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.

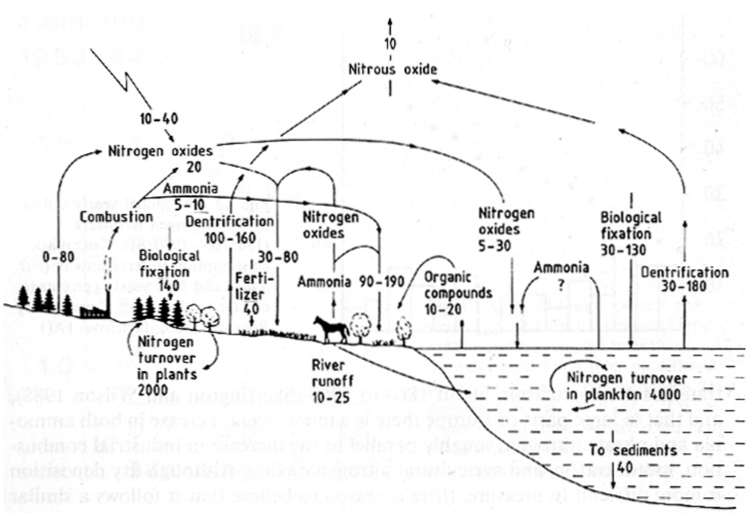
This 19th century engraving of Lake Erie evokes the interdependent cycle of water, plants, and animals. *In:* Kerner von Marilaun, A., The Natural History of Plants, translated by F.W. Oliver, Blackie & Sons, Ltd. 1896.

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.

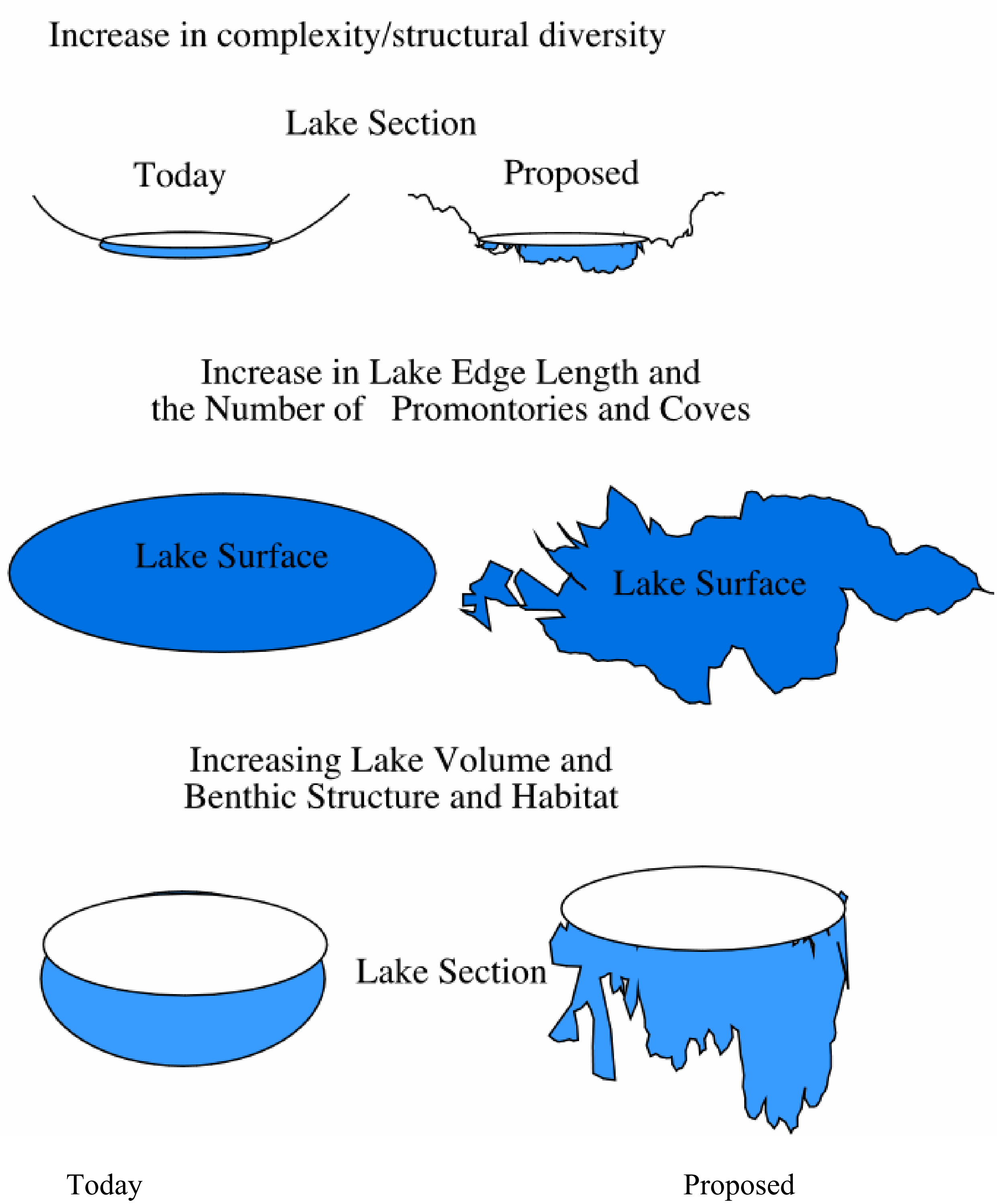
Strategies to enhance ecosystem services would require the increase of structural complexity of the land, an increase of the areas where the land is "complicated" instead of "simple" (i.e., native plant communities instead of lawns), and increase water holding capacity. This provides straightforward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