coupling of active recreation areas with ecological enhancement. Specifically, the recreational amenities in the park could become functional components of the ecosystem, as described:

1. ***Triassic and Jurassic Parks:*** These areas are now surrounded by standard fencing, pathway infrastructure, and turf grass. With directed effort, these wonderfully imaginative playscapes could be surrounded with organisms that are direct descendants of plants that were alive during the age of dinosaurs. Wetlands and moist soil buffers could be created around Triassic and Jurassic Parks to provide habitat for horsetails, clubmosses, and ferns, with full-scale models of the Triassic and Jurassic ancestors of these living relics. Small children and their parents could come to see how the wastes of the dinosaur age were cleaned up by plants and wetlands between 245 and 144 million years ago, just as our own wastes and non-point pollutants can be removed by well designed wetlands and soil buffers, using modern relatives of these ancient organisms.

2. ***Ball fields***: Because of the proximity of the land surface to the water table, the distance required for a recycle pump to move ground or lake water for irrigation through the root zone of the outfield grass is not great. A solar driven system could thus treat groundwater and/or lake water in the process of irrigating playing fields. Beyond allowing for much more intensive use and higher quality turf, the use of the fields as a water filter could demonstrate how active recreation uses like baseball and soccer could be coupled with the aims of improved environmental quality. Given the nutrient status of runoff and lake water, recycling lake or stormwater through turf grass could make fertilizer addition unnecessary.

3. ***Model airplane field:*** Here, the impervious area required could be coupled with thickly vegetated rich soil infiltration galleries at the edges, or potentially in "vegetated islands" to create a zero-discharge zone for stormwater runoff around the model airplane facilities, a worthy model for airports of all sizes.

Together, the constraints of existing infrastructure may be taken as a proper challenge to standard notions of park design. Ball fields can function to both support our best athletic efforts and to clean water. Specifically, the conflicting goals of good drainage to avoid flooding or ponding may be optimized so turf grass in playing field areas are not killed during times of drought, since good drainage puts grass cover at risk during low water periods. Scoreboards and subsurface ground water irrigation systems could be designed to run from energy generated by solar collectors, which could again be a project of local schools, colleges, little leagues, and other park users.

Theme parks such as Disney World and Busch Gardens have attempted to portray their activities in an environmentally forward-looking context, with advanced natural water treatment facilities and similar programs. Triassic and Jurassic playgrounds could be supported to grow into functional and educational features, demonstrating how natural systems have recycled wastes in the long term, and how the living relatives of ancient organisms are still at work in the modern world, supporting human populations, much as their ancestors supported and contributed to life in the Triassic and Jurassic periods.

Transforming the ratio of soil and wetland filters to match inputs

Soils and wetlands filter or sequester pollutants and nutrients in different ways. The size and distribution of these natural buffers in and around a lake is usually a matter of geological history, but human modifications of the landscape have changed virtually all the surface features around Flushing Meadows. Because of this, the ratio of meadows, shrublands, forests and wetlands to stormwater inputs and lake volume is an accident of recent history. Restoration efforts, however, could change watershed and lake characteristics to better serve water quality and biodiversity goals.

We know that the load of nitrate can be one to two parts per million in stormwater runoff, and also that wetlands and soils are capable of removing variable quantities, from part of a ton per acre per year in certain wetland environments, to tens of pounds per acre per year in productive soils[vii]. This allows an estimation of how large natural systems would need to be in order to remove pollutant loads.

If wetlands alone were used to remove nitrate (NO_3) it would be necessary to divide the total inputs by expected removal rates. The spreadsheet below shows minimal to maximal expected removal from wetlands, from a hundred pounds of NO_3 removal per acre per year to a ton and a half of NO_3 removal per acre per year.

Water input to 6 sq.mi watershed (In cu.ft.).	Water input (In pounds)	Nitrate mass loading (in pounds) (NO_3 concentration of 1 ppm)
167,270,400	10,437,672,960	10,438

Wetland acres to remove NO_3 load at 100 lbs./acre/yr	Wetland acres to remove NO_3 load at 1/2 tons/acre/yr	Wetland acres to remove NO_3 load at 1.5 tons/acre/yr.
104 acres	10 acres	3 acres

Increasing exposure to filter area

In the porous glacial materials on the hillslopes, inputs to groundwater could readily be increased by a factor of two or more, if more stormwater could be brought into contact with the porous material from the impervious surfaces. If, at the same time, lake sediments were removed by dredging, a large source of pollutants would be eliminated, increasing lake water quality in the process.

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[i] Not since the peat moss, mulch and topsoil brought in by Robert Moses for the 1939 Worlds Fair, and relatively smaller projects since, has any quantity of organic matter be brought into Flushing Meadows. See Moses, op cit.
[ii] Kadlek, R.H., & R.L. Knight, 1996. Treatment Wetlands, CRC Press, Lewis Publishers, Boca Raton, FL; Mitsch, W.J. & J.G. Gosselink. 3rd Ed. 2000. John Wiley & Sons, Inc. New York.
[iii] Wood, T.E. 1980. Biological and Chemical Control of Phosphorus Cycling in a Northern Hardwood Forest. Yale University Thesis. Jackson, R.B., H.A. Mooney and E. D. Schulze. 1997. A global budget for fine root biomass, surface area, and nutrient content. Proceedings of the National Academy of Sciences Vol. 94: 7362-7366.
[iv] Jackson et. al. 1997, above cite, provide data for temperate forests and other ecosystems in the global biosphere, indicating the immense global and local role of roots and the rhizosphere in global material cycles.
[v] BioCycle. January 2001. Vol. 42, No.1. Cover articles on pp 26-33. Earlier on the learning curve is an issue of BioCycle featuring “Compost on the Highway”, BioCycle. July 1997. Vol. 36, No.7: pp 75-80. “State Transportation Departments Expand Compost Use”.
[vi] The use of such natural systems to control stormwater and non-point pollution is documented in a number of scientific literatures, including solid waste recycling. Recent articles include two from BioCycle: Tyler, Ron. 2001. Compost filter berms and blankets take on the silt fence. BioCycle. January 2001: pp 26-31. Organics in Action: Composted Woody Materials Become Erosion Control Product, BioCycle. January 2001: pp 32-33.
[vii] Christ, M, Y. Zhang, G.E. Likens, & C.T. Driscoll. 1995. Nitrogen retention capacity of a northern hardwood forests under ammonium sulfate additions. Ecological Applications. 5(3) 1995. pp. 802-812; Groffman, PM, G. Howard, AJ. Gold, & WM. Nelson. 1996. Microbial nitrate processing in shallow groundwater in a riparian forest. Journal of Environmental Quality. 25: 1309-1316 (1996); Starr, JL., AM. Sadeghi, TB. Parkin, & JJ. Meisinger. 1996. Wetlands and Aquatic Processes: A tracer test to determine the fate of nitrate in shallow groundwater. Journal of Environmental Quality. 25:917-923 (1996).

VI. USING THE OLYMPIC PROGRAM FOR ENVIRONMENTAL ENHANCEMENT

Many projects fail environmentally because the fundamental criteria of ecological enhancement – energy flow, material cycles, natural systems development, and biodiversity – are not integrated into the planning process from the onset. This can readily be avoided in the Olympic rowing program if specific ecological enhancement goals for the watershed, park, and lakes permeate the planning and design process.

The specific steps that will be necessary include addressing the size of wetlands and their drainage areas, as well as the functional capacities and biological diversity of wetland and upland habitat and buffers. Details such as the richness of the soil in the watershed must be addressed, since upland soils in and around Flushing Meadows are presently depauperate. The opposite problem exists in and around the lakes, where the nutrient rich sediments degrade the aesthetic and ecological value of the water bodies. Park and lake design will have to take a new turn, since the pastoral smooth curves of the great 19^{th} century parks do not generally work ecologically, and probably cannot work in Flushing Meadows. Floating garbage cannot continue to be an acceptable by-product of stormwater catchment. Nor can public exclusion from the quiet, naturalizing landscape around Willow Lake remain an acceptable land use. We learn best through encounters with what is close to our day-to-day lives, and in this context the NYC2012 proposal should join forces with educational interests – from grammar schools, to colleges, to museums of science – to realize and enhance the learning potential of what we have made of Flushing Meadows.

Given the intrinsic aim of producing an ecologically sustainable, low nutrient water body surrounded by a mosaic of native plant communities, soil buffers, and biologically diverse, productive wetlands, there is no essential conflict between the goals of NYC2012 and environmental quality. In fact, in this instance, given the history of landfill and ash dumping, as well as the high nutrient sediments at lake bottom left from thousands of years of marsh growth, there are many potentially fruitful restoration steps and enhancement scenarios which could increase biological diversity and ecosystem services that are only likely to be taken with the kinds of funds available for developing the park for Olympic use.

Opportunities and constraints are best evaluated in the context of prior impacts on Flushing Meadows. The hydrology of the area was entirely changed prior to construction of the World's Fairs. Robert Moses himself may be said to have increased the hydroperiod, or the amount of time water was held on the site prior to discharge into Flushing Bay, by creating Willow and Meadow Lakes. These lakes were designed to receive and hold stormwater runoff from the Grand Central Parkway and are scaled such that they keep water on the site for an average of about two- to two-and-a-half months.

While such water retention goals are often worthy, in this case it was not connected to a means for enhancing the ecology of the area in terms of size or structural diversity of wetlands. Potentials for beneficial changes are thus enormous, since the stormwater spends minimal time on the land, and the lakes and surrounding landscape are simple structures not designed to increase contact between pollutants and natural filters. In this context, were it to be conceived and executed according to strict performance criteria, the Olympic proposal would represent the largest and best potential investment in the ecology of Flushing Meadows on the horizon.

The Olympic Rowing proposal

The design of the 2,000-meter rowing course proposed for use during the Olympic Games has been environmentally engineered by the Gaia Institute to more than quadruple the acreage of productive wetlands and dramatically expand natural habitats. In order to be used for competition, the lakes must also be deepened below the racing lanes to a depth of 3.5 meters, and the necessary dredging will remove many of the nutrient-rich sediments that contribute to the poor water quality of the lakes today.

The Olympic Rowing proposal necessitates radical and dramatic water quality improvements at several levels. Local and regional interests support the conservation of valuable habitat and the elimination of fish kills and odors in the Twin Lakes and their surroundings. The U.S. and International Olympic Committee are increasingly committed and demanding of real, as opposed to apparent, environmental quality standards. World-class athletes in rowing also bring their own high standards, which are not likely to be met by the lakes in their present condition. In the past, water quality has been momentarily improved with short term chemical treatments, as was done to improve the appearance of the water for the 1964 World's Fair, or by high powered bubblers to oxidize sediments as has been done for some prior Olympic rowing events. These approaches do not produce sustainable improvements, and therefore will not attain the legacy of permanent environmental quality enhancement sought by the International Olympic Committee.

Finally, the increased recreational use of the water is not inherently at odds with environmental enhancement. Rowing is in many ways a sport aimed at minimizing impacts: boat are designed with shallow draft and smooth skins to shear and glide over the very surface of the water with little wake. Trained rowers slice oars into water, and aim to eliminate turbulence and splash with each entry and return. Speed comes from quiet strokes, that leave the water as calm as possible. It is perhaps then not surprising that mergansers, buffle heads, black ducks, and rafts of brant, amongst others, are often within 50 meters of the sculls in Pelham Bay Lagoon. A number of the rowers here have even described this closeness to wildlife in Pelham Bay as one of the attractions of their sport here.

Incorporating Environmental Concerns

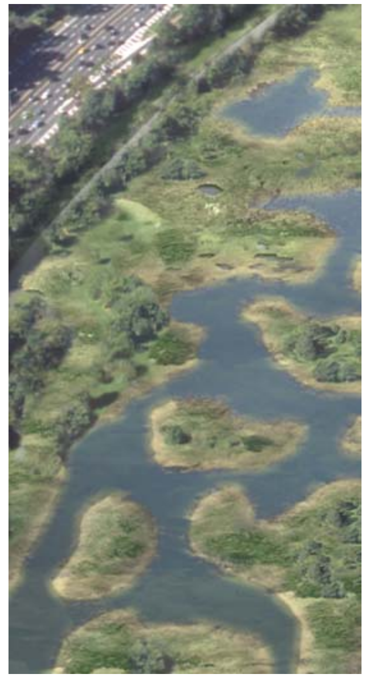
Below are specific techniques that can be incorporated into the NYC2012 proposal to ensure that it not only benefits the Olympic rowers, but the environment of the park as well. Many have already been incorporated into the preliminary design through the extensive input of the Gaia Institute.

Increasing wetland size

While the twin lakes hold water for two to three months before discharge into Flushing Bay, the roadways, paths, parking lots and lawns hold water minimally, discharging during or shortly following a storm event. For every acre of impervious area, a meadow with deep soil about a hundred feet long and thirty feet wide would be needed to capture, treat, and infiltrate the runoff. The shape, size, and depth could be varied to meet local aesthetic and land use patterns, but the scaling of catchment to runoff is necessary to reach performance criteria in ecological engineering, and, specifically, the ratio of runoff to catchment area provides the physical and geometric requirements for clean water production.

The twin lakes today are rimmed by about 15 acres of low diversity wetlands, which remove a substantial quantity of pollutants. The ring of common reed, however, is positioned to only intercept a limited proportion of flow into Willow Lake. The NYC2012 program, however, could expand the wetland areas substantially in both lakes, providing 80 to 90 acres, or increasing coverage by some 500%. Placed strategically to intercept runoff, this wetland buffer area would be sufficient to handle runoff from 1,250 acres of impervious surface – or at least 50% of the entire watershed. At the same time, soil buffers and wetlands could be positioned to intercept a much larger proportion of stormwater from the surrounding landscape. All of this can be physically accommodated along with the Olympic Rowing proposal.

Creating archipelagoes and wetlands in series

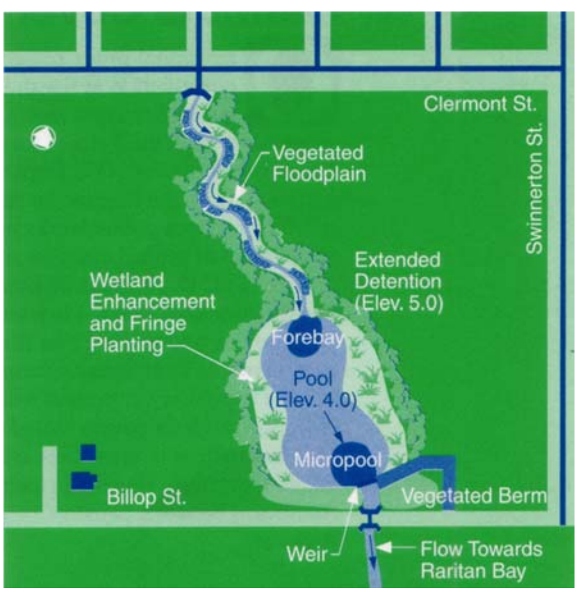


The Gaia Institute design framework for the rowing facility in Flushing Meadows incorporates an integrated mosaic of landscape and wetland features, including a series of spits of land, terraces, and soil berms creating multiple wetland cells. The land connecting and dividing these wet areas provides landscapes for groups of terrestrial plant communities, from sweet gum and red maple swamp forest to Atlantic white cedar pools, wild rice meadows, shrublands, and water lily ponds. Connecting the two lakes in this context can increase habitat types by coupling deep-water environments with a greatly increased number of shallow water and littoral habitat types.

By filtering stormwater through an alternating series, i.e., soils-wetlands-soils-wetlands- soils, the removal capacity of these systems is increased dramatically. Water passing through a single wetland prior to entering lakes and ponds has approximately 50 –90% of nitrogen, heavy metals, and pathogens removed, depending on hydroperiod. The wetland series proposed in the NYC2012 plan would pass that same water through three to four cycles before allowing it to enter the twin lakes, removing approximately 90 to 99% of nitrogen, phosphorus, heavy metals, and pathogens. Removal rates are likely to be even higher as the natural systems develop in and around the wetland cells.

Daylighting stormwater pipes

Re-opening or daylighting the buried streams in underground pipes and culverts that channel water directly in the twin lakes will have two major benefits. First, it will allow nature to filter the water with plants, soil and sun. Second, it will allow the restoration of more natural landscape features, instead of the concrete bulkheads that grace Willow Lake today.



The typical stormwater pipes that dot the edge of Willow Lake today (above) could easily be replaced with a much more ecologically beneficial treatment. Stream, floodplain, and wetland restoration projects, such as the one proposed at Conference House Park on Staten Island (plan pictured at left) provide the most cost effective means of increasing environmental quality by creating habitat and protecting natural resources.

Enhancing wetland quality

In addition to increased filter area, the NYC2012 proposal could incorporate more efficient filters. By incorporating some of the existing *Phragmites* in more diverse wetland communities, replacing areas of invasive *Phragmites* monoculture with a mixture of native plantings, the structural diversity and habitat value of the wetlands will be substantially enhanced. Tree and shrub plantings should also increase the depth of the biogeochemical filter on this site. A literature review is presently underway to evaluate the contribution of structural diversity, soil diversity, and species diversity to biogeochemical filtration capacity.

Adding a humic layer

The NYC2012 proposal includes re-landscaping the park as a means of enhancing its aesthetic value and improving its sustainability. A new humus layer a foot and a half thick and the restoration of pore spaces in compacted subsoils would allow these below ground features to support ecosystem function. Infiltration capacity would likely increase from present negligible rates (0 to 1/2 inches of runoff per hour) to a foot per hour or more. While testing of existing soils will be required (and has been initiated) to accurately evaluate and predict results, the application of a humic layer over compacted urban fill has achieved similar results elsewhere in New York City and around the country.

Adding a fresh topsoil layer, like this one shown earlier, could bring the compacted soil around Meadow and Willow Lakes back into the ecosystem of the park, while also reducing flooding and enhancing biogeochemical filtration.

Contaminant removal through dredging

The NYC2012 proposal requires dredging to depths necessary to accommodate the 2,000-meter rowing competition. By removing sediments, the primary source of phosphorus will be removed. If layers of sediment-free sand lie beneath these, or if such a material is used to cap deeper sediments, this source of phosphorus for the lakes can be removed or greatly diminished. Tests of the exact depth of the nutrient-rich sediments, presence or availability of clean sand or another appropriate “capping” material, and ecologically sound methods for moving and removing sediments are critical elements in the solution to the undesirable eutrophic condition which prevails in the twin lakes today.

The cores from Willow Lake pictured above are 2.5” in diameter and 18” to 20” long.

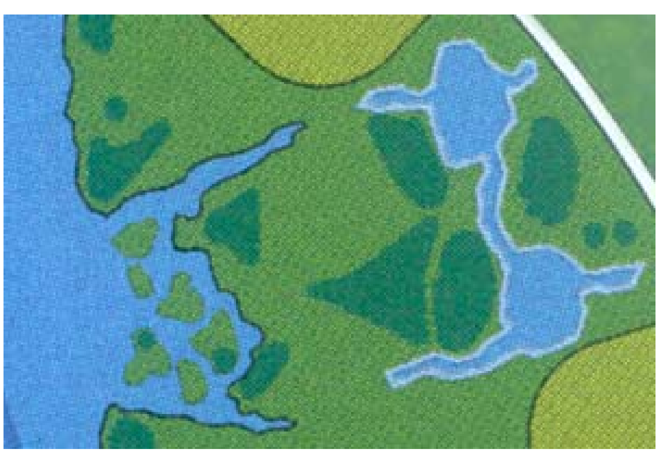
Ecosystem growth and development

Three critical steps are included in the NYC2012 proposal that are necessary to increase or enhance structures to integrate multiple natural and ecologically engineered filters. These are essential to achieve aesthetic and environmental quality goals, particularly when the lake volume is increased.

1. **Ecological mosaics in variegated upland terraces,** water features, shore and near-shore habitat. Water catchment structures stepping down slopes and around roads, walkways and thoroughfares can capture water on the land and treat it in multiple vegetated cells prior to release into the lakes. Such multiple modules are the optimal means of maximizing water filtration and purification while providing habitat for wildlife, including migratory and nesting birds.

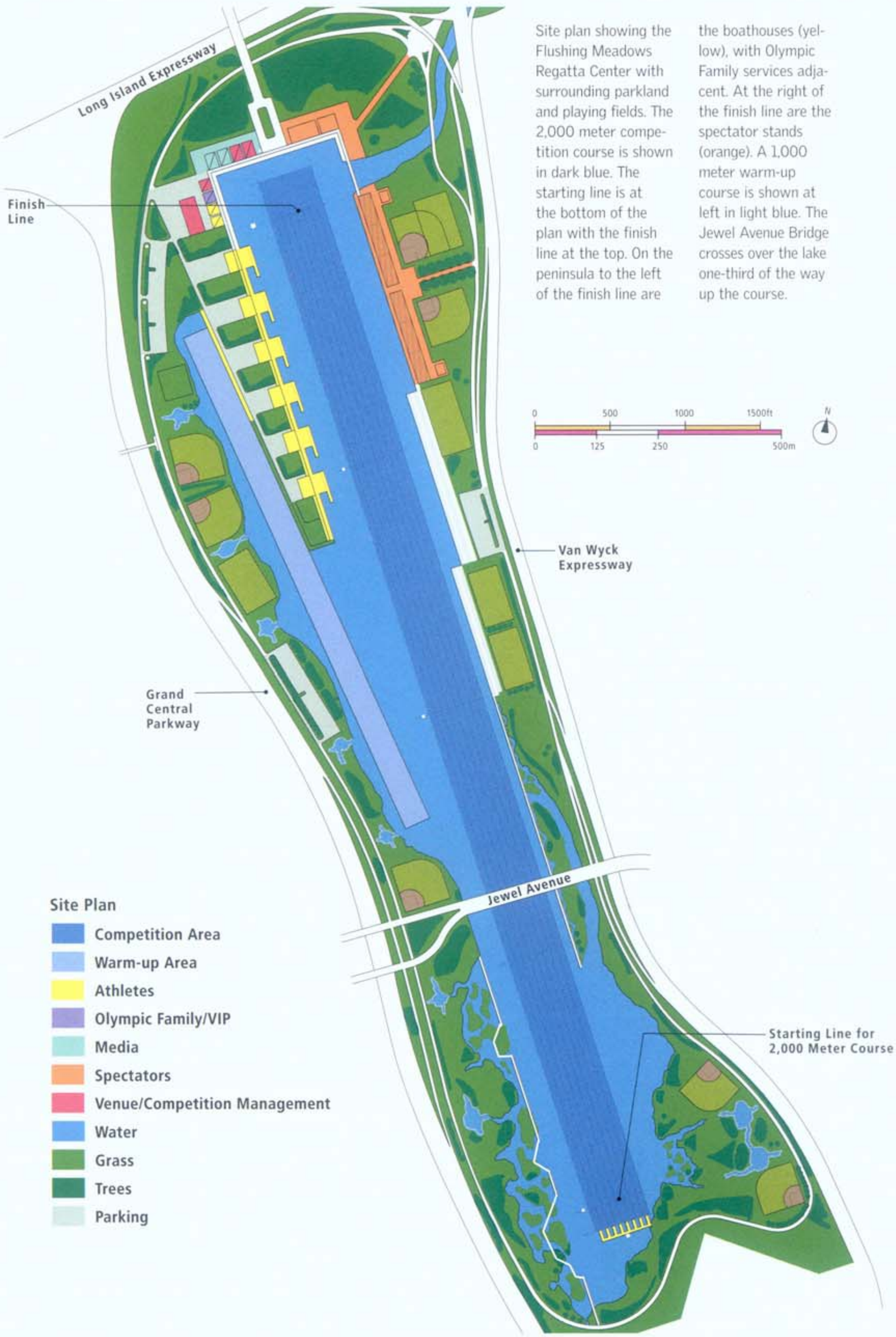
2. **Open creeks, wetlands, and water features and soil berms for stormwater runoff**. Daylighting underground bodies of water and exposing them to the sun and air can replace buried culverts with biogeochemically powerful yet aesthetically pleasing biofilters. The path of stormwater can be filtered first through coarse rushes, sedges and cattails to remove major pollutants, sediments, and suspended solids. Downstream, water-lily gardens, white cedar bogs and pools, meadows of marsh mallow and cardinal flower, shallows of wild rice, edges of native iris and deltas of arrowhead may be used to achieve wildlife support and aesthetic goals which are far beyond the developmental capacity of the lake system as it is presently structured.

3. **Garbage catch-basin systems.** Trash migrating from the land must be stopped before it can enter the water at all drainage points from highways and city streets. Each storm pipe should be identified with signage and a map of its drainage watershed or catchment area. The size and land-use pattern of these areas should be used to determine maintenance and cleanout schedules. Coupled with an educational program within the watershed of each catch-basin, this approach can clearly demonstrate to the public that a portion of the Styrofoam cups, soda cans, straws and plastic bags dropped on a specific block are inevitably delivered as garbage to a particular part of the lake, diminishing the value of the park for visitors here.



A shallow stream bed under construction in Blue Heron Park will reduce flooding and erosion, much as the daylit wetlands will in the Olympic rowing proposal.

Rowing: Site Plan



Site plan showing the Flushing Meadows Regatta Center with surrounding parkland and playing fields. The 2,000 meter competition course is shown in dark blue. The starting line is at the bottom of the plan with the finish line at the top. On the peninsula to the left of the finish line are the boathouses (yellow), with Olympic Family services adjacent. At the right of the finish line are the spectator stands (orange). A 1,000 meter warm-up course is shown at left in light blue. The Jewel Avenue Bridge crosses over the lake one-third of the way up the course.

Human access and environmental education

The surrounding communities, educational facilities, neighborhoods and visitors to the park are the ultimate barriers against ecological degradation in Flushing Meadows. Human beings are known to protect what they know and love. By enriching the experience of neighboring community members and school groups by designing inroads and pathways around the waterways, marshes, meadows and developing forests, those of us who walk around the south end of the lake can learn to mark the seasons' arrivals and departures of kinglets, warblers, and thrushes. Naturalists and parents can teach young people how to watch the comings and goings of mergansers and grebes without disturbing these fishing birds.

The proposed boardwalk in the NYC2012 plan across "marshes" and "archipelagoes" can allow for observation while also creating habitats presently non-existent where *Phragmites* dominates the existing shoreline. By keeping park visitors at a safe distance, wildlife habitats can be left undisturbed. Nearby educational facilities can themselves become centers of habitat restoration and study, focusing the curriculum on plantings attractive for specific groups of birds, reptiles, amphibians, and fish. Projects to make wildlife habitat from old logs, timbers, bark, bird houses, and other structures could also become an ongoing feature of curricula in surrounding schools, from pre-K to Queens College. By such steps, it may be possible to make Flushing Meadows a richer habitat for human beings and their neighbors, including an increasing number of species.

The Olympic rowing proposal would incorporate six new boathouses for recreational use by the public, high schools, colleges and universities. At the same time, the natural areas to the south will be accessible only by a raised boardwalk, allowing public access with limited disturbance to wildlife.

VII. CONCLUSION: EXPECTED RESULTS

Reaching goals, and achieving biodiversity outcomes requires evaluating what natural systems can do to sustain and improve environmental quality, and establishing criteria which need to be met to reach them, as well as specific conservation and restoration steps to get from here to there. Both expected positive results as well as potential negative impacts need to be authentically considered and evaluated. This being said, there is near universal accord on a major problem with urban centers and developments generally: they do not “hold water”.

If the impervious landscape is an enemy of natural system development, to reverse such impacts it will be necessary to create terraces, meadows, and upslope hollows to catch water, and clean it through earthen filters. It is necessary to recognize at the onset, however, that in the dense population center of New York City, parks are and should be attractors of the people, and the education of park users as to the value of native plant communities, soils, natural systems, and proper maintenance to ensure that these green and earthern filters continue to meet performance goals, is necessary to bring a broad based sociology and community ecology together. To nurture these acres of Nature in the City, we must somehow all learn to be caretakers, stewards, even whistleblowers, to make sure that we protect what sustains us all. Only in such a context can the environment come to improve.

Conserving, enhancing, restoring and creating soil and wetland buffers around the twin lakes is expected to decrease pollutant inputs by a factor of ten, and similarly increase plant biodiversity ten fold. While invasive, wind distributed plant species are likely to find their way to the Flushing Meadows area at any time, many native plant population are repressed by the lack of water, nutrients, soils, and seed sources which presently characterize much of the area around the twin lakes.

Water quality improved to swimmable/fishable level

Water quality will improve when pollutants from runoff are diminished, and when the superabundant nutrients supporting algal blooms presently entering lake waters from sediments are eliminated.

Projected increase in habitat diversity and plant diversity

Nutrient-poor and eutrophic environments each diminish biodiversity. Dry environments have many fewer species than temperate landscapes. By adding the primary nutrient regulator in the biosphere, i.e., humic materials in the form of compost, it is expected that habitats can be restored, and thus become capable of sustaining a ten-fold increase in native plant species. This same humic matter is a fundamental regulator of water holding capacity in the terrestrial biosphere. The addition of humus will, in one step, address two of the conditions presently limiting biodiversity in Flushing Meadows: water and nutrients.

Most of the ground coverage around Willow Lake is dominated by three species of invasive plants: common reed, ragweed, and porcelain berry. Approximately 30 species of trees, shrubs, and herbaceous plants make up the rest of the flora, but a number of these are disappearing under pressures from the invasives, especially *Phragmites* and porcelain berry. Native trees, shrubs, and herbaceous plantings will add the individuals and seed sources necessary to sustain biodiversity increases of up to 400 species, or more.

Reduction in runoff added to the city sewer system will complement clean-up efforts underway in Flushing Bay

Lack of water limits plant growth and development in every environment in the terrestrial biosphere at some part of the day or year. In urban environments, water availability follows in short bursts immediately after storm events. Wet areas can be sustained for days to weeks in rainy periods, creating mosquito-breeding habitat in the process. Such periods are inevitably followed by dry, droughty conditions for many parts of the growing season. The addition of water is essential to increase plant and ecosystem growth, and the capture of stormwater in Flushing Meadows could both increase ecological productivity and biodiversity, as well as environmental quality. The creation of permanent water features would also provide habitat for mosquito predators, such as fish, frogs, and dragonflies, amongst others, creating a 'sink' for mosquitoes and their larvae. By holding water on the land, stormwater runoff can also be diminished, thus eliminating some discharge into the combined sewer system, which compromises water quality in Flushing Bay.[1]

Topsoil improvements will enhance plant diversity and increase the health of turf grasses on playing fields, stormwater capture, and biogeochemical filtration

By restoring thick organic soils with native plantings, air and water purification zones would be enlarged and increased in capacity. Humus itself inhibits the growth of fungal infections of turf grass. The addition of humic matter in the form of compost in soils can increase the rate of growth and development of below and above ground ecological systems in and around Flushing Meadows, and could be utilized in more active filtration if recycle water pumps are used to keep playing fields green.

Protecting existing wetland resources

Willow Lake is fringed with wetlands, though they are dominated by the growth of common reed around the lake perimeter. There are, however, patches and edges of native iris, cattails, arrowheads, water lilies, and other native wetland plants. To deepen the lakes for the rowing course will require careful removal of these edge communities in a number of areas, and their replanting elsewhere on the site. Transplanting these organisms will inevitably cause some wetland disruption and damage, but most of the plants should not only survive, but also increase in coverage and biomass in extensive habitat created to meet the depth, light, and soil requirements of each species.

The final lake edge and watershed will, by following these protocols, contain much more wetland area of higher diversity than is presently in and around the twin lakes. Preliminary estimates indicate an increase of wetland area by about a factor of five, i.e., at least five times the existing wetland area. Spreadsheet models are presently under development to estimate expected water quality outputs from differing wetland configurations and sizes. Predicted water quality enhancements based on increases in wetland scale will be used together with topographic considerations to optimize wetland configuration around Flushing Meadows.

To minimize damage to existing habitat, movement of any existing wetland plant communities can be staged for windows in winter months. This could make it possible to transplant existing plants and peat systems during their quiescent phase in large sections with front end loaders and other machinery capable of moving large chunks or modules of the wetland system. In this way, whole communities, including insects, crustaceans, annelids, and other invertebrates, roots and seeds can be “transplanted” as a unit when they are least prone to trauma. Such an approach should act to maintain populations, communities, and even a major fraction of biogeochemical filtration capacity, since a module of the active “system” could be moved and relocated in functional groups.

Connecting a greenbelt-bluebelt of parks and greenspaces

An unprecedented biogeographic opportunity exists in Flushing Meadows and its surroundings to create an extensive, integrated greenway and blue belt, from Alley Pond, Kissena Park, Mt. Hebron and Cedar Grove Cemeteries, Queens Botanical Garden and the Kissena corridor to the northeast and east, Cemetery of the Evergreens and Forest Park to the west and southwest, and Maple Grove Cemetery to the South. If these landscapes became special conservation planting areas with groves and copses of native vegetation, it would be possible to restore centers and corridors of biodiversity in and amongst the parklands and green spaces of Queens and Brooklyn, so that native plant and animal populations would have closer connections between neighboring habitats which could mutually support one another. Thus, the goal of an interconnected Queens-wide and Western Long Island park system could be achieved, to the mutual benefit of those who live in or pass through this landscape.

Conclusion

Based on an investigation and evaluation of existing conditions, the structural requirements for Olympic rowing events, and an extensive redesign of the original plan, we conclude that the present NYC2012 planned rowing course, constructed according to strict performance criteria, would establish demonstrably superior ecological conditions than the no-build alternative. Given the relatively small scale and limited budgets of restoration and enhancement programs in the New York/New Jersey Harbor Estuary at present, it is unlikely that any similarly scaled investment in ecosystem services to enhance environmental quality and biodiversity is on the immediate horizon.

Authorship

Paul S. Mankiewicz, Ph.D.
Executive Director, The Gaia Institute

Julie A. Mankiewicz, Ph.D.
Assistant Professor, School of Earth & Environmental Sciences, Queens College/CUNY
Director of Research & Education, The Gaia Institute

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[1] Even with the new tank on line, limiting the amount of stormwater that “dilutes” the raw sewage discharge will increase the efficiency of this CSO catchment and treatment system.