RiverBend
Greenway and Green Infrastructure Plan

Biohabitats, Inc.
July 26, 2011

I. Introduction to Green Infrastructure within the Great Lakes Region

Green infrastructure is defined widely as "strategically planned and managed networks of natural lands, working landscapes and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations" (The Conservation Fund at greeninfrastructure.net, 2010). This definition includes stormwater management, as well as natural and designed systems including ecological corridors, recreational trails and open space, wastewater treatment, renewable energy systems, and public transportation.

Green infrastructure is an inherently place-based process contributing to the health and long-term success of both the physical landscape as well as the socio-cultural landscape. While it provides functional habitat for native wildlife it should also contribute to the physical and mental health and well-being of the human user. A functioning green infrastructure approach should foster stewardship and learning, developing stronger relationships between people and the natural resources that provide the foundation for functioning living systems. The residents who understand and appreciate the benefits of green infrastructure within their community are often those who are most likely to become the long-term stewards of a site.

Within the Great Lakes ecosystem these benefits are particularly important in terms of sustaining and strengthening ecosystem health and resilience. The Great Lakes basin, which covers 20,000 square miles, has an incredible level of biodiversity. According to a study done by The Nature Conservancy, there over 30 natural communities that are almost entirely unique to the basin. The Great Lakes ecosystem contains one fifth of the world's freshwater supply, with its rivers and streams providing important spawning habitats and migration corridors for songbirds and waterfowl. Native ecological systems of note include: grasslands, forests including beech-maple, oak-hickory, mixed forest, as well as unique post-glacial landscapes that include bogs, fens, wetlands and kettle lakes which provide important habitat to wildlife as well as recreational and respite activities for residents. New York' dependence on the Great Lakes, as a water resource and economic driver, also highlights the importance of the overall sustainability of the Great Lakes ecosystem.

Green infrastructure calls for the integration of many of the following practices: planting and design decisions including natural meadow and woodland vegetation in lieu of conventional turf areas; managing, preserving, and restoring healthy forest stands and ecological corridors along streams and waterways; less consumptive maintenance decisions; the integration of stormwater management features as part of a "functional landscape"; integrating vegetation into building architecture in green roofs and living walls; integrating cisterns and other water capture and reuse systems; using permeable pavement and other alternatives to impervious surface; integrating natural outfall designs; utilizing onsite treatment of wastewater; the integration of renewable energy and transportation planning; carbon sequestration as a consideration in management of vegetation; and the inclusion of edible landscapes or urban agriculture as well as other programming decisions. Green infrastructure designs that incorporate these practices can scale up to the landscape ecological perspective and scale down to the site-specific treatment of the landscape, delivering natural capital and goods and services for a more sustainable future.

As a holistic approach to site planning and design, green infrastructure provides a multitude of benefits. These benefits include the reduction and delay of stormwater runoff volume, enhanced groundwater recharge, reduced stormwater pollutants, increased carbon sequestration, decreased potable water consumption, onsite wastewater treatment, decreased maintenance costs, urban heat island mitigation, reduced energy demands, and reduced operation and maintenance costs. Further benefits include: improved air quality, the provision of enhanced wildlife habitat for diverse ecosystems, improved recreational space, improved human health, increased land values, and innovative new educational opportunities.

The biological and natural resource richness of the Great Lakes basin is tied to the integrity of the many smaller watersheds that are found within. Disturbances in one location may have many unintended effects elsewhere. By the same token, restored functionality in the Buffalo region may have important implications for improved ecosystem health in other parts of the basin, and beyond. There are many opportunities to integrate green infrastructure into site planning.

II. Relevance to the RiverBend Site

A holistic approach to regenerative design and development integrates the rich ecological legacy of the RiverBend site with proposed development, creating a functional and sustainable landscape while cultivating a thriving and complimentary human and natural resource community. The first step in understanding the site's potential for fostering ecological functionality is to examine the landscape's natural and hydrologic patterns (both current and historic) and the ecosystem services that could potentially be provided if the site is restored to its full ecological potential, despite its decades-long history of industry.

Through this lens, RiverBend is seen as a place that reconnects to the river corridor and neighboring natural areas, including the Tifft and Times Beach Nature Preserves. With full ecological restoration of the site, RiverBend would experience the return of a natural matrix of habitat types including riparian forest along the river shoreline; mesic forest on upland areas and along a corridor that extends along the eastern edge of the site; marsh areas in areas historically showing wetland characteristics; grassland on the containment zone; and a shoreline restoration that provides habitat improvements both for aquatic as well as terrestrial species. Once full ecological potential of the site is understood, the most natural and functional locations for ecological restoration and management are identified. These locations are then integrated with redevelopment in a design that is responsive to ecological function and hydrologic management. Along with the integration of these ecological patches of riparian forest, mesic forest, marsh and wetland, grassland, and natural shoreline, is the addition of green infrastructure.

Green (or living) infrastructure can be integrated into the development footprint of the RiverBend site in a way that bridges the natural landscape with the built environment, providing more natural approaches to stormwater and landscape management. Green infrastructure is a seamless combination of natural and designed features that are linked and integrated across the development footprint, providing a variety of ecological, stormwater, and community benefits. The forms of green infrastructure most appropriate for the RiverBend site include the following: native landscape vegetation in lieu of conventional turf, biofiltration, bioswale conveyance; stormwater ponds and wetlands; and outfall treatment. The practices form a treatment train for stormwater that promotes infiltration and evaporation, as well quality and quantity control.

Innovative onsite wastewater treatment practices could also be integrated into the site design as development moves forward at RiverBend. While onsite treatment saves costs by avoiding offsite municipal sewage treatment, it also provides savings associated with limiting potable water demand onsite, through selective reuse of treated water. Onsite treatment practices like constructed wetlands provide even further green infrastructure benefit through added wildlife habitat.

Restored riparian and mesic forest and grassland on the RiverBend site will provide habitat corridors and connections to existing preserves, as important ecological stepping-stones for birds and other native wildlife. Integrating mesic and riparian forest, as well as grassland, will increase biodiversity and restore ecological function to the RiverBend site. Habitat improvements along the shoreline of the Buffalo River will also contribute to concurrent river restoration efforts, providing improved water filtration before it reaches the river, and increased shade from overhanging vegetation will improve cover for aquatic species. See Figure 1 below for the Green Infrastructure overlay for RiverBend, which includes the Greenway Plan, Urban Ecology and Stormwater Management.

It is important to note that little is known about soil conditions on the site and that slag may be present. Soil amendments will be a critical component of ecological restoration but specific recommendations cannot be made at this time. A soil amendment plan should be developed once more site soil data has been collected. It is expected that necessary soil amendments will vary for the different types of restoration and urban ecology proposed. The soil amendment and planting plans will have to take slag into account, if present. Suggested plant palettes are provided throughout this report; species adapted to subsurface slag conditions have been noted.

Figure 1. Green Infrastructure Overlay

III. Greenway Plan

The planned greenway along the edge of the RiverBend site embraces the Buffalo River shoreline and integrates shoreline ecological restoration and enhancement into the redevelopment of the RiverBend site as a whole. The Greenway Plan describes the enhancement needs in the river and the approaches that could be taken along the shoreline to restore natural habitat function in conjunction with the Buffalo Riverkeeper's work. It also provides suggested design and plant palette recommendations for the riparian woodland enhancement and urban tree canopy along the greenway, and describes the integration of trails and access points.

As part of the broader green infrastructure framework, the Greenway Plan's habitat improvements along the Buffalo River shoreline will also contribute to concurrent river restoration efforts, providing improved water filtration before it reaches the river, and increased shade from overhanging vegetation will improve cover for aquatic species.

A. Buffalo River Habitat Enhancement

The ideal greenway river habitat enhancement would have all areas along the RiverBend site rehabilitated to a more natural condition, but the past industrial legacy (primarily floodplain filling), continued uses of the river for shipping, and high costs of shoreline excavation and bulkhead removal make comprehensive rehabilitation and restoration impractical. A realistic approach has been selected that includes areas of stabilization, areas of habitat enhancement, and areas where the existing concrete and steel bulkheads would remain in place.

Areas where river habitat enhancements are proposed include approximately 750 feet of river bank along the south bank in the first bend west of South Park Avenue (Area A), approximately 800 feet along the south bank upstream of South Park Avenue (Area B), approximately 250 feet along the southwest bank between two existing concrete bulkheads that are proposed to become fishing piers (Area C), and 600 feet of stabilization on the west bank along the most upstream edge of the RiverBend site (Area D) (Figure 5).

Given the existing river morphology, creating spawning habitat for migratory fish species appears both inappropriate and unfeasible. Based on these parameters, the design is to create nursery and refuge habitat for the fry and juveniles of these migratory species, and additional cover to support resident warmwater and nearshore/lake species. Example species include the smallmouth bass and pumpkin seed sunfish (Figures 2 and 3). Great Lakes marsh habitat would be an appropriate restoration benchmark for this section of the Buffalo River. Such a habitat would include zones of deeper water dominated by submerged aquatic and floating-leaf vegetation, as well as, a zone of emergent plants (Figure 4) that would transition along with the shoreline elevation to wet meadow. Logs and woody debris would also be randomly anchored around the marsh to add habitat variability and cover.

In most areas, the river habitat enhancement should begin by grading a gradual slope into the existing banks from the edge of the water. In Areas, A, B and C engineered breakwaters could be constructed near, or slightly stream ward from the existing edge of water. Additional material can be excavated from behind the breakwaters to create aquatic benches and relatively deeper water habitat for the establishment for an aquatic bed. In these areas, the nearshore grading should ensure that at least 20 to 50 feet of shoreline would be frequently or continuously inundated. Aquatic benches in the nearshore areas provide vital spawning and nursery habitat for warmwater and nearshore lake species. In Area C, the proposed aquatic bench will also improve access and provide fishable habitat along the shore of the river. In Area D the proposed habitat enhancements are limited to shoreline grading to create a more stable bank slope. Once a stable slope has been established, the existing soil may require augmentation with topsoil or organic material, and should be stabilized with bioengineering. More detail on considerations for shoreline restoration is provided below.

It is important to note that the Buffalo River is the subject of intensive study and investment. The Buffalo River Area of Concern (AOC) is 6.2 miles long and extends from the mouth of the river to the farthest point upstream at which the backwater condition exists during Lake Erie's highest monthly average lake level, past the RiverBend site. The U.S. Army Corps of Engineers, Buffalo District performed a reconnaissance level study from 2001-2003, which determined that there was Federal interest in initiating a cost-shared feasibility study of environmental dredging on the Buffalo River from Hamburg Street to the confluence of Cazenovia Creek and the River. The non-federal sponsor for the feasibility study is Buffalo Niagara Riverkeeper. Based on the feasibility study it was determined that the US Army Corp of Engineers will dredge contaminated sediment from areas of authorized Buffalo Harbor Federal navigation channels in 2011. Under the Great Lakes Legacy Act, US EPA will dredge additional areas outside of the navigation channels. This work will be followed by aquatic habitat restoration, which is early in the design process.

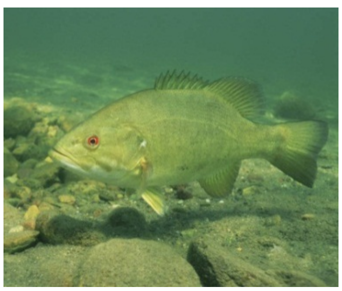

Figure 2. Smallmouth bass (*Micropterus dolomieui*) *Photo by Eric Engbreston- USFWS*

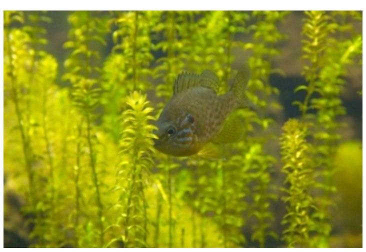

Figure 3. Pumpkinseed sunfish (*Lepomis gibbosus*) *Photo by Tino Strauss*

Figure 4. Arrowhead (*Sagittaria latifolia*) *Photo by Robert H Mohlenbrock, USDA-NRCS*

Figure 5. River Habitat Enhancement

Buffalo River Habitat Enhancement Suggested Plant Palette – Aquatic	
Submerged	
Characteristic Species	
Brasenia schreberi	watershield
Nuphar advena	spatterdock
Nymphaea odorata	American white waterlily

Buffalo River Habitat Enhancement Suggested Plant Palette – Aquatic	
Polygonum amphibium	water smartweed
Potamogeton	pondweeds
Vallisneria americana	American eelgrass
Associates	
Elodea canadensis	Canadian waterweed
Najas flexilis	nodding waternymph
Floating	
Ceratophyllum demersum	coontail
Lemna minor	lesser duckweed
Myriophyllum	watermilfoil
Utricularia macrorhiza	common bladderwort
Emergent	
Characteristic Species	
Carex lacustris	lake sedge
Carex stricta	tussock sedge
Iris virginica	blue flag iris
Leersia oryzoides	rice cutgrass
Pontederia cordata	pickerelweed
Potamogeton nodosus	longleaf pondweed
Potamogeton pectinatus	sago pondweed
Sagittaria latifolia	broadleaf arrowhead
Schoenoplectus acutus	hardstem bulrush
Schoenoplectus fluviatilis	river bulrush
Schoenoplectus tabernaemontani	softstem bulrush
Sparganium eurycarpum	greater bur-reed

B. River Shoreline Restoration

The shoreline in this section of the river is currently composed of a mixture cobble rip rap, concrete debris, and steel and concrete bulkheads, with a narrow strip of trees and shrubs that have sprouted on the relatively steep bank slopes. An example of a natural shoreline typical of this section of the Buffalo River would exhibit a gradual upward transition in elevation with associated shifts in the vegetation community from emergent aquatic vegetation, to wet meadow, then to hydrophytic shrub and riparian forest vegetation. To maximize shoreline habitat and align with the Buffalo Niagara Riverkeeper Conservation Framework (2005), the minimum width for the shoreline restoration should be approximately 100 feet extending from the edge of the water.

Ideally, all of the rehabilitated shoreline in Areas A through C would be constructed as a low profile bench along the water with a relatively flat (>15:1 slope) (Figure 7). This slope will encourage migration of semiaquatic herpetofauna between riverine and terrestrial habitats. Frequent inundation will promote the processing of riverine sediment, nutrients (N & P) and organic matter. Carbon sequestration will also be made possible through the creation and storage of plant biomass in the newly restored shoreline.

The slope transition to existing upland in Area A is proposed to have an approximate slope of 8.5:1. The proposed shoreline slope in Area B is approximately 8:1, and will be graded to include the proposed regenerative stormwater conveyance (RSC) structure that will drain to the Buffalo River from the west. The shoreline slope in Area C is proposed to be 5:1, to accommodate a larger aquatic bench area for fishing. The shoreline rehabilitation in Area D will involve grading the existing unstable slope to an approximate 3:1 slope. Once a stable slope has been established, the existing soil may require augmentation with topsoil, or organic material and should be stabilized with bioengineering.

Above the low bench, the restoration plantings should include a mix of canopy, woody understory, herbaceous understory and appropriate associate plant species to provide a diverse matrix of vegetation for forage, shelter, and nesting habitat. This will provide increased aquatic habitat connectivity between the lake and the upper watershed of the Buffalo River, as well as upland habitat for associated birds and other shoreline wildlife species (Figure 6). The list provided below includes species that are adapted to nearshore habitats that experience frequent inundation and can withstand impacts from floating debris such as snags and ice. Many of the species are also appropriate for riparian plantings.

Figure 6. Blue spotted salamander (*Ambystoma laterale*) *Photo by IronChris – Wikimedia Commons*

Biohabitats GREAT LAKES BIOREGION

Figure 7. Shoreline Restoration

River Shoreline Restoration Suggested Plant Palette – Terrestrial	
Canopy	
Characteristic Species	
Acer saccharinum	silver maple
Juglans nigra	black walnut
**Platanus occidentalis*	American sycamore

River Shoreline Restoration Suggested Plant Palette – Terrestrial	
**Ulmus americana*	American elm
Associates	
**Acer negundo*	box elder
**Populus deltoides*	eastern cottonwood
Salix nigra	black willow
Woody Understory	
Characteristic Species	
Cornus amomum	silky dogwood
Cornus sericea	red-osier dogwood
Salix interior	sandbar willow
Associates	
**Alnus serrulata*	hazel alder
**Alnus rugosa*	speckled alder
Cephalanthus occidentalis	buttonbush
Clematis virginiana	Virgin's bower
**Parthenocissus quinquefolia*	Virginia creeper
Rosa palustris	swamp rose
Salix bebbiana	Bebb's willow
Salix discolor	pussy willow
Salix eriocephala	heart-leaf willow
Salix lucida	shining willow
Salix petiolaris	meadow willow
Salix sericea	silky willow
Salix serissima	Autumn willow
**Vitis riparia*	riverbank grape
Herbaceous Understory	
Characteristic Species	
Buphthalmum salicifolium	ox-eye
Carex emoryi	Emory's sedge
Eupatorium purpureum	joe-pye weed
**Solidago gigantea*	smooth goldenrod
Symphyotrichum lanceolatum	white panicled aster
Verbesina alternifolia	wingstem
Associates	
Cinna arundinacea	sweet woodreed
Elymus virginicus	Virginia wildrye
Impatiens capensis	jewelweed
Laportea Canadensis	Canadian woodnettle
Leersia virginica	whitegrass
Muhlenbergia frondosa	wirestem muhly
Pilea pumila	Canadian clearweed
Teurium canadense	Canada germander
*species adapted to subsurface slag conditions	

C. Riparian Woodland

Floodplain forest occurs on floodplain soils that are deep, fertile, and mesic. This community occurs along rivers throughout the Eastern Great Lakes region. Soils are seasonally saturated, as a result of overflow from a nearby water body, groundwater, or drainage form adjacent uplands.

Trees and shrubs dominate this woodland area, with multiple layers of vegetation creating a dense and diverse character. The vegetation, as listed below, should be native and flood tolerant, and provide for complete canopy closure at maturity. The proposed riparian woodland is located adjacent to the river. The width varies from approximately 100’ to 250’, which will allow for functional habitat (Figure 10). This provides for nesting and forage habitat for birds and other wildlife (Figures 8 and 9), travel corridors for migration and dispersal for birds and wildlife. The riparian buffer that this woodland creates is important in providing a cooler microclimate along the river’s edge, which then also provides shade for more diverse aquatic habitat in the adjacent water body.

Where regenerative stormwater conveyance (RSC) is designed in the riparian buffer (an outfall treatment that is described in further detail in the stormwater section of this report), vegetation should be integrated into the design to transition naturally between the conveyance and the surrounding woodland. Transitional vegetation between the RSC and riparian woodland can include the following woody species: buttonbush, dogwood species, winterberry, elderberry, hazel alder, spicebush, swamp rose, red maple, black gum, sycamore, swamp white oak.

Figure 8. Yellow throated vireo (*Vireo flavifrons*) *Photo by Mdf- Wikimedia Commons*

Figure 9. Hermit thrush (*Catharus guttatus*) *Photo by Lee Karney, USFWS*

Figure 10. Riparian Woodland

Riparian Woodland Suggested Plant Palette	
Canopy	
Characteristic Species	
Acer rubrum	red maple
Acer saccharinum	silver maple
Carya ovata	shagbark hickory
Liriodendron tulipifera	tulip tree
**Platanus occidentalis*	American sycamore
Pinus strobes	white pine

Riparian Woodland Suggested Plant Palette	
**Populus deltoides*	eastern cottonwood
Quercus bicolor	swamp white oak
Salix nigra	black willow
Tilia americana	American basswood
Associates	
**Acer negundo*	box elder
Betula populifolia	grey birch
Carya cordiformis	bitternut hickory
Juglans cinerea	butternut
Juglans nigra	black walnut
Larix laricina	tamarack
Nyssa sylvatica	black gum
Quercus macrocarpa	burr oak
Quercus palustris	pin oak
**Ulmus americana*	American elm
Woody Understory	
**Alnus serrulata*	hazel alder
**Alnus rugosa*	speckled alder
Amelanchier canadensis	Allegheny serviceberry
Carpinus caroliniana	ironwood
Clematis virginiana	Virgin's bower
Cornus amomum	silky dogwood
Cornus sericea	red-osier dogwood
Hamamelis virginiana	witchhazel
Ilex verticillata	winterberry
Lindera benzoin	spicebush
**Parthenocissus quinquefolia*	Virginia creeper
Physocarpus opulifolius	ninebark
Salix bebbiana	Bebb's willow
Sambucus canadensis	American elderberry
Sassafras albidum	sassafras
Viburnum lentago	nannyberry viburnum
Viburnum trilobum	cranberrybush viburnum
Herbaceous Understory	
Ageratina altissima	white snakeroot
Arisaema dracontium	greendragon
Boehmeria cylindrica	false nettle
Impatiens capensis	spotted jewelweed
Impatiens pallida	pale touch-me-not
Laportea canadensis	Canadian wood nettle
Lobelia cardinalis	cardinal flower
Lobelia siphilitica	great blue lobelia
Onoclea sensibilis	sensitive fern
Peltandra virginica	green arrow arum
Polygonum virginianum	Virginia knotweed

Riparian Woodland Suggested Plant Palette	
Saururus cernuus	lizard's tail
Symphyotrichum puniceus	purple stem aster
*species adapted to subsurface slag conditions	

D. Greenway Urban Canopy and Vegetative Plantings in Open Spaces

In areas where structures and hardscape open spaces are planned along the river shoreline, a buffer of mature tree canopy will be integrated into the design of these open spaces including plazas, shoreline walkways, and other hardscape areas (Figure 11). Woody understory shrubs and small trees, as well as flowering herbaceous natives and meadow species, will be integrated into planters and other planted areas in the public areas as well, creating a more diverse and multilayered native vegetation palette and creating linkages to the restored natural riparian and shoreline areas. A suggested plant palette is below.

Figure 11. Urban Canopy

Urban Canopy Suggested Plant Palette	
Urban and Street Trees	
Characteristic species	
Acer rubrum	red maple
Acer saccharinum	sugar maple
Betula nigra	river birch
Celtis occidentalis	hackberry
Cercis canadensis	eastern redbud
Cladrastis kentukea	yellowwood
Gleditsia triacanthos	honeylocust
Gymnocladus dioicus	Kentucky coffeetree
Liquidambar styraciflua	sweetgum
Liriodendron tulipera	tulip tree
Nyssa sylvatica	blackgum
Ostrya virginiana	hophornbeam
Quercus bicolor	swamp white oak
Quercus coccinea	scarlet oak
Quercus rubra	red oak
Tilia americana	American basswood
**Ulmus americana*	American elm
Woody Understory	
**Alnus serrulata*	hazel alder
Amelanchier canadensis	Allegheny serviceberry
Carpinus caroliniana	ironwood
Cornus amomum	silky dogwood
Cornus sericea	red-osier dogwood
Hamamelis virginiana	witchhazel
Ilex verticillata	winterberry
Lindera benzoin	spicebush
Physocarpus opulifolius	ninebark
Sambucus canadensis	American elderberry
Viburnum lentago	nannyberry viburnum
Viburnum trilobum	cranberrybush viburnum
Herbaceous Understory	
Ageratina altissima	white snakeroot
Boehmeria cylindrica	false nettle
Impatiens capensis	spotted jewelweed
Impatiens pallida	pale touch-me-not
Laportea canadensis	Canadian wood nettle
Lobelia cardinalis	cardinal flower
Onoclea sensibilis	sensitive fern
Peltandra virginica	green arrow arum
Polygonum virginianum	Virginia knotweed
Saururus cernuus	lizard's tail
Symphyotrichum puniceum	purple stem aster

Urban Canopy Suggested Plant Palette	
Grassland Species (can be integrated into planters in plaza and open space along the greenway)	
Andropogon gerardii	big bluestem
Helianthus grosseserratus	saw-tooth sunflower
Liatris spicata	dense blazing star
**Oligoneuron ohioense*	Ohio goldenrod
**Oligoneuron rigidum*	stiff goldenrod
Oxalis violacea	violet wood sorrel
Ratibida pinnata	gray head Mexican hat
Rudbeckia hirta	black-eyed Susan
Schizachyrium scoparium	little bluestem
Spartina pectinata	prairie cordgrass
Tradescantia ohiensis	Ohio spiderwort
*species adapted to subsurface slag conditions	

E. Trails and Access

The integration of a greenway trail network along the Buffalo River within RiverBend provides a valuable connection to the natural features of the site, highlighting the important role that the River plays in the site's history and its historic ecology. Highlighting the ecological restoration along the river and the valuable natural resource elements that are being integrated throughout provides a unique opportunity for learning and increased stewardship of the river resource. The visitors' experience is enhanced and informed by the ecological aesthetic of the riparian woodland and restored natural shoreline conditions. New opportunities are created for interacting with the river and nature including bird-watching, sport fishing, and kayaking. This can foster an improved understanding of hydrologic processes and native wildlife.

The layout for the trails and walkways takes into account the shoreline restoration, riparian corridor restoration, and upland uses (Figure 13). Trails and walkways will provide ample access to the native woodland habitat and the Buffalo River but will avoid some areas along the northern edge of the RiverBend site, where more skittish wildlife can safely and confidently nest and forage without the threat of human disturbance and fragmentation (Figure 12). Vegetation will vary as one moves from more natural shoreline riparian conditions to the urbanized canopy and open space plantings – as described above.

Figure 12. Hermit thrush (*Catharus guttatus*) *Photo by Dave Menke - USFWS*

Figure 13. Trails and Access

IV. Urban Ecology

Restored native forest, wetland, and meadow resources are integral to the green infrastructure network, providing habitat; open space and recreational areas; connections to the regional ecosystem; and stormwater management, among other benefits. As part of the green infrastructure network the restoration efforts provide habitat corridors and connections to existing preserves, as important ecological stepping-stones for birds and other native wildlife.

A vigorous forest cover is also critical to maintaining healthy stream ecosystems and flood control. Forests made up of native tree and understory species have a higher ecological function than invasive exotic tree and understory species. Invasive exotic species may be defined as non-native species that can adapt, grow and spread rapidly in an area, to the exclusion and displacement of native vegetation valuable to local fauna and ecological processes. Invasive species control and restoration of native forest species is recommended as a management strategy to maintain the function of the two existing forest stands. This section describes the urban ecological elements restored on the RiverBend site including: mesic woodland, wetlands, grassland, and urban canopy. In general, appropriate native vegetation should be planted, including plants in the canopy, understory, herbaceous and groundcover layers. Also, an integrated vegetation management plan should be developed and implemented.

The restoration of native forest and grassland will provide additional and complimentary nesting and forage habitat for birds and wildlife present at the neighboring Tifft Preserve and along the Buffalo River Corridor. It will provide travel corridors for migration and dispersal along the river. Enhanced tree canopy will also regulate the site's microclimate providing cool and comfortable spaces for human passage and screening along site boundaries. The native mesic woodland stands, including a combination of canopy, understory, and groundcover vegetation, will increase local biodiversity and local genetic diversity.

Native plants, once established, require little irrigation, fertilization and are resistant to most native pests and diseases, providing a relatively "low-maintenance" landscape. Each native plant species is a member of a balanced ecological community that includes other plants, animals and microorganisms. This natural balance keeps each species in check, allowing it to thrive in conditions where it is suited, but preventing it from becoming invasive, as plants introduced from other areas can be.

Design considerations for each element, as well as planting palettes, are described below. The plant lists developed evolved from species listings for native woodlands and grasslands as seen in *Harker, D. et al, 1993. Landscape Restoration Handbook . New York Audubon Society.; Leopold, D.2005. Native Plants of the Northeast. Timber Press.;* and *LEAP, 2007. A Legacy of Living Places, Conserving the Diversity of Nature in the Lake Erie Allegheny Ecoregion.*

A. Mesic Woodland

Mesophytic forest occurs on moist, well-drained soils. In the Eastern Great Lakes region, this forest type is most commonly located at low elevations and on fertile, loamy soils. This is a diverse community with an abundance of spring wildflowers.

The mesic forest, which will be located along the eastern boundary of the RiverBend site, will provide a wooded corridor south from the Buffalo River toward South Park Avenue (Figure 16). It will have varying widths of 100' to 300', with a minimum width of 100' in order to provide adequate cover for birds (Figures 14 and 15). As with the riparian forest, planting will be established to ensure complete canopy closure at maturity. There should be a diverse structure with multiple layers of vegetation, including canopy, understory, and groundcover and there should be limited breaks in cover for roads and other crossings. This plant palette will provide nesting and forage habitat for birds and other wildlife and travel corridors. As with the riparian forest, this woodland will help to regulate microclimate, providing shade and cooling, and screening as necessary. As an edge element, the woodland will provide aesthetic benefits, and could include flowering understory and groundcover plants.

Figure 14. Canada warbler (*Wilsonia canadensis*) *Photo by Emmett Hume*

Figure 15. Wood thrush (*Hylocichla mustelina) Photo by Steve Maslowski, USFWS*

Figure 16. Mesic Woodland

Mesic Woodland Suggested Plant Palette	
Canopy	
Characteristic species	
Acer rubrum	red maple
Acer saccharinum	sugar maple
Betula lenta	sweet birch
Fagus grandifolia	American beech
Liriodendron tulipifera	tulip tree
Prunus serotina	black cherry

Mesic Woodland Suggested Plant Palette	
Quercus rubra	northern red oak
Associates	
Carya cordiformis	bitternut hickory
Carya ovata	shagbark hickory
Juglans nigra	black walnut
Magnolia acuminata	cucumber magnolia
Nyssa sylvatica	black gum
Pinus strobus	eastern white pine
Quercus alba	northern white oak
Tilia americana	American basswood
Tsuga canadensis	eastern hemlock
**Ulmus americana*	American elm
**Ulmus rubra*	slippery elm
Woody Understory	
Acer pensylvanicum	striped maple
Amelanchier laevis	Allegheny serviceberry
Asimina triloba	pawpaw
Carpinus caroliniana	ironwood
Cornus alternifolia	alternate-leaf dogwood
Cornus rugosa	round-leaf dogwood
Diervilla lonicera	northern bush honeysuckle
Hamamelis virginiana	witchhazel
Lindera benzoin	spicebush
Lonicera canadensis	American fly honeysuckle
Staphylea trifolia	American bladdernut
Vaccinium pallidum	lowbush blueberry
Viburnum acerifolium	maple-leaf viburnum
Viburnum lantanoides	hobblebush
Herbaceous Understory	
Actaea pachypoda	white baneberry
Actaea racemosa	black cohosh
Allium tricoccum	ramp
Arisaema triphyllum	jack-in-the-pulpit
Asarum canadense	wild ginger
Aster macrophyllus	large-leaf aster
Cardamine diphylla	crinkleroot
Carex plantaginea	plantain-leaved sedge
Caulophyllum giganteum	giant blue cohosh
Caulophyllum thalictroides	blue cohosh
Claytonia virginica	Virginia springbeauty
Clintonia umbellulata	white bluebead-lily
Collinsonia canadensis	richweed
Dentaria laciniata	cutleaf toothwort
Dicentra canadensis	squirrel corn
Dicentra cucullaria	Dutchman’s breeches

Mesic Woodland Suggested Plant Palette	
Disporum lanuginosum	yellow fairybells
Erigenia bulbosa	Harbinger of spring
Erythronium americanum	American trout lily
Eurybia divaricata	white wood aster
Eurybia macrophylla	large-leaved aster
Hepatica nobilis	liverwort
Mertensia virginica	Virginia bluebells
Mitchella repens	partridge berry
Osmunda claytoniana	interrupted fern
Podophyllum peltatum	mayapple
Polygonatum pubescens	downy Solomon's seal
Polystichum acrostichoides	Christmas fern
Sanguinaria canadensis	bloodroot
Sanicula marilandica	black snakeroot
**Solidago caesia*	wreath goldenrod
**Solidago flexicaulis*	zigzag goldenrod
Smilacina racemosa	false Solomon's seal
Thalictrum dioicum	early meadow rue
Tiarella cordifolia	foamflower
Trillium erectum	stinking Benjamin
Trillium grandiflorum	Large flowered trillium
Viola blanda	sweet white violet
Viola canadensis	Canada violet
Viola pubescens	downy yellow violet
Viola rostrata	long spurred violet
Viola sororia	common blue violet
*species adapted to subsurface slag conditions	

B. Wetland

Wetlands are proposed for two locations on the site – west of the containment area and within public park (Figure 18). The proposed wetlands will be planted and maintained primarily with vegetation adapted wetlands and wetland fringes. This will consist primarily of plant species characteristic of forested, scrub-shrub, and emergent wetlands. In general, the low lying fringes would be planted with forested and scrub-shrub wetland species; while the area in lowered ponds would be planted with emergent wetland species. The wetland west of the containment area will resemble a natural wetland, whereas the wetland proposed for Republic Park will have a more structured form with a combination of natural and hardened edges (Figure 17). Both wetlands will be incorporated into the stormwater management system for the site, more detail is provided in Section V.

Figure 17. Wetland Restoration incorporating hardscape and native plantings. *Copyright Biohabitats*

Figure 18. Wetlands

C. Grassland

Mesic grassland, proposed for the containment area, is a grassland community characterized by high species diversity on deep, fertile, and well-drained soils. Dominant grasses in the mesic grassland are big bluestem, little bluestem, switchgrass, Indian grass, and prairie drop seed (Figure 19). Forbs are also abundant but usually sub-dominant to grasses.

The grassland plant palette below includes many native drought tolerant herbaceous plant species with a mixture of grasses and wildflowers. The containment zone provides approximately 40 acres of potential habitat, which is ample area for functional habitat for grassland birds as well as pollinators (Figures 20 and 21), which require a minimum of 10 acres. The grassland is situated in an area with direct aerial access to the Tifft Nature Preserve (over railroad tracks) (Figure 22).

The native grassland restoration on the containment zone will increase local and regional biodiversity through the restoration of native meadow species. It will provide forage and resting habitat for migratory bird and butterfly species. The inclusion of native grassland species, in lieu of conventional turf will prevent soil loss and damage from erosion on the containment zone. It will also provide an important location for pollinators of native plants and an additional opportunity for ecotourism and wildlife viewing in conjunction with the neighboring Tifft Preserve.

Figure 19. Native grassland restoration *Copyright Biohabitats*

Figure 20. Karner blue butterfly (*Lycaeides melissa samuelis) Photo by J&K Hollingsworth, USFWS*

Figure 21. Baltimore oriole (*Icterus galbula*) *Photo by David Brezinski, USFWS*

Figure 22. Grassland

Grassland Suggested Plant Palette	
Characteristic Species	
Andropogon gerardii	big bluestem
Galium tinctorium	stiff marsh bedstraw
Helianthus grosseserratus	saw-tooth sunflower
Liatris spicata	dense blazing star
**Oligoneuron ohioense*	Ohio goldenrod
**Oligoneuron rigidum*	stiff goldenrod
Oxalis violacea	violet wood sorrel

Grassland Suggested Plant Palette	
Panicum virgatum	switchgrass
Ratibida pinnata	gray head Mexican hat
Rudbeckia hirta	black-eyed Susan
Schizachyrium scoparium	little bluestem
Sorghastrum nutans	yellow Indian grass
Spartina pectinata	prairie cordgrass
Tradescantia ohiensis	Ohio spiderwort
*species adapted to subsurface slag conditions	

D. Urban Canopy and Vegetative Plantings in Open Spaces

Throughout the development footprint of RiverBend, but especially at the interface of the restored natural ecological areas, a mature tree canopy should be integrated into the design of open spaces including plazas, walkways, streets, and other hardscape areas (Figure 23). The suggested planting palette for Mesic Woodlands is applicable to these areas, as well as the species in the table below.

Figure 23. Urban Canopy

Urban Canopy Suggested Plant Palette	
Urban and Street Trees	
Characteristic species	
Betula nigra	river birch
Celtis occidentalis	hackberry
Cercis canadensis	eastern redbud
Cladrastis kentukea	yellowwood
Gleditsia triacanthos	honeylocust
Gymnocladus dioicus	Kentucky coffeetree
Liquidambar styraciflua	sweetgum
Ostrya virginiana	hophornbeam
Quercus bicolor	swamp white oak
Quercus coccinea	scarlet oak
Woody Understory	
**Alnus serrulata*	hazel alder
Ilex verticillata	winterberry
Physocarpus opulifolius	ninebark
Sambucus canadensis	American elderberry
Viburnum lentago	nannyberry viburnum
Herbaceous Understory	
Ageratina altissima	white snakeroot
Aquilegia Canadensis	Eastern red columbine
Asclepias tuberose	butterflyweed
Impatiens capensis	spotted jewelweed
Impatiens pallida	pale touch-me-not
Laportea canadensis	Canadian wood nettle
Lobelia cardinalis	cardinal flower
Onoclea sensibilis	sensitive fern
Polygonum virginianum	Virginia knotweed
Symphyotrichum novae-angliae	New England aster
Meadow Species (can be integrated into planters in plaza and open space along the greenway)	
Andropogon gerardii	big bluestem
Helianthus grosseserratus	saw-tooth sunflower
Liatris spicata	dense blazing star
**Oligoneuron ohioense*	Ohio goldenrod
**Oligoneuron rigidum*	stiff goldenrod
Oxalis violacea	violet wood sorrel
Ratibida pinnata	gray head Mexican hat
Rudbeckia hirta	black-eyed Susan
Schizachyrium scoparium	little bluestem
Spartina pectinata	prairie cordgrass
Tradescantia ohiensis	Ohio spiderwort
*species adapted to subsurface slag conditions	

V. Stormwater Management

The stormwater management approach proposed for the RiverBend site is a treatment train of vegetated best management practices (BMPs) that will provide water quality treatment, reduce runoff, and safely convey flows to the Buffalo River. The guiding principles and assumptions for this approach include:

- The site will serve as a green infrastructure demonstration site, complementing on-going efforts by the Buffalo Sewer Authority (BSA) and the Buffalo Niagara Riverkeeper to demonstrate the feasibility of using green infrastructure for stormwater management in Buffalo.
- No stormwater runoff will be delivered to the City of Buffalo's combined sewer system. Instead, treated stormwater runoff will flow to the Buffalo River.
- The stormwater management approach will comply with the Buffalo Sewer Authority's (BSA) Sewer Use Regulations, which reference the New York State Stormwater Management Design Manual (NYS Stormwater Manual).
- The site is considered "new development" per the NYS Stormwater Manual. The full Water Quality Volume (WQv) for streets, rights-of-ways, parking lots, and public open spaces will be treated by the proposed series of BMPs.
- Runoff reduction will be maximized throughout the site through the use of vegetated BMPs. However, at his time the ability to infiltrate stormwater runoff on the site is unknown, so it may not be possible to achieve the full Runoff Reduction Volume (RRv), as described in the NYS Stormwater Manual.
- The RiverBend site has been divided into eight drainage areas based on proposed grading and discharge points to the Buffalo River (Figure 24). Estimated impervious cover and projected treatment volumes are displayed in the table below. The Runoff Reduction volume currently assumes a Specific Reduction Factor of 0.2, representing Hydrologic Soil Group D.
- As the site drains to the Buffalo River, management of the Channel Protection Volume (Cpv), Overbank Flood (Qp), and Extreme Storm (Qf) are not required.

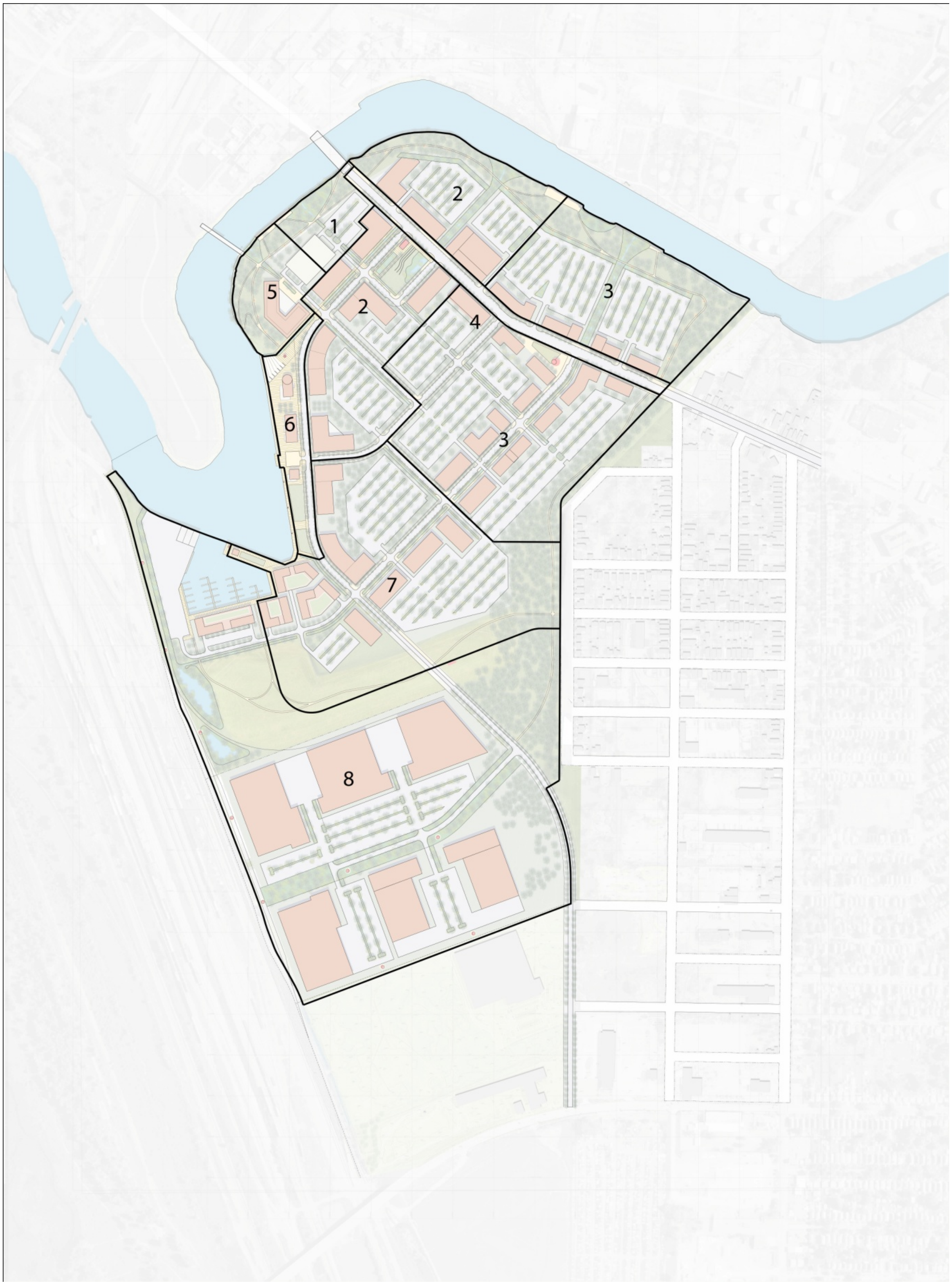

Figure 24. Proposed drainage areas

Estimated Impervious Cover and Projected Stormwater Runoff Treatment Volumes									
		Impervious Cover (acres)							
Zone	Total Area (acres)	Buildings	Parking Lots	Roads	Other (estimated)	Total Impervious Cover (acres)	Imperviousness (%)	Projected WQv (acre-feet)	Projected RRv (acre-feet)
1	4.6	0.52	0.95	0.13	0.32	1.9	42%	0.1	0.1
2	34.0	6.32	7.22	2.33	3.17	19.0	56%	1.4	0.5
3	54.8	6.01	19.25	2.90	5.63	33.8	62%	2.5	0.8
4	4.9	-	-	3.03	0.61	3.6	74%	0.3	0.1
5	6.6	1.83	-	0.12	0.39	2.3	35%	0.2	0.1
6	5.9	0.69	-	0.82	0.30	1.8	31%	0.1	0.1
7	42.2	6.27	9.99	2.49	3.75	22.5	53%	1.7	0.6
8	96.9	20.58	18.85	2.13	8.31	49.9	51%	3.7	1.4
TOTAL	**249.7**	**42.2**	**56.3**	**14.0**	**22.5**	**134.9**	**54%**	**10.0**	**3.6**

As stormwater BMPs are designed for the site several considerations will need to be addressed, including:

- The proposed series of BMPs is intended to manage stormwater runoff from streets, rights-of-ways, parking lots, and public open spaces. In addition, these BMPs will be sized to treat stormwater runoff from individual development parcels. However, later phases of development, particularly in drainage areas 3 and 7 may require additional on-lot stormwater treatment practices to meet full requirements in the NYS Stormwater Manual.

- Little is currently known about soil conditions on the site or the ability to infiltrate stormwater runoff. Soils on the site are classified “urban soils.” Testing will be necessary at proposed BMP locations to determine the need for impermeable liners on proposed biofilters and bioswales.

- Guidance provided in the NYS Stormwater Manual regarding designing for cold climates should be followed to counteract the potential impacts to BMPs from snow loads and road deicing.

- The proposed BMPs are intended to treat and convey stormwater runoff. The storm (e.g., 2-year return frequency, 10-year return frequency, etc.) used to size the BMPs for conveyance should be determined during the design process.

Six key landscape positions on the RiverBend site present opportunities for innovative stormwater management strategies utilizing a combination of best management practices (BMPs) and other regenerative practices. Together, these are the backbone of an integrated green infrastructure approach.

A. Parking Lot Bioswales

Figure 25. Parking Lot Bioswales

Runoff from parking lots will be treated by bioswales within landscaped areas between parking bays and along perimeters (Figure 25). Bioswales are vegetated swales and channels that convey and filter stormwater runoff (Figures 26 and 27). A diverse structure of trees and understory plants will intercept and filter rainfall while providing habitat and shade. A suggested planting palette for bioswales and biofilters is provided below. Bioswales use soil amendments or layers of engineered soil to encourage filtration and infiltration of runoff. Underdrains and overflow drains collect water that is not absorbed by vegetation. Impermeable liners may be necessary in some areas of the site to prevent infiltration.

These bioswales will convey treated runoff, and overflow runoff, from the parking lots to larger bioswales proposed within the streets rights-of-way.

Bioswales proposed for parking lots in RiverBend should be designed in accordance with the "dry swale" performance criteria in the NYS Stormwater Manual (Figure 28). Designs should also incorporate considerations for cold climates in the Manuals's performance criteria.

Figure 26. Bioswales along the edge of a parking lot. *Photo by Biohabitats*

Figure 27. Bioswales between parking bays.

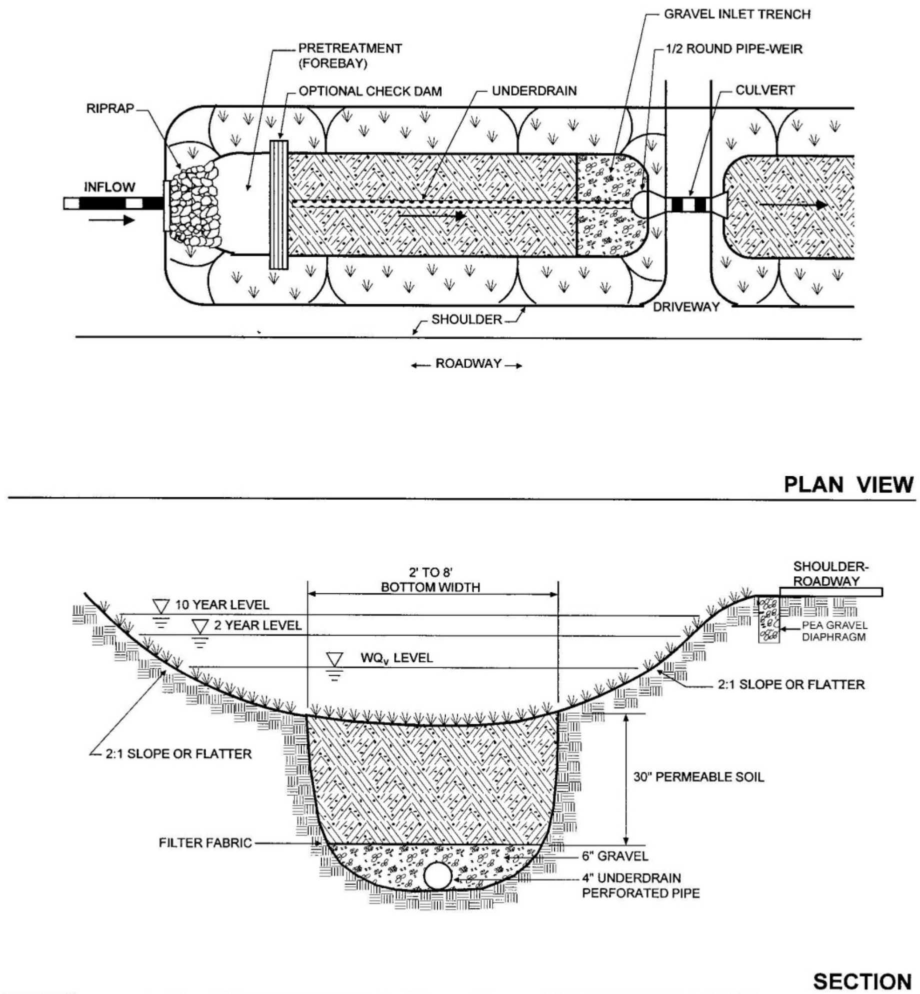

Figure 28. Bioswale typical plan and cross-section. *Source: NYS Stormwater Manual*

Bioswale and Biolfilter Suggested Plant Palette	
Biofiltration Salt Tolerant Trees and Shrubs	
Amelanchier canadensis	serviceberry
Aronia arbutifolia	red chokeberry
Aronia melanocarpa	black chokeberry
Celtis occidentalis	hackberry
Cephalanthus occidentalis	buttonbush
Ilex verticillata	winterberry
Juniperus virginiana	Eastern red cedar
Larix laricina	tamarack
Lindera benzoin	Spicebush
**Myrica pensylvanica*	northern bayberry
Nyssa sylvatica	blackgum
**Platanus occidentalis*	sycamore
**Populus deltoides*	cottonwood

Bioswale and Biolfilter Suggested Plant Palette	
Prunus serotina	black cherry
Quercus bicolor	swamp white oak
Quercus palustris	pin oak
Rosa palustris	swamp rose
Salix discolor	pussy willow
Sambucus canadensis	elderberry
Vaccinium angustifolium	lowbush blueberry
Vaccinium corymbosum	highbush blueberry
Biofiltration Herbaceous (salt tolerant species)**	
Acorus calamus	sweet flag
Calamagrostis canadensis	blue joint grass
Carex vulpinoidea	fox sedge
Elymus virginicus	Virginia wild rye
Eupatorium maculatum	spotted joe pye weed
**Eupatorium perfoliatum*	common bonset
Glyceria striata	fowl manna grass
Hibiscus moscheutos	**marsh mallow
Iris virginica	blue flag iris
Juncus effusus	common rush
Leersia oryzoides	rice cut grass
Panicum virgatum	**switchgrass
Pontederia cordata	**pickerel weed
Sagittaria latifolia	**arrowhead
Scirpus acutus	hard stem bulrush
Scirpus pungens	**common three-square
Scirpus validus	**soft stem bulrush
Spartina pectinata	**prairie cordgrass
Verbena hastata	blue vervain
*species adapted to subsurface slag conditions	

B. Street Bioswales

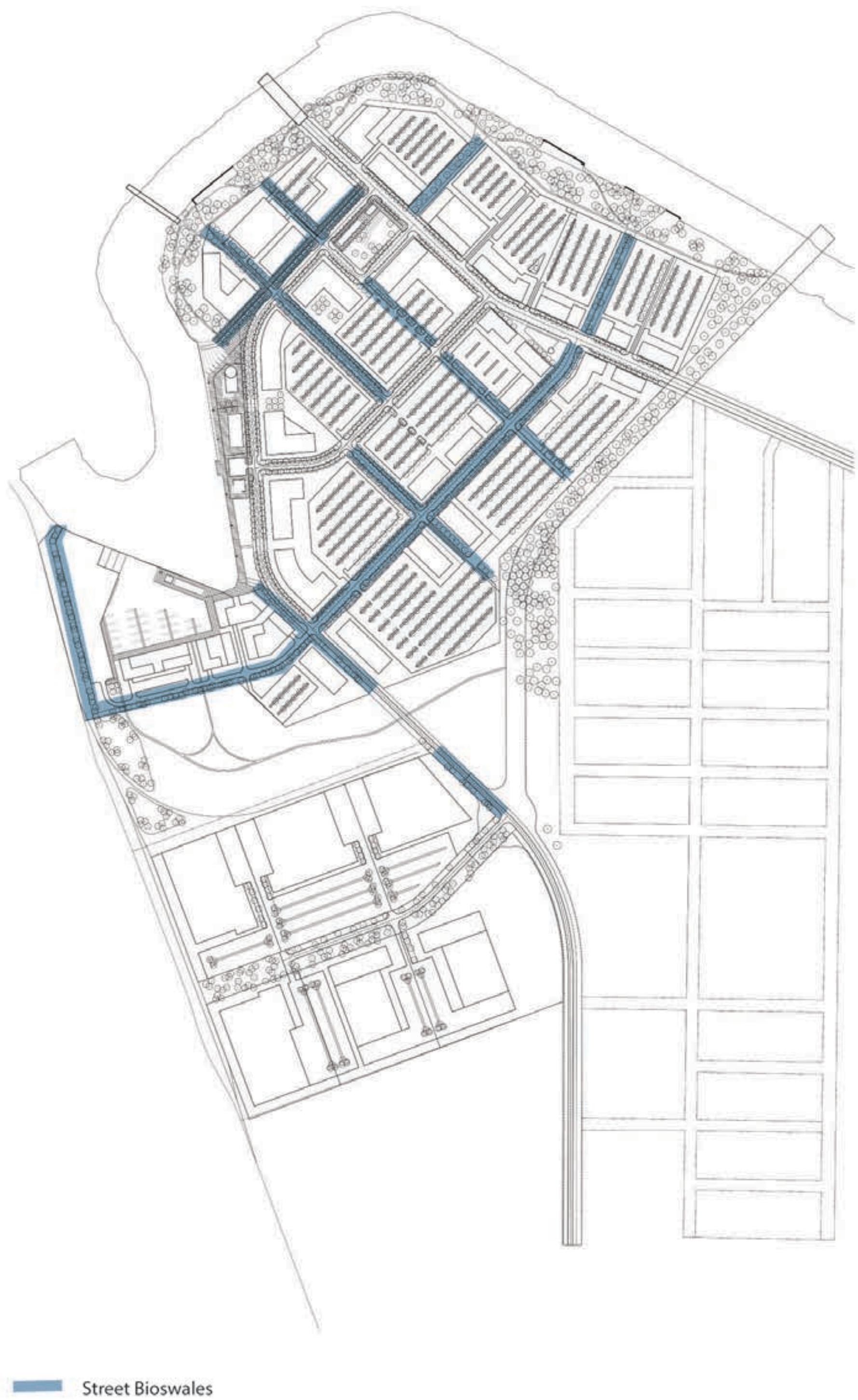

Figure 29. Street Bioswales

A series of bioswales within rights-of-way will filter and treat runoff from streets and adjacent areas, and will collect and convey flows from smaller BMPs on the site (Figure 29). As described above, bioswales are vegetated swales and channels that incorporate a diverse structure of trees and understory plants, soils, underdrains, and overflow drains. Street bioswales will be larger than proposed parking lot bioswales (Figures 30 and 31), but should still be designed in accordance with the “dry swale” performance criteria in the NYS Stormwater Manual.

Figure 30. Street bioswale.

Figure 31. Street bioswale.

C. Biofilters

Figure 32. Biofilter

A series of biofilters are proposed to provide treatment of stormwater runoff from light industrial parcels and the roads south of the containment area (Figure 32). Biofilters are vegetated, depressed landscape areas which collect and either retain or infiltrate stormwater (Figures 33 and 34). They are meant to be integrated into the landscape, capturing runoff from the impervious areas immediately around them, rather than becoming centralized detention basins. As with bioswales, a diverse structure of trees and understory plants will intercept and filter rainfall while providing habitat and shade. Soil amendments or layers of engineered soil encourage filtration and infiltration of runoff. Underdrains and overflow drains collect water that is not absorbed by vegetation. Impermeable liners may be necessary in some areas of the site to prevent infiltration.

The biofilters should be designed in accordance with the “bioretention” performance criteria in the NYS Stormwater Manual (Figure 35). Designs should also incorporate considerations for cold climates in the Manuals’s performance criteria.

Figure 33. Biofilter.

Figure 34. Biofilter.

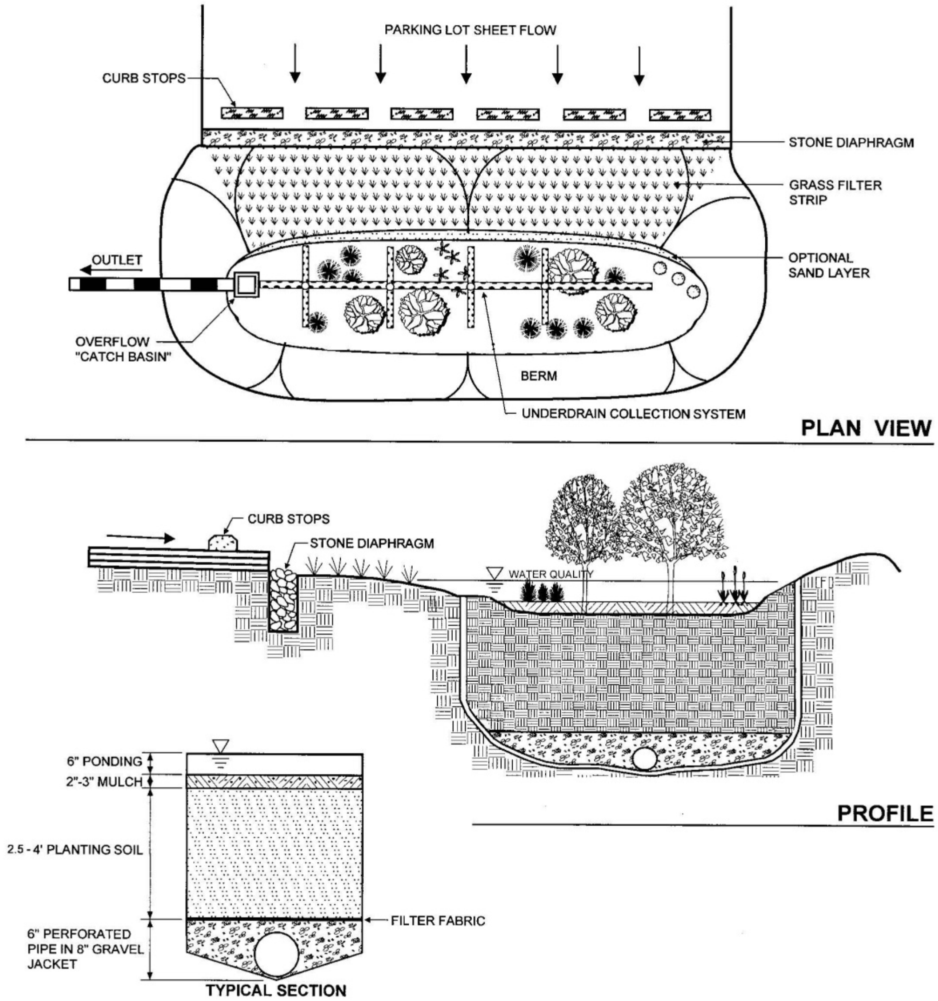

Figure 35. Biofilter typical plan and cross-section. *Source: NYS Stormwater Manual*

D. Biofilter Planters

Figure 36. Biofilter Planters

A more structured approach to vegetated BMPs is proposed for the denser, more urban RiverBend Drive and South Park (Figure 36). Biofilter planters are essentially biofilters incorporated into the sidewalk (Figures 37 and 38). Guidance provided above applies to these proposed locations.

Figure 37. Biofilter planter in Buffalo*. Source: Buffalo Niagara Riverkeeper*

Figure 38. Biofilter planter. *Source: Allegra Bukojemsky*

E. Stormwater Wetlands

Figure 39. Wetlands

Stormwater wetlands can be created to enhance water quality treatment. These practices can be designed in a way that responds to the natural processes and contours in the landscape, providing the stormwater treatment needed as a functional landscape while offering aesthetic effect, and habitat function (Figure 40 and 41). The edges of these practices are as important in design as the handling capacity. The integration of native vegetation along the edges can serve to provide further filtration as well as enhanced habitat benefit.

As described in Section IV, two stormwater wetlands are proposed for the site. The wetland west of the containment area will capture runoff from the southern portion of the containment area and the light industrial area. Most of this runoff will have already been filtered through bioswales and biofilters. The wetland proposed for Republic Park will capture runoff from buildings, parking lots and roads. Again, much of this runoff will have already been filtered. (Figure 39)

Both wetlands should be designed in accordance with performance criteria provided in the NYS Stormwater Manual (Figure 42).

Figure 40. A stormwater wetland with a native vegetative edge. *Photo by Biohabitats*

Figure 41. A stormwater wetland with a more formal edge. *Copyright Biohabitats*

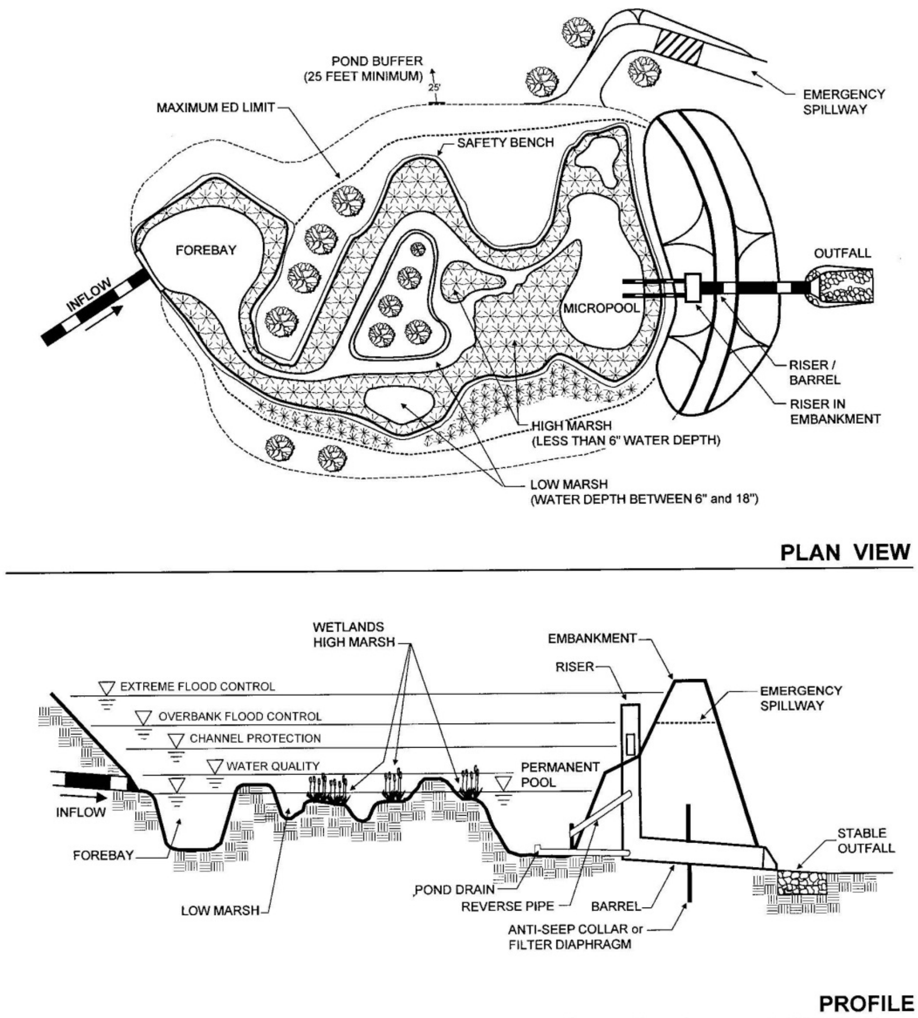

Figure 42. Stormwater wetland typical plan and cross-section. *Source: NYS Stormwater Manual*

F. Outfall Treatment

Figure 43. Outfall treatment

Conveying stormwater through pipes or concrete channels degrades the surrounding environment by speeding up flows, causing erosion, and denying infiltration. Outfall treatment, in the form of Regenerative Stormwater Conveyance (RSC) is recommended for four locations on the RiverBend site (Figure 43). This is not simply outfall stabilization (e.g., with riprap), but rather a vegetative regenerative design that creates a more stable stream-like system to help convey, filter, and provide habitat (Figure 44).

RSC uses stream restoration techniques to create open channel flow at stormwater outfalls, allowing sedimentation in pools, aeration in riffle structures, and restored ecological function. RSC is used to convey water down slopes from impervious areas or pipe outfalls. It is composed of a sand seepage bed, riffle weirs made of boulders and cobbles, a mulch and compost layer, and native plants (Figure 45). RSC is less intrusive than other conveyance stabilization techniques. It dissipates energy by slowing the flows, provides infiltration through the sand bed, and has a natural appearance.

Figure 44. Regenerative Stormwater Conveyance outfall treatment*, Photo Biohabitats*

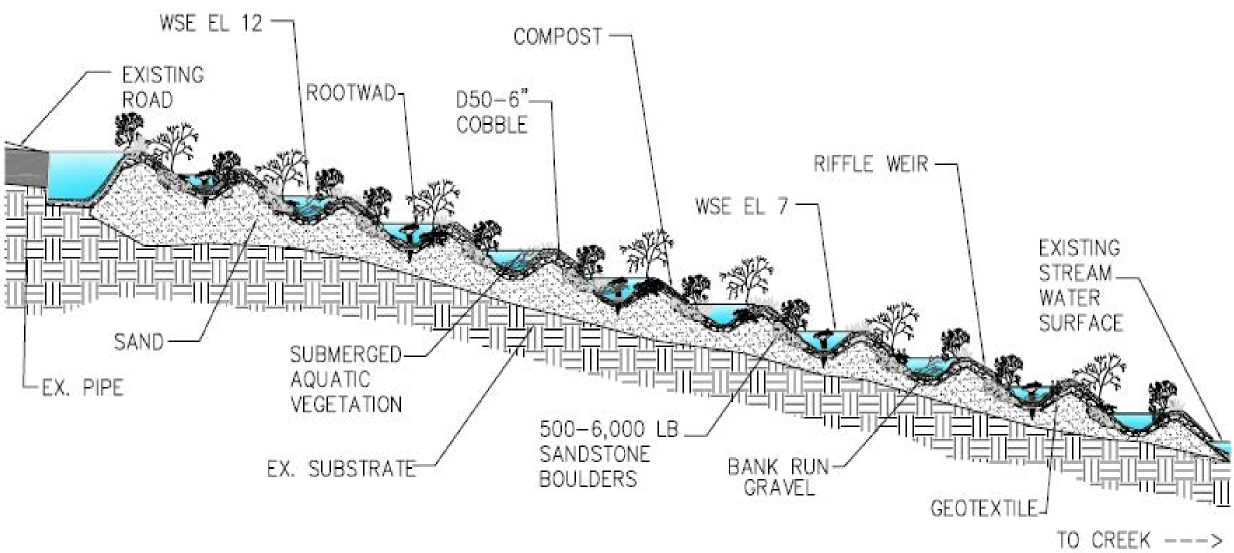

Figure 45. RSC typical cross-section. *Credit Biohabitats*

VI. Alternative Wastewater Treatment

Along with the integration of the green infrastructure elements described above the RiverBend site could become a regional model of holistic and sustainable wastewater management through the application of onsite alternative wastewater treatment.

Conventional wastewater treatment often takes one of two forms: decentralized septic systems or centralized municipal treatment systems. Septic systems, often found in rural residential locations, utilize a combination of tanks and drain fields, and are space and energy intensive. Municipal sewer systems require large amounts of energy and built infrastructure to pump and process waste at a central location. Often, both types of systems are accompanied by a risk of freshwater contamination due to sewer overflows or damaged pipe infrastructure. Both are resource-intensive, not only in terms of energy but also in terms of overall water use.

Alternatives to conventional treatment focus on a decentralized approach that uses processes modeled after natural systems. Alternatives include sand and peat filters, constructed treatment wetlands, and aerobic tanks. With these systems, treatment can be dispersed throughout the site and installed according to phased development needs. This avoids the need to connect to the municipal wastewater system and allows for new opportunities for water reuse onsite. Alternative wastewater treatment design relies on biologically-robust, low-energy technologies that are simple to build, operate, and maintain, and are modeled on the structure and function of natural systems including the forest floor, meadows, wetlands, and pond edges. These ecological zones are incorporated with technological solutions for managing water and waste within the development footprint. Instead of sending water and waste away (to an offsite municipal treatment location) residents and visitors will have a daily opportunity to experience, observe, and interact with these treatment systems (Figures 46-47). Technological elements of the alternative wastewater design include: primary treatment tanks which can be integrated into building design, secondary treatment wetlands which are integrated into the site design, and tertiary treatment which includes water reuse storage tanks, micro-infiltation through trickling water filters that can be vegetated, and ultraviolet disinfection.

The proposed alternative wastewater treatment systems for the RiverBend site can be designed to serve multiple functions and provide many benefits, moving the development beyond conventional approaches to water supply and waste disposal. Among the benefits of onsite wastewater treatment are: minimized potable water demand through the use of reclaimed greywater for onsite irrigation and nonpotable uses including toilet flushing, provision of nutrient reductions which limit impacts to groundwater, and cost savings associated with not having to tie into municipal treatment and any associated service fees. The added benefit of increased wildlife habitat is an element that ties the treatment systems into the broader green infrastructure framework of the RiverBend site.

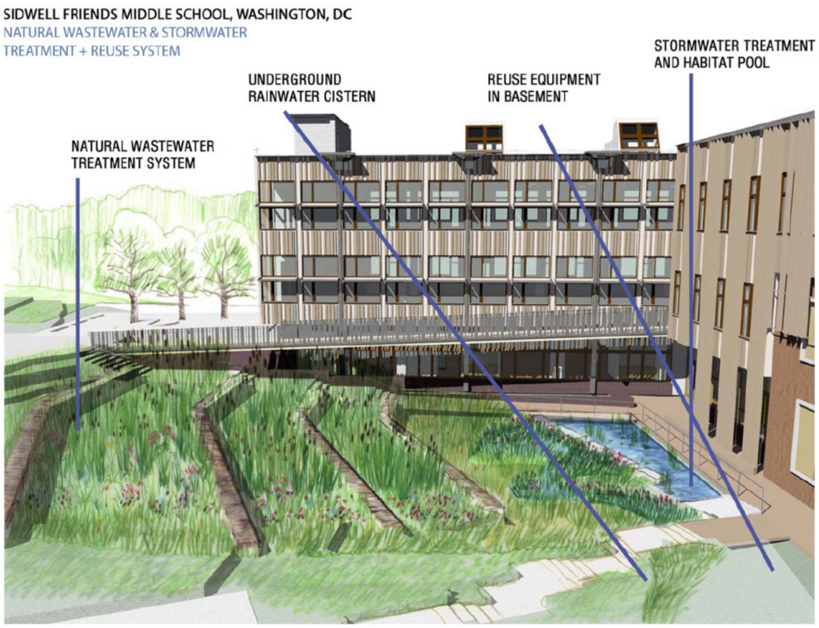

Figure 46. Constructed treatment wetlands are integrated into the design of the landscape at the Sidwell Friends School in Washington, DC. *Copyright NSI*

Figure 47. A photo of the completed alternative wastewater treatment system at the Sidwell Friends School. *Copyright NSI*

A preliminary assessment of the feasibility of using an alternative wastewater treatment system for the site was conducted. Based on the current program proposed for the site, approximately 500,000 gallons per day (gpd) of wastewater effluent is projected. Estimated conceptual wastewater design flow rates are summarized in the table below.

The following conceptual approach expands upon initial infrastructure discussions by detailing conceptual space and energy requirements. Wastewater infrastructure needed to treat and reuse approximately 500,000 gpd includes:

- Building/Block scale primary treatment (septic) tanks (approximately 10-20,000 gallons for each building/block)
- Septic tank effluent pump (STEP) system when gravity is not feasible
- Secondary treatment: eight acres of wetlands
- Tertiary treatment : a two to three acre complex called the Tertiary Treatment and Water Reuse Center containing:
  - two acres of nitrifying trickling filters,
  - recirculating pumps,
  - a 250,000 gallon non-potable water reuse tank (under reuse building),
  - pumps capable of maintaining building non-potable water pressure requirements (not fire requirements),
  - a water reuse building containing offices and treatment, monitoring and testing equipment,
  - micro filtration equipment (less than five (5) micron)
  - ultraviolet (UV) disinfection equipment,
  - NTU meter and automatic three-way diversion valve,
  - backup municipal potable water connection,
  - backup power supply, and
  - system controls and monitoring equipment.

Water not utilized in buildings for non-potable uses (toilets and cooling towers) may be used for irrigation.

As building program, architecture, and occupant use are better understood the conceptual design can be altered or adapted. This approach is a land intensive infrastructure; the secondary and tertiary infrastructure may be replaced with more energy intensive but smaller footprint systems.

Building	Total Floor Area (square feet)	Use	Flow Estimate (gallons per sq. ft.)	Estimated Flow	
				(gpd)	(m3/d)
A1	102,768	R & D, Office	0.1	10,277	38.9
A2	51,023	R & D, Office	0.1	5,102	19.3
A3	190,818	Hotel	0.35	66,786	252.8
B1	87,789	R & D, Office	0.1	8,779	33.2
B2	66,352	R & D, Office	0.1	6,635	25.1
C1	60,000	Sports / Entertainment	0.05	3,000	11.4

Building	Total Floor Area (square feet)	Use	Flow Estimate (gallons per sq. ft.)	Estimated Flow (gpd)	(m3/d)
D1	58,852	R & D, Office	0.1	5,885	22.3
D2	27,790	R & D, Office	0.1	2,779	10.5
D3	82,502	R & D, Office	0.1	8,250	31.2
E1	125,437	R & D, Office	0.1	12,544	47.5
E2	128,244	R & D, Office	0.1	12,824	48.5
F1	8,100	Retail, Water related use	0.05	405	1.5
F2	11,900	Retail, Water related use	0.05	595	2.3
F3	3,600	Retail, Water related use	0.05	180	0.7
G1	111,000	R & D, Office	0.1	11,100	42.0
G2	124,766	R & D, Office	0.1	12,477	47.2
H1	41,834	Mixed Infill	0.15	6,275	23.8
H2	35,902	Mixed Infill	0.15	5,385	20.4
H3	20,266	Mixed Infill	0.15	3,040	11.5
I1	27,014	Mixed Infill	0.15	4,052	15.3
I2	45,309	Mixed Infill	0.15	6,796	25.7
I3	41,304	Mixed Infill	0.15	6,196	23.5
J1	74,909	Mixed Infill	0.15	11,236	42.5
K1	59,160	Mixed Infill	0.15	8,874	33.6
L1	45,525	Mixed Infill	0.15	6,829	25.8
M1	44,549	Mixed Infill	0.15	6,682	25.3
N1	27,065	Mixed Infill	0.15	4,060	15.4
N2	70,390	Mixed Infill	0.15	10,559	40.0
N3	35,099	Mixed Infill	0.15	5,265	19.9
O1	23,080	R & D, Office	0.1	2,308	8.7
O2	41,207	Mixed Infill	0.15	6,181	23.4
P1	47,494	R & D, Office	0.1	4,749	18.0
P2	25,700	R & D, Office	0.1	2,570	9.7
P3	45,000	R & D, Office	0.1	4,500	17.0
Q1	159,040	Housing	0.18	28,627	108.4
Q2	90,500	Housing	0.18	16,290	61.7
Q3	74,000	Housing	0.18	13,320	50.4
Q4	73,040	R & D, Office	0.1	7,304	27.6
Q5	50,000	R & D, Office	0.1	5,000	18.9
R1	155,503	Light Industrial	0.1	15,550	58.9
S1	157,511	Light Industrial	0.1	15,751	59.6
T1	151,250	Light Industrial	0.1	15,125	57.2
U1	112,724	Light Industrial	0.1	11,272	42.7
V1	112,724	Light Industrial	0.1	11,272	42.7
W1	165,485	Light Industrial	0.1	16,549	62.6
	3,293,527		**Total Estimated Flow**	**429,237**	**1,624.7**
1 - Mixed Infill = Incubator, Office, Live / Work, Food / Drink, Retail					