Final Draft

Saw Mill River Daylighting Project At Larkin Plaza, Yonkers, NY

Photo: Larkin Plaza looking west toward the Hudson, May 2009

Restoration Plan

A Review of Ecological Opportunities and Physical Limitations

Prepared for the City of Yonkers
By Groundwork Hudson Valley

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Executive Summary

The daylighting of the Saw Mill River in Larkin Plaza offers a unique, and in the northeastern United States, unprecedented opportunity to incorporate ecological functions into a highly visible engineered daylighting project. A general lack of comparison projects and natural sites of similar character resulted in a synthetic approach to integrating habitat requirements with given basic engineering parameters, such as elevations, stream flow volumes, velocities and physical dimension. Based on the results of previous studies commissioned by the Saw Mill River Coalition, which found the water quality of the Saw Mill River impaired, ecologists and engineers together, in a cooperative process, evaluated the feasibility of implementing desirable ecosystem characteristics into the engineering design.

This report evaluates 11 such “Target Ecosystem Characteristics” (TECs) for their feasibility and rates their sustainability. A generally imperiled resource, the American eel, is given highest priority, with fish passage opportunities and introductions of an alewife spawning run also high on the priority list. The introduction of riparian and submerged aquatic vegetation has the potential to improve water quality, a critical element to support a viable food web.

Other TECs – while considered desirable – are given lower priorities because they are either (1) aesthetically not desirable, (2) simply don’t fit into the available space, (3) the feasibility needs further exploration and research, or (4) they are subject to regulatory constraints which may or may not be overcome with time.

The TECs that are going to be implemented should be closely monitored, documented and maintained, with management adapting to unforeseen and changing environmental challenges. Adaptive management will be the key to success. It is not sufficient to simply identify problems as they arise; the project management MUST include the funds and flexibility to take corrective action should ecological targets not be met.

The new section of the Saw Mill River should be reasonably biologically diverse and self-sustaining provided adaptive management succeeds to show positive results for a period of 5 years.

Introduction

The Saw Mill River enters the Hudson River approximately 17 miles north of Battery Park (southern tip of Manhattan island in New York City) in Yonkers. The river is located in the northern part of the Hudson River Estuary restoration study area, within which the US Army Corps of Engineers and the Port Authority of New York and New Jersey in partnership with the New York-New Jersey Harbor Estuary Program attempt to coordinate and guide ecological restoration efforts. The Saw Mill River was heavily altered during hundreds of years of commercial and industrial development. Within the city limits of Yonkers much of it runs within the confines of armored and straightened embankments until it disappears from view underground into a large culvert (the "flume"), an especially designed dome-shaped structure that takes the river below the inner city until it empties unceremoniously into the Hudson beneath the central train station.

The city government of Yonkers, as part of an ambitious downtown revitalization plan, has targeted approximately 800 feet of the Saw Mill River in Larkin Plaza for a "daylighting" project that will bring the river back to the light of day. The "daylighting project", as it is commonly called, will actually create a new path for the river to flow alongside the flume—which will remain in place to provide flood protection. A preliminary plan was developed prior to in-depth engineering studies. It called for the new river to have two separate and distinct aquatic environments: The upper section will be largely freshwater, and provide a location for the creation of a freshwater pool, which could provide water quality benefits. The lower section would be subjected to brackish water from the tidal Hudson River. This study was developed based on this concept in conjunction and cooperation with the design of final engineering plans. The final engineering plans modified the original concept, enlarging the freshwater portion and drastically reducing tidal and saltwater influence on the daylighted Saw Mill River in the new Larkin Plaza.

Comparable projects are rare and none have been done in the northeastern United States. Aside from the obvious importance of aesthetics, the health of the river is of concern. The newly daylighted section of the river has the potential to revitalize a severely degraded natural resource where it is most visible and will be noticed by thousands of commuters, shoppers and residents daily. The health of the river will be visible in the river's appearance and educational exhibits hold the promise of teaching the general public about basic important ecological principles, about watersheds and the balance between human development and natural systems—particularly because the project resides in a very urban area.

This report explores the potential for restoration of ecosystem components into the proposed daylighted river. Its purpose is to provide to the City's engineering and landscaping team—to the greatest extent possible—the richest habitat restoration scenarios and guidelines to be incorporated in the final plan. The various ecosystem components are evaluated for their apparent practicality and finally discussed with the design engineering team for inclusion into the final construction plans. The City anticipates that the coordination of the City's engineering/landscape team with the habitat team will be critical to the ultimate success of the habitat at Larkin Plaza.

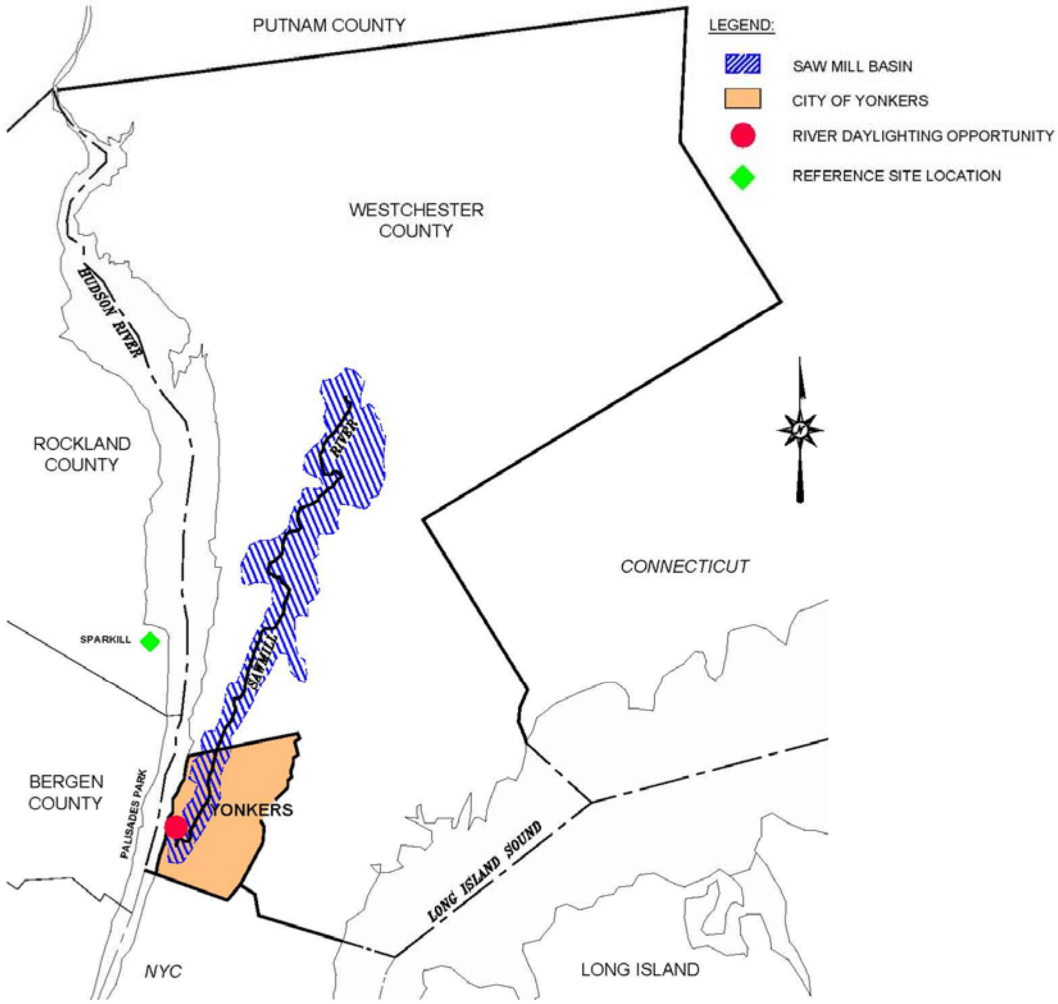


Exhibit 1
Location of the project site within Westchester County. The Saw Mill watershed is shown in blue shading. Larkin Plaza (red dot) is located at the very bottom of the watershed, just as the Saw Mill River empties into the Hudson River in downtown Yonkers.

Goals and Objectives

The overall stated goal is the establishment of a self-sustaining ecology for the newly daylighted Saw Mill River in Yonkers at Larkin Plaza. This goal includes the functional connectivity of this stretch of the river with its upstream watershed and with it's downstream estuary. The daylighting project takes up a large portion of Larkin Plaza. It begins east of the Metro North rail lines and extends approximately 800 feet upstream. The daylighting project will also attempt to restore attractive habitats at and near the mouth of the Saw Mill River, located west of the railroad, so that a greater number of fish and invertebrates will cross underneath the railroad into the daylighted stream instead of bypassing the Saw Mill River on their migrations up and down the Hudson.

The objectives range from the preservation and improvement of an existing resource, such as the use of the Saw Mill River by the American eel (*Anguilla rostrata*), to the restoration of historically known habitats and species, such as oysters (*Crassostrea virginica)*, several fish species, and submerged aquatic vegetation (SAV). The objectives also include the creation of new habitats that may never have existed at this particular location, but may be appropriate and will stand in for permanently lost opportunities. This includes the introduction of alewife (*Alosa pseudoharengus*), a river herring that migrates from the Atlantic into freshwater streams for spawning, also the spawning and juvenile habitat for white perch (*Morone americana*), and the provision of fish passage for various other fishes that are primarily living in freshwater but will travel through the brackish Hudson to migrate from one tributary to the next, such as white sucker (*Catostomus commersonii*), yellow perch (*Perca flavenscens*), and small-mouth bass (*Micropterus dolomieu*).

Given the unique site constraints as the centerpiece of an urban renewal plan, the restoration of historical marshes and shoreline forest vegetation will be confined to small token examples that have educational and symbolic rather than significant habitat value. Similarly, the restoration of a brackish lagoon or a historically dimensioned waterfall may be impossible to achieve. Emphasis will therefore be primarily on future function, not on a replication of the past.

Goals and objectives can only be achieved in an environment of constructive engagement and reassessment, especially in light of the fact that there is no known precedent for this project. For example, the daylighting will open the river to intense sunshine and therefore warming, which is a potential hazard that needs to be watched as the project is implemented. High water temperatures render the water low on physiologically available oxygen and can therefore threaten many of the stated objectives, or worse, result in fish kills and ecological setbacks. Along with the implementation of the project there must be a willingness to employ adaptive management techniques to address potentially hazardous environmental conditions as they arise, even if that would mean to re-think initial design concepts. As stated, it is foreseeable that the lack of sufficient shading on the river could result in the described scenario of oxygen deficiencies. If that were the case, the landscaping plan may need to be revisited and potentially altered to include additional shade trees, overhanging shrubs or other, as of yet unexplored solutions to lower the water temperature.

Site Description

The daylighting project begins east of the downtown Yonkers Metro North commuter train station at Larkin Plaza, occupied by a small municipal park, a war memorial, and by municipal parking. The terrain there is flat, rising at first slowly and then more noticeably toward the east. The new river will be the center of a renovated pedestrian plaza, ringed by low- and mid-rise commercial buildings, the library, the elevated train tracks and the station. Historically the entire Larkin Plaza was a bay of the Hudson river that was filled in over time as the city developed. The rise to the far east of the site represents the approximate location of the historic Saw Mill falls, which would have separated the estuarine mouth of the river from the freshwater upstream watershed and would have been insurmountable for most aquatic creatures, exempting perhaps the American eel and a few invertebrates. Today's Saw Mill River flows underground at the northern side of the existing park and plaza in a "flume" or engineered, large concrete pipe invisible to the general observer that was constructed by the Army Corps of Engineers in the early 1920's. The lower 500 to 600 feet of the flume are tidally influenced. Regardless of a final daylighting design, this flume will remain in place and functional to serve as a stormwater bypass to prevent flooding of the low-lying downtown area and importantly, to prevent the new park from flooding too. Given the site's central location and the long and diverse industrial history of Yonkers, there is a multitude of existing infrastructure features to be considered in the engineering design. The design must work for hydrology and stream flow considerations. It is also very likely that the soils may be deemed potentially contaminated. At the very minimum the daylighting design will therefore cap all existing soils and import known substrates for the new river bed and embankments. Complicating ecological planning is the known trash load carried by the river from its urban and suburban watershed of approximately 26.5 square miles. To limit the amount of debris and to exclude trash from the daylighted stream the flow will be strained through permanently installed trash nets that can be cleaned out just like garbage cans.

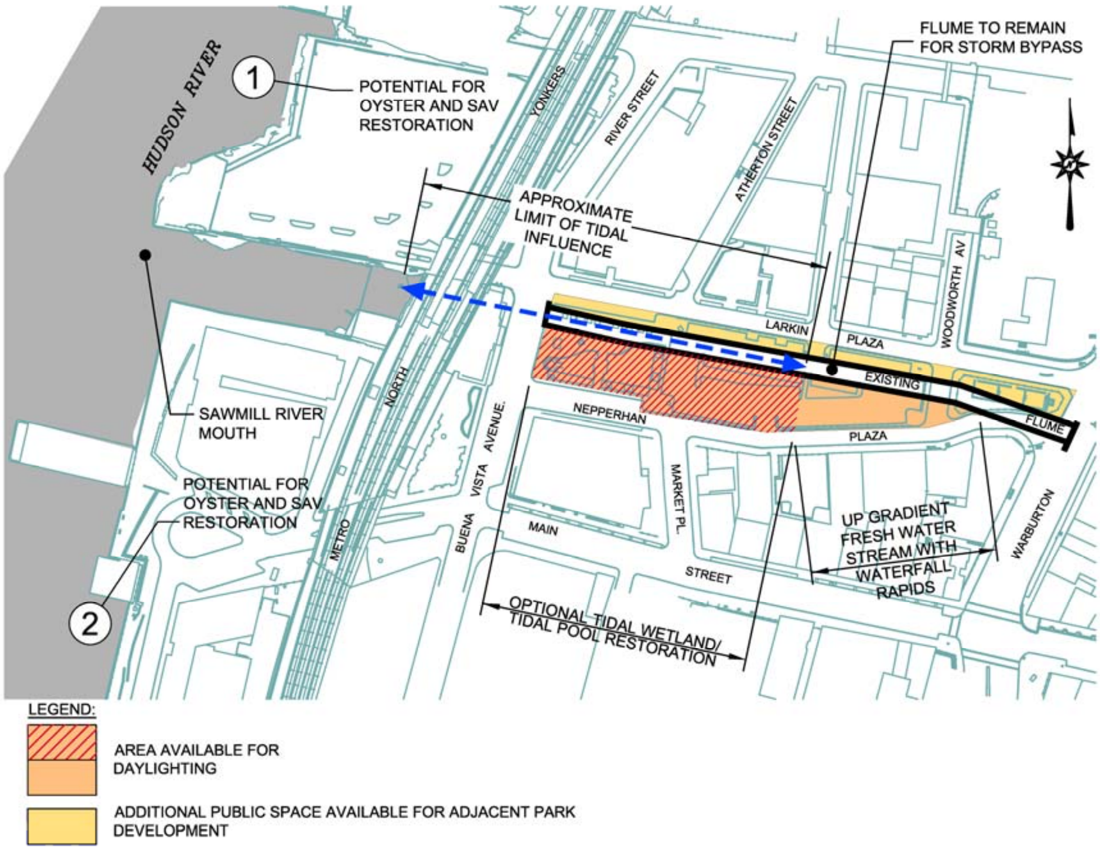


Exhibit 2

Plan view of Larkin Plaza and surroundings, highlighting portions of the plaza and the Hudson River as potential sites for the implementation of targeted ecological restoration projects. The dark orange hatching indicates the area of the future new channel that are theoretically within the tidal influence of the Hudson River, the lighter color orange highlights elevations above tidal influence. The numbered circles 1 and 2 indicate substitute locations for ecological restoration of the mouth of the Saw Mill River, which is restricted by historical preservation concerns.

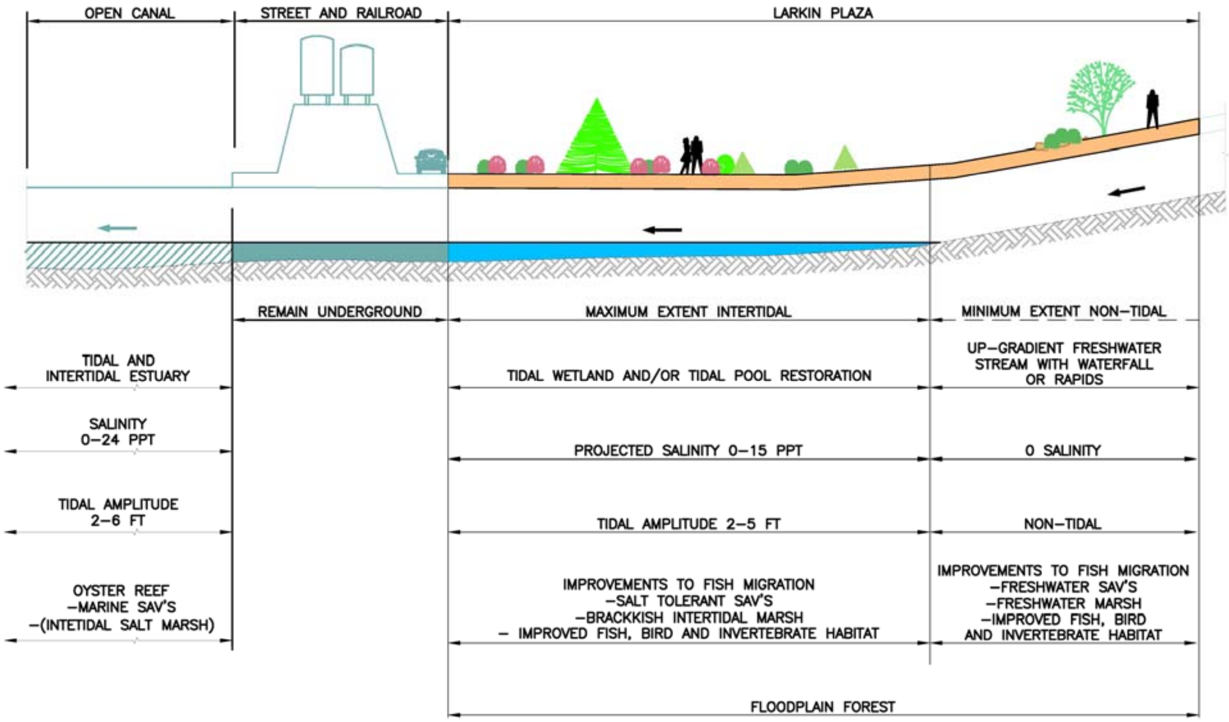


Exhibit 3
Theoretical cross section through Larkin Plaza and the mouth of the Saw Mill River referencing Exhibit 2. The diagram indicates projected tidal reach, amplitude and water quality characteristics. The potential extent of broadly described coastal and riverine systems and ecological target characteristics are listed in conjunction with tidal and water quality projections.

Ecosystem Targets

The daylighting of the Saw Mill River will create an entirely new stream that parallels the bypass flume. This stream will be very different from it's historical predecessor; there are no other known projects or natural sites for comparison. The engineering design will take ecological targets into consideration. These targets differ from most other restoration projects insofar as they are geared to achieve the most diverse array of ecological functioning without trying to fit the stream design into any pre-existing definition or characterization, maximizing hydrology, soils, plantings, etc. to create the most "habitat" for the largest number of animals and plants within the physical constraints of the site. Restoration targets attempt to mimic existing ecosystems and specialized habitat components, geared towards individual species, such as the American eel. The report follows the example and terminology used in the Hudson-Rariton Estuary Comprehensive Restoration Plan (Draft March 2009), circulated by the US Army Corps of Engineers, the Port Authority of NY & NJ, and the New York-New Jersey Harbor Estuary Program.

Referred to in this report as Target Ecosystem Characteristics (TECs), the defined targets for the daylighting project at Larkin Plaza are:

TEC 1: Preservation of the American eel and improvement of existing populations, by preventing blockage of migration corridors up and down the river, adding new passage opportunities and improving habitat for juveniles

TEC 2: Enabling fish passage by preventing the introduction of barriers while providing structures for fish passage, such as fish ladders, orifices, suitable openings, proper stream flow conditions, etc. for a variety of diadromous and potamodromous fishes

TEC 3: Establishment of beds of Submerged Aquatic Vegetation (SAV) in the freshwater portion of the river.

TEC 4: Restoration of beds of Submerged Aquatic Vegetation (SAV) in the brackish portion of the river mouth and nearby Hudson River

TEC 5: Introduction of alewife (river herring) **spawning run** and larval nursery

TEC 6: Restoration of an historical oyster reef

TEC 7: Restoration of a brackish intertidal marsh

TEC 8: Establishment of freshwater marsh vegetation along the shores of the new river

TEC 9: Restoration of the historic waterfall

TEC 10: Restoration of floodplain forest vegetation

TEC 11: Establishment of in-stream habitat complexity

Each Target Ecosystem Characteristic is described hereafter in detail. Following the individual descriptions, Table 3, in the Appendix, also provides a summary and overview.

Reference Ecosystems

Given the project location in the center of Yonkers, part of the greater New York City metropolitan area, it is very challenging to find appropriate reference ecosystems after which to model the restoration project. The Saw Mill River was historically a high-gradient stream, meaning that it fairly steeply descended to the Hudson, including a waterfall, insurmountable to migratory fish.

Approximately a dozen small streams, mostly in Palisades Interstate Park – on the opposite shores of the Hudson, west of Yonkers – still exist and can serve as a template for typical vegetation growing along such an embankment. On the Westchester shores of the Hudson, we found Barney Brook in Irvington as a potentially similar natural model for a "restoration" of the Saw Mill River.

Today's Larkin Plaza occupies approximately the space where the historic Saw Mill River had transitioned into a shallow estuarine bay; there, freshwater and brackish Hudson River water mixed. It was known for its rich fishing and as a safe port. The only and closest comparison of an existing bay in the same geographic region is the mouth of the Spar Kill at the northern end of the Piermont Marsh, just south and west of the Tappan Zee Bridge.

An investigation of the potential reference sites yielded very little information that could be of use at the Larkin Plaza setting. The list of tree and shrub species found at these sites, shown in Table I in the Appendix, may serve as a guide to species selection that will appropriately reflect our local riparian ecology.

Existing Data

The description of our target systems relies heavily on known species ecology (such as the American eel), on experience, on existing data from a nearby artificial brackish marsh at the Beczak Environmental Education Center, and on observations currently being conducted for this particular project.

In addition to the list of fishes recorded in seinings in the Hudson River by school classes at the Beczak Environmental Education Center (Table 2, in the Appendix), Pappanttoniou, in his 2003 study, recorded the following species in the Saw Mill River immediately above or below Larkin Plaza: American eel (*Anguilla rostrata)*, blacknose dace (*Rhinichthys atratulus)*, carp (*Cyprinus carpio)*, longnose dace (*Rhinichthys cataractae)*, mummichog (*Fundulus heteroclitus)*, striped bass (*Morone saxatilis)*, tessellated darter (*Etheostoma olmstedi)* and white perch (*Morone americana)*.

In 2002, the Saw Mill River Coalition conducted its first stream-walk and compiled a short report about benthic invertebrates in the upstream watershed just outside of Yonkers (Christie/Feller). The analysis concluded that there were not enough macro invertebrates present for a characterization beyond saying, that the water quality is impaired. This leaves us to conclude that the same or further deteriorated water quality will be flowing through the daylighting section at Larkin Plaza, making it most important to avoid additional negative impacts on water quality and providing as many water quality enhancing features as possible, such as plantings of marsh, riparian and submerged aquatic vegetation.

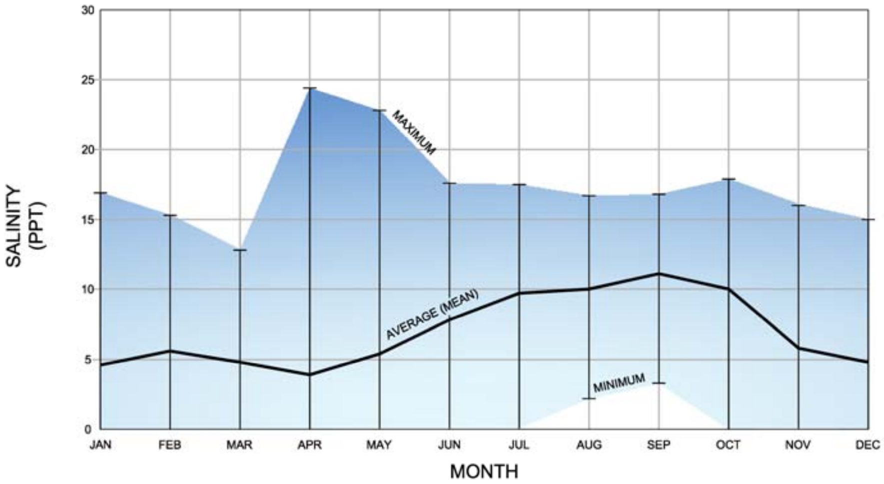
Other known data are a tidal amplitude of up to 1.8 meters during spring tides, 1.2 meters at neap tides and 0.6 meters of mean high water at the mouth of the river, salinity values of 0 to 24 ppt, with the average and the overwhelming majority of them in the range under 10 ppt, and water temperatures that more or less follow the average high air temperature with some delay, reaching a peek around 25 degrees Celsius (average) during August.

The tide data were derived from a NOAA tide gage at Alpine and were calculated by PS&S engineers, the design engineers for the daylighting project. The salinity and temperature data came from a permanent climate and tidal monitoring station located at the Beczak Environmental Education Center a few hundred feet upstream of the mouth of the Saw Mill River (see Exhibit 4). These data were averaged from roughly 30,000 data points over a 5-year period (as shown in Table 4 in the Appendix). The instrument operated for long stretches of time with interruptions for maintenance and malfunction. The data shown here were selected from a larger number of data, some of which were eliminated because they were suspected of having been faulty. The extremes of the data most likely resulted from the data collector's positioning near the water surface – and possibly slightly above the water surface during very low ebb tides. The static sensors captured data from a variable depth of water column ranging from 0 to 1.5 meters as rising and falling tides passed the instrument.

All three parameters will change with increasing distance from the Hudson River. Salinity, for example, will be of negligible influence within the daylighted portion of the river, but may in some instances reach the tidal pool in the lower portion of the project. The tide has the potential to reach farther upstream as freshwater backs up onto an incoming tide. Water temperatures will be heavily influenced by the warming and cooling of water in the entire watershed and could exceed those of the Hudson River.

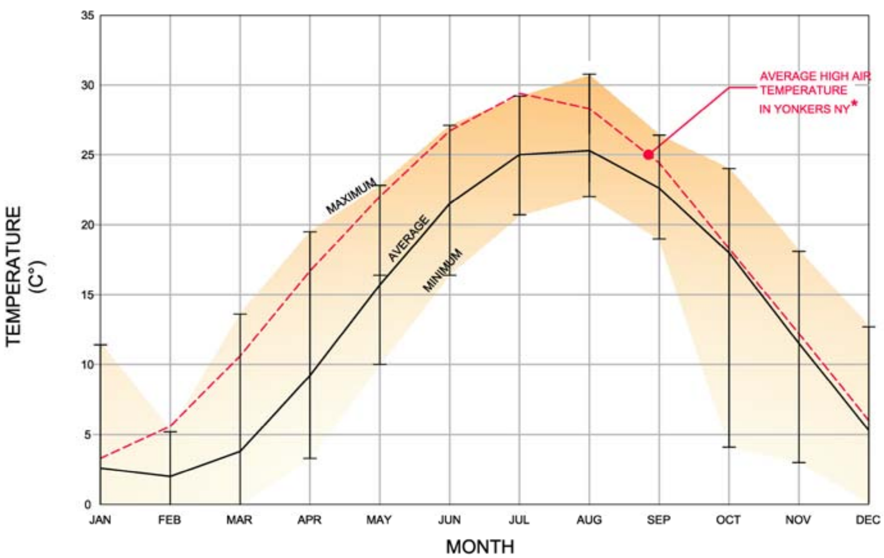
Site topography and overall shape will be determined based primarily on engineering priorities, such as the need to preserve existing infrastructure and by substrate characteristics. Site design will also be driven by the future use of the site. It may prove impractical to implement the list of ecosystem targets in its entirety. Target priorities may shift or they may be abandoned altogether.

To some degree permanent Best Management Practices (BMP's), such as stormwater filtration and infiltration trenches, litter-traps, road maintenance and safety operations (mowing, sanding, salting), surface treatments, grease traps (storm-ceptor etc.) will be taken into account and will influence the final design. Likewise stream flow velocity and volume projections will dictate design elements such as bank and streambed materials.



SALINITY (PPT) IN SHALLOW HUDSON RIVER WATERS

DEC 2005-MAR 2010



WATER TEMPERATURES (C°) IN SHALLOW HUDSON RIVER WATERS

*AIR TEMPERATURE SOURCE: THE WEATHER CHANNEL

DEC 2005-MAR 2010

Exhibit 4

5-year average salinity and water temperature graphs as recorded by an automated data logger stationed at the Beczak Environmental Education Center just a few hundred feet upstream of the mouth of the Saw Mill River in the Hudson River. While the average salinity rises to approximately 10 ppt during the summer (July – October), from a winter average of around 5 ppt, it clearly is not predictable at any given moment, ranging from extremes of 0 ppt to over 20 ppt within the same month (faded blue range). The water temperature, on the other hand, appears to be closely correlated with the average air temperature.

<u>Detailed Descriptions of Target Ecosystem Characteristics (TEC)</u>
(A summary and overview of all TEC's is shown in Table 3 in the Appendix.)

<u>TEC No. 1:</u>
Preservation and Improvement of American Eel Populations (*Anguilla rostrata)*

The Saw Mill River has a watershed of approximately 26.5 square miles but only limited migration by the American eel, as documented by Schmidt in 2008. Here the species is mostly impaired by a dearth of suitable habitat for juveniles and by a dam at Woodlands Lake (7 miles upstream of the mouth of the river) that only passes few specimen. Specifically designed eel ladders can ease the migration past Larkin Plaza in both directions. While changes at Woodlands Lake are not covered by this project, eel passage past Larkin Plaza provides new opportunities within the upstream watershed and future projects may want to address the impact this dam has on the species.

Eels generally shun the daylight and are therefore not necessarily drawn to the daylighted river section. To get the eel to enter into and through the daylighted stream at Larkin plaza, conditions to make them want to enter this section must be attractive to them. We presume that a constant low velocity flow and suitable substrate should accomplish that. Incidentally, eels tend to remain in the lower section of streams for several years before migrating upstream as three- to five-year old yellow eels (10 to 15 cm long). The upstream migration of eels arriving from the spawning grounds as large larvae (glass eels) and as small juveniles (elvers) is very slow, making it MOST important to provide them with as much quantity as well as quality juvenile habitat at Larkin Plaza as possible. The larvae and juvenile eels must survive and grow here for 3 to 5 years before their upstream migration. Nevertheless, a small number of glass eels and elvers does attempt to migrate upstream as soon as they arrive at the mouth of the river, making it important that the velocities and substrates of the river also meet the requirements for upstream migration of these size and developmental classes. In a small 2010 DEC American eel study , glass eels were found at the mouth of the Saw Mill River, but not upstream of the flume. The poor habitat condition of the flume may be preventing glass eels and elvers from growing into large enough specimen to reach the upstream end of the flume in significant numbers, therefore limiting the total number of adult eels in the watershed. Downstream migration, on the other hand, occurs in the fall and involves adult eels that are on their way to the spawning grounds. They typically follow the flow of the river, so that nets and trash racks can be impediments and deadly traps for them. Eels only spawn once and die at the spawning grounds (presumed to be the Sargasso Sea in the Atlantic Ocean off the Bermuda islands). They never return as adults to their freshwater habitat. Soon after entering the freshwater stream as juveniles the eels will look for suitable habitat and food. Small eels (under 35 mm long) feed primarily on aquatic insects. Eels greater than 35 mm in length eat mostly crayfish and finfish, including smaller eels. Their habitat consists primarily of nooks and crevices to hide in, such as space between roots of trees along the embankment and rocks in the bed of streams. They will also burrow into soft mud. Eels will leave the water on wet surfaces to move from place to place and they can scale almost vertical rises as long as the substrate allows them to propel themselves forward. The use of lots of rock with crevices between them will benefit the young eels as they begin to establish themselves in the freshwater environment before moving further upstream. As yellow eels they move up the Saw Mill River looking for better habitat and larger prey. As large eels, they slow down and become mostly sedentary. They will do so for up to 20 years until maturity and before returning to the sea to spawn. Eel ladders to facilitate their movement farther upstream are important and must be part of the overall site design.

Future consideration should be given to enhance the eel habitat in miles of channelized sections of the Saw Mill River and to building an eel ladder at Woodlands Lake dam. In this way the improvements afforded by the daylighting project can increase the survival of the species throughout the system and improve their numbers in the Saw Mill River.

Improvements to the habitat and survival of the American eel are particularly timely and important at this location, since the discovery of a parasitic swim bladder disease (the nematode *Anguillicola crassus*) in a large portion of eels along the American eastern seaboard, estimated to affect up to 60 percent of all eels in the Hudson River. The disease appears to infect eels living in the Hudson tributaries less then in the Hudson main stem (Machut et al. 2004). Tributaries serve as nurseries for juvenile eels. Barriers in the tributaries often prevent a significant number of eels from moving upstream in the tributaries, so that the majority of eels in the Hudson River drainage reside and mature in the Hudson River itself. The disease-causing nematode, a natural parasite of the Japanese eel (*Anguilla japonica*) was presumably introduced to the Atlantic eels (*A. rostrata* and *A. anguilla*) through aquaculture facilities and was discovered first in Europe in the early 1980's and subsequently in America in the early 1990's. While not proven, it stands to reason that improvements in the permeability of tributaries to juvenile eels into uninfected habitats would enhance their chance to grow, mature and migrate to the spawning grounds (the swim bladder infection does not kill the eel but prevents it from swimming in open water, thereby preventing migration of infected individuals to the spawning grounds).

Recommended Basic Actions:

a) Provide notch in diversion dam (inside existing flume) and ramp with suitable surface substrate for passage upstream to the notch and into ponded water of the diversion chamber, suitable for glass eel and elver migration.
b) Provide notch and low-flow conditions at confluence weir suitable for glass eel and elver upstream migration into the daylighted river section.
c) Provide low-flow conditions and eel ladders at various locations beginning at the tidal pool and ending at the diversion chamber.
d) Provide downstream bypass at netting chamber for adult eels.
e) Use rocks as substrate, create embankment overhangs, and provide snags for cover.
f) Provide ample Submerged Aquatic Vegetation (SAV) in the future freshwater stream channel for eel nursery habitat and aquatic insect habitat (food source for small eels).
g) Provide low-flow areas for resting migratory eels.
h) Provide eel ladders with options for trapping devices to conduct monitoring and scientific research.
i) Provide monitoring and maintenance.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

j) Substrate materials on eel ladders and velocity of flow must be suitable for eel size classes encountered at the lower Saw Mill River. Unsuitable substrates and flow velocities will act as barriers.

k) Presumed passages may not work as anticipated, or unexpected barriers could be found.

l) Eel passages must be made "attractive" to migrating eels – velocity and sound of flowing water must draw eels in – distraction to insurmountable "falls" should be avoided.

m) Eel passages and notches in weirs may get blocked by floating debris. Periodic maintenance will be required; lack thereof could prevent eel passage.

Feasibility and Sustainability are both ranked very high. This TEC can be implemented. The implementation of this TEC carries with it the opportunity of improving a threatened natural resource for the entire length of the Saw Mill River. A measurable increase in all size classes is anticipated over the first 5 years after installation.

Desirability

Due to the imperiled nature of the American eel, implementation of Tec No. 1 is highly desirable and it is highly recommended.

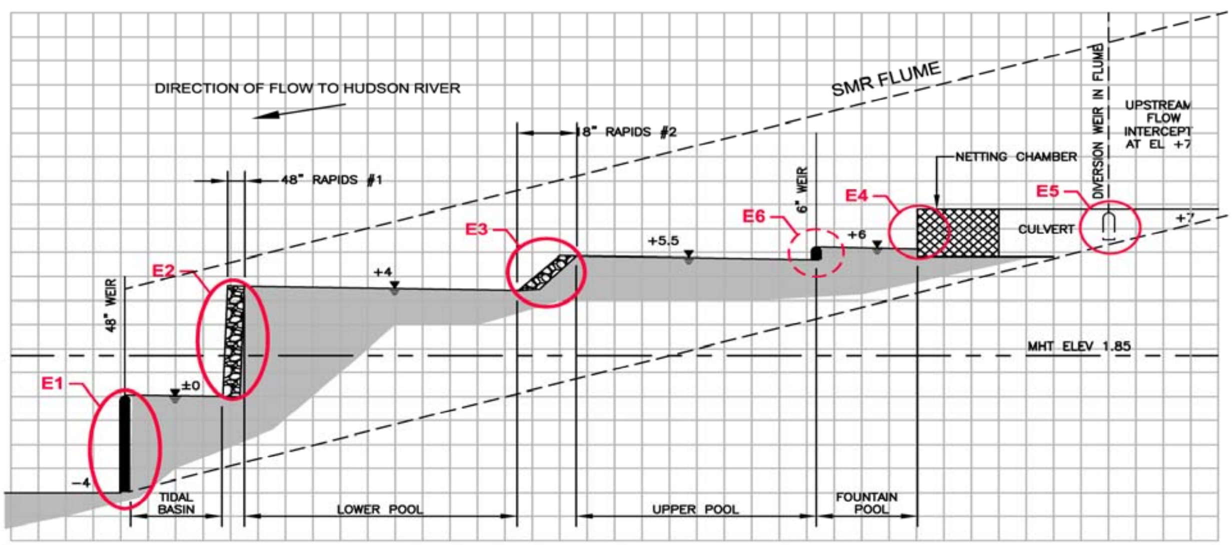


Exhibit 5

Schematic cross section of potential blockages for eel migration into, within and out of the daylighted Saw Mill River at Larkin Plaza. Each location must be reviewed separately and individual technical solutions for the incorporation of eel ladders and avoidance of obstacles (such as the nets in the netting chamber) must be found. This schematic was based on preliminary engineering plans.

TEC No. 2:
Enable Fish Passage, Eliminate Barriers and Establish Structures

Barriers, such as dams, weirs, culverts and concentrated flows are commonplace in Hudson River tributaries. They reduce or entirely prevent the upstream mobility of fish within a stream. For the daylighted section of the Saw Mill River to have a fish population and for this population to have the ability to potentially expand further upstream into the watershed, the new stream must be built without barriers to fish passage.

Fish passage structures must address at the very minimum the transition between flume and daylighted river section in both directions, upstream and downstream. The fish must be positively attracted to the new river bed, there must be sufficiently sized openings to pass the fish, water velocities must be varied, have certain maximum speeds for individual species, and resting places where longer runs or larger elevation differences are targeted. Typical structures passing fish would be notches in weirs or uneven weir crests, fish ladders (preferred for this project is the Alaskan Steep Pass), naturalistic boulder arrangements in fast-flowing sections of the stream, and simple lateral bypasses of obstructions, such as is the case with the debris catching nets. For monitoring purposes, some of these structures should be build to allow for the occasional installation of research fish traps.

Fishes that would benefit from access to the newly created section of stream are the diadromous white perch (*Morone americana*), which is common in the Hudson River and spawns in tributaries roughly at the intersection of fresh and brackish water (documented at Dock Street, Pappanttoniou 2003, and the alewife (*Alosa pseudoharengus*), which is discussed in much detail in TEC 5, below.

Other species potentially benefiting from fish passages are white sucker (*Catostomus commersonii*), yellow perch (*Perca flavenscens*), and smallmouth bass (*Micropterus dolomieu*), Schmidt 2008.

Fish passage past the daylighted section of the river should also be considered important, even though there will remain a long underground section of the river after the daylighting project is complete. Forward looking, the possibility that additional stretches of the Saw Mill River could be daylighted should not be ignored, as for example a large development at Chicken Island (where the river goes underground) proposes to daylight five hundred (500) feet of river, and thereby re-creating fish habitat and migration opportunities.

TEC No. 2: Enable Fish Passage, Eliminate Barriers and Establish Structures, continued:

Recommended Basic Actions:

a) Provide notch and low-flow conditions at confluence weir suitable for passage of various size classes of fishes into the daylighted river section.
b) Provide low-flow conditions and fish ladders at various locations beginning at the tidal pool upstream and ending at the diversion chamber, such as an Alaskan Steep Pass between tidal pool and lower freshwater pool, design boulder placement and sizing suitable for fish passage from lower freshwater pool to upper freshwater pool, and provide weir modification, such as tilted crest, notch or orifices in weir between upper pool and fountain (daylight) pool.
c) Provide bypass at netting chamber for migrating fish.
d) Use rocks as substrate, create embankment overhangs, and provide snags for cover.
e) Provide ample Submerged Aquatic Vegetation (SAV) for nursery habitat and aquatic insect habitat (food source for fish).
f) Provide low-flow areas for resting migratory fish.
g) Provide fish ladders with options for trapping devices to conduct monitoring and scientific research.
h) Provide monitoring and maintenance.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

i) Size of passage structures and velocity of flow through them must be suitable for various size classes of fishes. Unsuitable structures and flow velocities will act as barriers.
j) Presumed passages may not work as anticipated, or unexpected barriers could be found.
n) Fish passages must be made “attractive” to fish – velocity and sound of flowing water must draw them in - distraction to insurmountable “falls” should be avoided..
k) Fish ladders and notches in weirs may get blocked by floating debris. Periodic maintenance will be required; lack thereof could prevent fish passage.

Feasibility and Sustainability are both ranked high. This TEC can be implemented. The implementation of this TEC will populate the Larkin Plaza portion of the Saw Mill River with natural resources that currently are not using the site. An increase of species diversity over 5 years is expected.

Desirability

Tec No. 2 is highly desirable and it is highly recommended as it opens up habitat opportunities at Larkin Plaza for a variety of species. Implementation will set the stage for upstream fish migration, once such opportunities arise as future daylighting projects occur.

TEC No. 3:
Establishment of Freshwater Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation would have been a typical and integral part of all natural tributaries in the Hudson River estuary before urbanization changed the hydrology, water chemistry and ecology. SAVs provide food and shelter for invertebrates and fish alike, thereby contributing significantly to the health and abundance of life in a river.

Stream flow, bed and bank conditions in the daylighted section of the Saw Mill River are man-made and can therefore be engineered to allow for the establishment of SAVs, much in contrast to long stretches of the “unaltered” river further upstream, where flashy urban and suburban stormwater flows promote variable bank and bed erosion as well as sedimentation. Nevertheless, there are no examples of SAV establishment in comparable settings known to the investigator.

Target species for Larkin Plaza could be American eelgrass (*Vallisneria Americana)*, Nuttall’s waterweed (*Elodea nuttallii)*, coontail (*Ceratophyllum demersum)*, and marsh seedbox (*Ludwigia palustris)*.

The establishment of SAVs will require plantings into suitable substrate (gravel or sand), in places of moderate stream flow velocity, with adequate predator protections (against snapping turtles, muskrats and geese). If successful, the beds should be self-sustaining within 1 to 3 years.

Feasibility is ranked high**.**

Sustainability is unknown, but conceivable effort should be made to enable this TEC be self-sustaining within 3 years of planting. The implementation of this TEC will provide significant structure and natural resources to the Larkin Plaza portion of the Saw Mill River.

Recommended Basic Actions:

a) Provide suitable substrate – sand, gravel – in locations with moderate flow and water depth greater than 0.5 meters.
b) Plant at high density at season recommended by suppliers.
c) Protect planting with temporary predator excluder below and above water.
d) Provide monitoring and maintenance.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

e) Unforeseen predators (biting, chomping, digging), such as various invertebrates or fish species; be prepared to modify predator excluders accordingly.
f) Scouring and ripping water currents; be prepared to relocate planting as needed.
g) Debris damage to predator excluders; be prepared to fortify excluders, remove debris regularly

Desirability

Tec No. 3 is highly desirable and highly recommended as a vital habitat and water quality component that will substantially contribute to the success of Tec No.1 and Tec No. 2.

TEC No. 4:
Establishment of brackish-water Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation (SAV) would have been a typical and integral part of the sheltered bay below the Saw Mill River falls in the Hudson River estuary. Since there are known records of these plants, a re-construction of SAV beds in brackish water will be experimental and unprecedented for the lower Hudson. The importance of SAVs for food and shelter for invertebrates and fish however makes such an attempt desirable. If SAVs can be restored to the mouth of the Saw Mill River that will contribute significantly to the health, abundance and diversity of life in the river.

According to the New York Natural Heritage Program Conservation Guide brackish subtidal aquatic vegetation beds are characterized by rooted aquatic vegetation. The water salinity values range from 0.5 to 18 parts per thousand (ppt) – similar to the values recorded nearby at the Beczak Environmental Education Center (see Table 4), and the water depth at low tide is typically less than 2 m (6 feet). Plant species may include sago pondweed (*Stuckenia pectinata*), widgeon grass (*Ruppia maritima*), coontail (*Ceratophyllum demersum*), and naiad (*Najas guadalupensis*).

Complicating the restoration of SAV beds in the tidal Hudson is the turbidity of the water (which would have been significantly less in the historic, protected bay below the falls), limiting light penetration into the water column and therefore the depth at which plants can grow. Furthermore, the remnants of a historic wharf at the mouth of the Saw Mill River prohibit any structural or other modifications there, so that the establishment of SAVs should be attempted in nearby sheltered coves of the Hudson River.

Prior to finalizing plans for SAV restoration in the tidal Hudson, data gathered from experiments undertaken to see if the turbidity can be reduced are being conducted (by installing turbidity curtains and observing and measuring if reductions in turbidity occur). Simultaneously the natural background turbidity at known brackish water SAV beds should be documented and compared to the experimental values behind turbidity curtains at the mouth of the Saw Mill River. Ultimately, if turbidity curtains hold promise to produce suitable habitat conditions, environmental permits for the establishments of SAV beds may need to be acquired from the New York State Department of Environmental Conservation.

Recommended Basic Actions:

a) Data gathering on background turbidity in natural stand of the listed target species for use as benchmarks.
b) Construction of experimental silt excluders in the proposed SAV planting locations.
c) Turbidity measurements in experimental silt excluders to compare to benchmark values.

TEC No. 4: Establishment of brackish-water Submerged Aquatic Vegetation (SAV), continued:

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

d) Suitable field locations of the plant species must be identified.
e) If field conditions prove promising for the future establishment of brackish SAV beds at the mouth of the Saw Mill River, funding and a sustained commitment to further experiments with plant species and silt excluders as well as environmental permits from regulatory agencies must be secured.

Feasibility and Sustainability are unknown; further site investigation and research will be necessary to ascertain its potential for implementation.

Desirability

Tec No. 4 is desirable as a magnet for a multitude of species to the mouth of the Saw Mill River.

<u>TEC No. 5:</u>
Introduction of Alewife Spawning Runs

Alewife (*Alosa pseudoharengus*), are river herrings that migrate from the Atlantic into freshwater streams for spawning, returning to their ancestral streams where they had hatched. In the lower freshwater Hudson drainage alewife find it difficult to imprint on individual streams, as their larvae do not spend long enough time in their natal rivers, being flushed downstream before they can reach several months of age (verbal communications, R. Schmidt 2009). Daylighting of the Saw Mill River affords the opportunity to establish an additional site for alewife to spawn – and for larval development pending successful SAV establishment. The Saw Mill River would be the first tributary in the lower Hudson the fish would encounter to be suitable for spawning on their migration upstream, and would therefore almost certainly attract alewife.

For alewife to pass into the daylighted river, velocities must not exceed 3 feet per second and there must be suitable passages for them to advance to low velocity portions of the stream where they can spawn. There is a good possibility that the alewife will choose to travel up the Saw Mill River on their own after suitable conditions have been created.

There have been precedents where fish have been moved from one part of an estuary to new spawning grounds in an effort to establish a new herring run, as was recently the case in the Bronx River NYC Parks Department Press Release. In order to imprint alewife onto the Saw Mill River, larval development must be sustained in the river for 4 to 6 weeks (verbal communications R. Schmidt). The nearest suitable larval nursery can be found in Woodlands Lake, a man-made lake located approximately 7 miles upstream in a county-owned park. A 15-foot high dam blocks access to the lake for fish. Fitting that dam with a fish ladder and releasing spawning alewife into the lake could potentially lead to the establishment of an alewife run independent of those of the Hudson River.

Recommended Basic Actions:

a) Provide suitable fish ladders/passage as described in Tec #2.
b) Provide low-flow conditions in portions of the upper and lower freshwater pools suitable for spawning and larval retention – preferably near stands of SAVs.
c) Identify donor site for spawning adults in coordination and under permit by the NYS Department of Environmental Conservation.
d) Check if the species will "discover" the daylighted Saw Mill River on its own – if not capture gravid adults and release at "fountain" and "upper pools"(see Exhibit 6).
e) Monitor for larval retention time and for return of hatchlings as adults approximately four years after birth.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

f) Insufficient larval retention time may cause failure to imprint on the Saw Mill River and failure of hatchlings to return as spawning adults.
g) Dark culvert passage under the railroad tracks may prevent passage of adults into the Larkin Plaza section unless they are imprinted on the Saw Mill River.

TEC No. 5: Introduction of Alewife Spawning Runs, continued:

Feasibility is ranked high and **Sustainability** is probable. Sustainability should be detectible within 4 years of first spawning.

Desirability

Tec No. 5 is desirable as this natural resource has historically been prevented by dams and weirs from entering into suitable breeding habitat. If successful, the introduction of an alewife spawning run will afford a rare environmental education opportunity at a heavily frequented inner-city location.

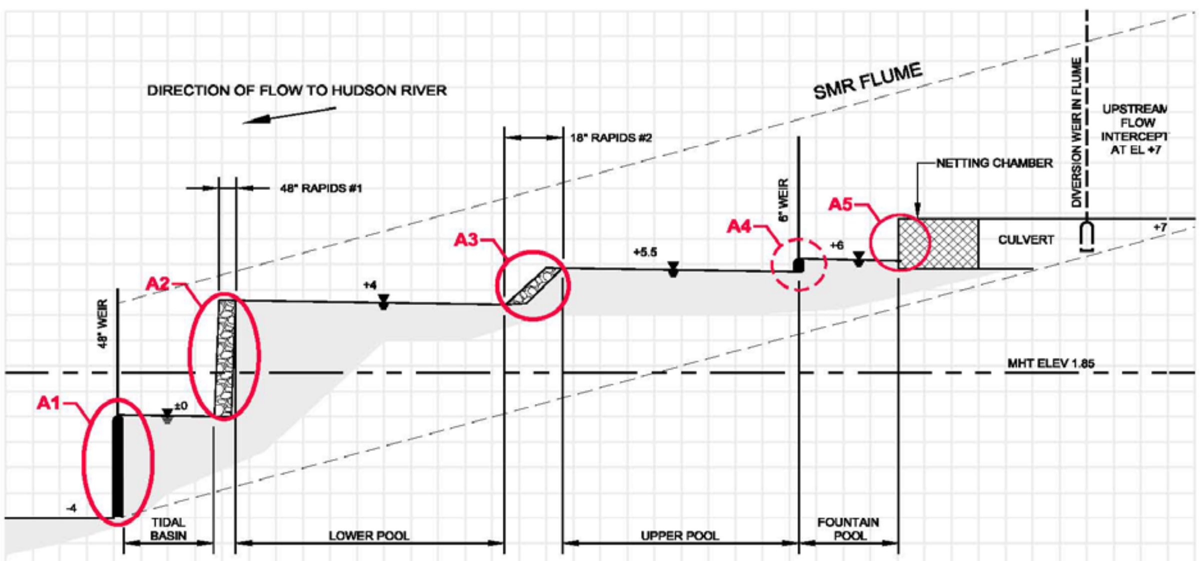


Exhibit 6

Schematic cross section of potential blockages for fish migration into, within and out of the daylighted Saw Mill River at Larkin Plaza. Each location must be reviewed separately and individual technical solutions for the incorporation of fish ladders and avoidance of obstacles (such as the nets in the netting chamber) must be found. This schematic was based on preliminary engineering plans.

TEC No. 6:
Restoration of Historic Oyster Beds

The Eastern oyster *(Crassostrea virginica*, a.k.a.: American, Atlantic or Virginia oyster) has established populations in the Hudson River not far from the restoration site. One of those populations has persisted for at least 10 years at Alpine, just across the Hudson River on subtidal stone. We also found evidence of perhaps failed establishment at the mouth of the Saw Mill River in form of juvenile oyster shells in subtidal waters. The oyster is native to the Hudson as far north as the Haverstraw Bay, where it still exists under nearly freshwater conditions (verbal communications Jeffrey Levinton). Historically this species was considered a keystone species in the Hudson estuary that many other species depended on for their survival. Since the crash of the population approximately 100 years ago, the restoration of large reefs has become of scientific interest only within the past decade. To date there are no known pilot reef projects in the Hudson River. The NY/NJ Baykeeper on the other hand establishes and maintains community-based oyster gardens in many locations in New York City, a few of which are in the Hudson River – one of them at the Beczack Environmental Education Center.

The regulatory environment does currently discourage the re-establishment of oyster beds, particularly due to concerns by the New York State Department of Environmental Conservation about health risks associated with water contamination (sewage) of the Hudson River. Oysters are filter feeders that accumulate pathogens and toxins, such deadly cholera bacteria (*Vibrio cholerae*) and PCB's, contaminants in Hudson River sediments. Because oysters are also considered a delicacy and are frequently harvested for human consumption, poaching of an artificial, highly visible reef remains a serious concern. A restored oyster bed would therefore have to be safely guarded, a stipulation difficult to guarantee at a publicly accessible site.

The restoration of historic oyster beds, desirable as it would be, will have to be phased in over time. Groundwork Hudson Valley's participation in the oyster gardening program of the NY/NJ Baykeeper (began in 2009) opens an opportunity to study the growth and survival of these animal at the mouth of the Saw Mill River at the Science Barge. Over time and with sustained interest in the oyster gardening program, Groundwork Hudson Valley might hatch it's own larvae and raise it's own spat (small oysters). From there the step to establishing an artificial reef is small. The schematic in Exhibit 7 shows how an artificial oyster reef could be "seeded" and maintained in combination with an oyster gardening program. Artificial reef substrate for oyster attachment can be studied experimentally. It may include ceramic tiles, fossil clamshells, and plastic structures, or the oysters could be maintained in removable wire baskets, where they could be inspected, measured and weighed (research). Maintaining an artificial reef is ultimately a numbers game, as oysters mature rapidly, are normally short-lived due to predation and parasitism, and spawn prolifically. If enough of the larvae can be retained and settled on the reef, the cycle can be maintained. For this to occur, the relative isolation of the site at the mouth of the Saw Mill River (at least a mile from Alpine) may require the artificial raising of oysters in a laboratory setting and the subsequent release of the spat onto the reef.

Recommended Basic Actions:

a) Continued cooperation with NY&NJ Baykeeper program of oyster gardening.
b) Expanded oyster gardening program involving larval rearing and setting.
c) Continued and expanded contacts to other "reef" initiatives within the New York harbor and Hudson-Raritan estuary.
d) Regular contact with regulatory agencies about conditions under which an artificial reef could be permitted.
e) Develop a site-specific design and permit proposal, including maintenance and operations program proposal.
f) Education campaigns at the Science Barge and Beczak Environmental Education Center.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

g) Poaching
h) Predators
i) Diseases

Feasibility is moderate from a technical perspective, but ranked "not feasible" at this time due to regulatory prohibition**.**
Sustainability – not self-sustaining; if implemented in the future this TEC will require consistent maintenance.

Desirability

Tec No. 6 is desirable as a magnet for a multitude of species to the mouth of the Saw Mill River and as an environmental teaching tool.

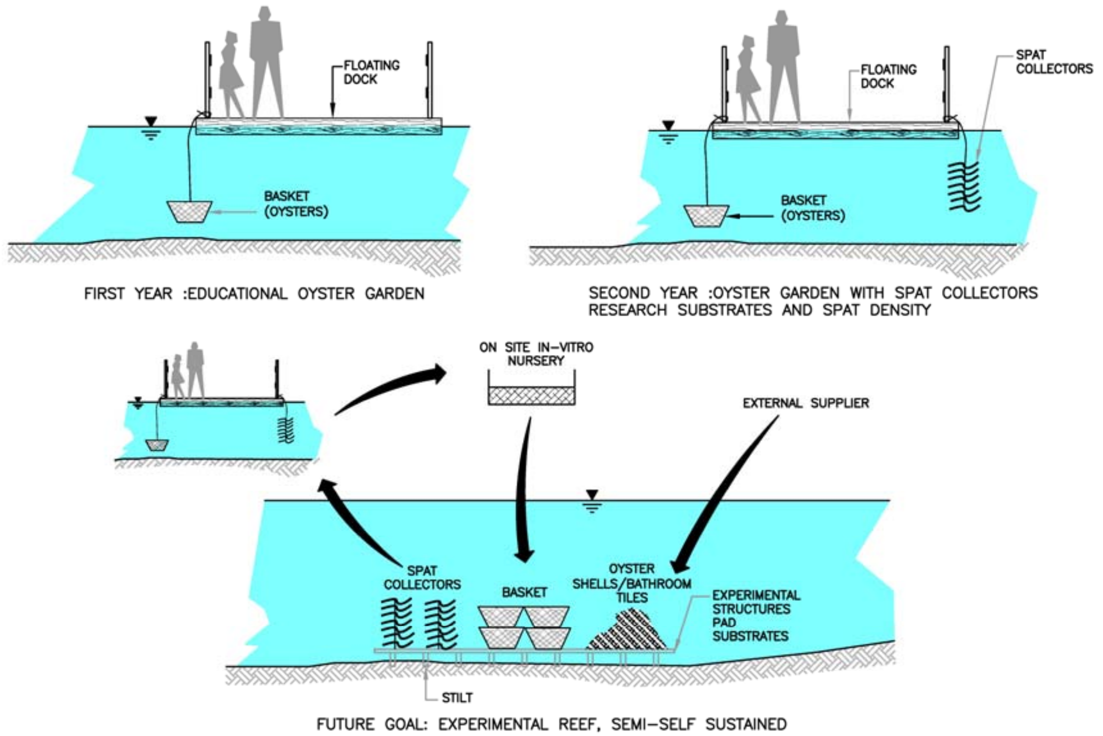


Exhibit 7
Schematic cross section of a hypothetical oyster gardening program that could be developed into a semi-self sustaining oyster reef. The oyster gardening/restoration project can be implemented independently of the daylighting project at the mouth of the Saw Mill River. Oyster reefs provide structure and habitat utilized by many Hudson River invertebrates and fish, increasing the attractiveness of the confluence region with the Saw Mill River for these organisms and thereby increasing the diversity of the Saw Mill River.

TEC No. 7:
Restoration of Brackish Intertidal Marsh

The precedent setting constructed intertidal marsh at the Beczak Environmental Educational Center, just hundreds of feet upstream of the confluence of the Saw Mill and Hudson rivers, can serve as a reference site for the establishment of similar small wetland pockets at the mouth of the Saw Mill River. Those marshes will be dominated by smooth cordgrass *(Spartina alterniflora*), black needlegrass (*Juncus gerardi*), hightide bush *(Iva frutrescens*), giant cordgrass *(Spartina cynosuroides*), prairie cordgrass *(Spartina pectinata*) and three-square *(Scirpus americanus*). Work to establish an intertidal marsh may require small amounts of fill to adjust site elevations, breakwater structures to mitigate wave energy, and temporary fences to keep off hungry Canada geese.

Brackish intertidal marshes characteristically share elements of the salt marsh with those of freshwater marshes. As such, they are sensitive to tidal elevations, meaning that the plants will not grow below a certain tidal threshold value, and they are tolerant of salt accumulation. The degree of salt tolerance will typically determine the zonation of the marsh. Very salt tolerant plants will occupy shallow depressions where evaporation elevates the salinity, while plants located near freshwater inflow and those along the edge of the marsh may be less tolerant of salinity but very good at dealing with inundation.

Ideally, intertidal marshes could line the mouth of the Saw Mill River west of the railroad station. However, the same historic preservation restrictions guiding the placement of potential SAV beds also prohibit the establishment of intertidal marsh at this location. It is likely that elements of the intertidal marsh communities can be planted inside the tidal portion of the daylighted section of the Saw Mill River at Larkin Plaza.

Recommended Basic Actions:

a) Determine proper elevations for intertidal marsh plantings and provide suitable substrate such as sandy loam amended with high percentage of organics.
b) Observe actual salinity occurring at the planting locations and determine plant species to be planted there.
c) Provide temporary predator excluder.
d) Provide monitoring and maintenance.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

e) Failure to adjust plant schedule to actual salinity readings
f) Predators
g) Invasive plants, such as the common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*)

Feasibility is moderate.
Sustainability is ranked fair. This TEC requires sufficient salt-water incursions during the growing season to maintain the natural resource. With sufficient salt influence this TEC will be self-sustaining within 5 years. Limited maintenance will be required.

Desirability

Given the space constraints, Tec No. 7 is only moderately desirable.

<u>TEC No. 8:</u>
Establishment of Freshwater Marsh Vegetation

A typical freshwater marsh would historically not have been found at the Larkin Plaza location. However, marshes do hold significant habitat value and their inclusion into the landscape plan should be considered. As engineering plans develop, freshwater marsh elements such as suitable soils and appropriately selected plants can easily be included along protected sections of streambank and along the upper pool. Marsh plant communities include many grasses, sedges and wildflowers that can add aesthetic value along with habitat and structure. The list of potential plants is long and varied and freshwater wetland plants are easily purchased from many sources.

Recommended Basic Actions:

a) Provide suitable substrate such as sandy loam amended with high percentage of organics.
b) Preferentially select plant species that will actively expand into plant beds – as opposed to plants that persist as single-stemmed individuals.
c) Select only “native” species with high structural habitat or “recycling” value.
d) Provide monitoring and maintenance.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

e) Road salt and other chemical pollution of the Saw Mill River watershed.
f) Predators
h) Invasive plants, such as the common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*).

Feasibility is ranked high.
Sustainability is ranked fair. This TEC requires sufficient soil along the embankments and absence of salt-water incursions during the growing season to maintain the natural resource. The TEC is expected to be sustainable within 5 years, although limited maintenance may be required indefinitely.

Desirability

Tec No. 8 is highly desirable as a vital habitat component of the daylighting project.

<u>TEC No. 9:</u>
Restoration of the River Falls

Historically the Saw Mill River flowed over falls at the eastern end of Larkin Plaza, near the historic Philipse Manor, where the sudden drop of the terrain also encouraged the building of the Lower Mills, a hydro-powered gristmill. Even today the topography of Larkin Plaza rises at least 4 feet up toward the east with a sudden further steep incline toward Warburton Avenue. A waterfall acts as a barrier to fish passage, but it also aerates the water. Sufficiently high levels of dissolved oxygen (higher than 6 g/ml) are necessary to maintain a diverse and healthy aquatic ecosystem.

This daylighting project clearly has to take topography into account and somehow deal with a drastic elevation change. Various engineering concepts have proposed a series of step-down pools and riffles or small falls in between. There is also the possibility of recreating the historic falls as an attraction and historic feature. Taking the historic concept further, the restoration of a hydro-powered “mill” - perhaps for the generation of electric energy – could also be envisioned.

River falls have the inherent barrier effect that will make fish migration difficult if not impossible. They also can become a safety hazard if the drop is too steep and easily accessible. The main hindrance in this case however is the existing flume and the need to maintain it as a stormwater bypass. The flume too rises steeply toward Warburton Avenue, but not steeply enough to allow the river to emerge in a dramatic way from underground. Other practical considerations, such as space constraints at that part of Larkin Plaza and the desire to intercept the trash load carried by the river before it surfaces, finally resulted in a design that pays homage to the concept of falls but puts them much farther west than they would originally have been – and reduced them to a four-foot step-down drop. The falls nevertheless are steep enough to require a fish ladder to allow fish to overcome them.

Recommended Basic Actions:

a) Alaskan Steep Pass fish ladder
b) Flow control structure allowing suitable flows in the fish ladder during critical times for fish migration.
c) Educational signage

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

d) Stream flow volumes will be divided between fish ladder and falls; during times of fish migration priority must be assigned to flows though the fish ladder as opposed to satisfying aesthetic concerns.

Feasibility: Highly feasible.
Sustainability: This TEC is self-sustaining and maintenance-free.

Desirability
The implementation of Tec No. 9 has a low degree of desirability but may be necessary as incorporated with the final construction plans.

<u>TEC No. 10:</u>
Restoration of Riparian Forest Vegetation

Existing riparian forests on tributary streams on both sides of the Hudson offer insights into typical "native" plant communities. Prominent species are red maple (*Acer rubrum)*, ash (*Fraxinus pennsylvanica)*, sycamore (*Platanus occidentalis)*, witch hazel (*Hamamelis virginiana)*, and spicebush (*Lindera benzoin)*. Often these species grow directly at the streams edge, where they shade the water and keep it cool during the summer. Leaf litter from these native trees and shrubs supports an entire aquatic food web of invertebrate species, which in turn are food for vertebrate species, such as fish, turtles, birds and mammals (amphibians are unlikely to colonize the Larkin Plaza daylighting project).

This project has the potential to re-create the canopy effect of the native riparian corridor forest. Given the fact that the daylighting project is not a restoration project, but a project borne from the desire to revitalize and enliven the inner city of Yonkers, landscape design principles such as view corridors, plant height and strategic locations will dictate the planting plan. But even if not implemented in its entirety, the concept of a riparian forest can be demonstrated and explained.

Recommended Basic Actions:

a) Allow enough space for root systems of smaller native trees near the stream edge
b) Educational signage

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

c) Lack of sufficient trees/shrub cover may raise water temperature to levels detrimental to diverse aquatic animal life.
d) Lack of detritus (leaf litter, etc) from native species may severely curtail the insect population of the daylighted river, an essential link in the food web of the aquatic ecosystem.

Feasibility is ranked low.

Sustainability: Self-sustaining within 3 years, will require limited maintenance

Desirability

Implementation of Tec No. 10 is desirable as a potential source of detritus and shading for the Saw Mill River, allowing it to maintain high levels basic food-web organisms and of dissolved oxygen during hot summer months.

TEC No. 11:
In-stream Habitat Variability

To be successful and meaningful to the fish passing into the daylighted river, habitat conditions must be suitable for survival and growth of fish. Since this project is intended to attract and benefit a variety of potential inhabitants, the in-stream conditions must be varied and abundant. They should include varied stream flow velocities from fast (riffles, rapids) to slow/no-flow (pools and ponds), varied soils/sediments from coarse (rock/gravel) to fine (sand/organic), varied structure from open to cavernous (overhangs) with snags/reefs and islands and varying side slopes from shallow to steep. The greater the variety, the larger the number of species attracted to it, including invertebrates such as crayfish, insects and worms, which provide a food source for fish, birds, reptiles (turtles) and mammals.

Recommended Basic Actions:

a) Aside from guidelines for the design of fish and eel ladders, provide enough flexibility in construction plans to modify substrates and embankments moderately to increase variability as much as possible.
b) Consider incorporation of a large root wad or large tree trunk with major branches as habitat structure in one of the pools.
c) Consider placing boulders at the edge of the stream or pools in a way that will create overhangs under the water surface.
d) Consider placing boulders at the edge of the stream or pools in a way that will create small calm zones.

Potential Hazards/Pitfalls (modifications of construction plans may be necessary):

e) Once built, it will be very difficult to retrofit the stream and the pools for these habitat enhancing amenities – budgets and expertise should be set aside to incorporate In-stream Habitat Variability to the highest degree possible.
f) Incorrectly placed, habitat features can be useless or unsightly.

Feasibility is ranked high.

Sustainability is ranked high. This TEC has the potential to increase diversity and quantity of various natural resources. Every effort to implement and maintain this TEC should be made.

Desirability

Implementation of Tec No. 11 is highly desirable. Habitat variability will likely be directly correlated with species diversity of the daylighting project.

Site design

Known site parameters, such as tidal influence, tidal amplitude, salinity, stream flow velocity and pollution load of the Saw Mill River only define the potential for restoration. The decision of which the TECs (Target Ecosystem Characteristic) can be realized in the daylighting design of the Saw Mill River will depend to a large part on practical, technical and engineering considerations, such as a declared desire to strain large floatable debris out of suspension before they float into and litter the newly daylighted stream, the flood control necessity of keeping the flume in place to divert excess storm flows down the bypass, existing buried infrastructure that cannot be relocated, historic preservation mandates and environmental regulations, such as the prohibition of alterations west of the railroad tracks (historical wharf remnants) and the hesitation of the New York State Department of Environmental Conservation to allow the restoration of an oyster reef because of the threat of contamination if oysters would be poached for human consumption – all these are mandates or existing conditions that dictate the framework within which the daylighted stream can be built. This report was compiled at the end of the design process after, at times, intense back and forth between the engineers and a variety of ecologist and fish migration experts. It became clear very early on in the design process, that this kind of cooperation would be necessary.

The civil engineering investigations of subterranean infrastructure and of surface elevations framed the limits and bottom elevations of the daylighting project.
At that point it became evident that the tidal influence into the site would be extremely limited, relegating **TEC No. 7**, the restoration of a brackish tidal marsh to a low priority, since the alternative site, west of the railroad tracks was out of bounds due to regulatory restrictions. Consequently, the final daylighting plans only contain a few square feet of brackish intertidal marsh vegetation as a token acknowledgement of their historic and ecological importance. **TEC No. 4**, restoration of brackish water submerged aquatic vegetation (SAV) was similarly affected, only that two alterative implementation sites near the mouth of the Saw Mill River have been found. Experimental investigations into the suitability of these two sites will be undertaken. **TEC No. 9**, restoration of the historic falls, fell victim to site constraints as well, resulting in an alternative that allows reference to the historic falls at a prominent location directly across from the train station, where the river will cascade down a set of steps 4 feet high. **TEC No. 6** had to be shelved altogether, since the Hudson is polluted and oysters, as filter feeders, are likely to be contaminated if they were to be grown on an artificial reef. Here Groundwork Hudson Valley and the NY&NJ Baykeeper may work on a long-term solution that includes the possibility of an oyster reef restoration near the mouth of the Saw Mill River at the Science Barge. For **TEC No. 10**, the restoration of a riparian forest canopy, there is simply not enough room to accommodate the expansive root systems of large canopy trees. Site designers also prefer smaller specimen for aesthetic reasons, keeping the site open for views from different angles. The lack of shading may prove to be a liability in the future, so that close monitoring of water temperatures in the daylighted river in dry summers will be of importance. If ecological problems arise from elevated temperatures perhaps a solution to shading the river can be found retroactively.

On the positive side of this design challenge, various ecologically significant objectives will be addressed and are likely to be met, most importantly **TEC No. 1**, the preservation and improvement of habitat for the American eel, **TEC No.2**, the elimination of barriers to and the provision of structures benefiting fish passage, **TEC No.3,** the establishment of freshwater submerged aquatic vegetation as an important habitat component, **TEC No.5,** an attempt to introduce alewife spawning runs, and **TEC No.8**, the planting of freshwater marsh vegetation along the embankments of the daylighted river.

In addition to these design achievements, the overall process has broadened the understanding of the connectivity of the daylighted section with the rest of the Saw Mill River watershed, potentially benefiting future daylighting projects, such as the Chicken Island development, further upstream with important options, such as providing access for fish to the top of the Larkin Plaza, and thereby shortening the rest of underground travel distance. The ongoing studies of American eels and their future in the river may also lead to further work on aiding this species with ladders and habitat structures further upstream. Even the discussion of possibly releasing spawning alewife into Woodlands Lake, some 7 miles upstream from the mouth, may prove fruitful and may stimulate deliberations about the desirability of a fish ladder at that dam.

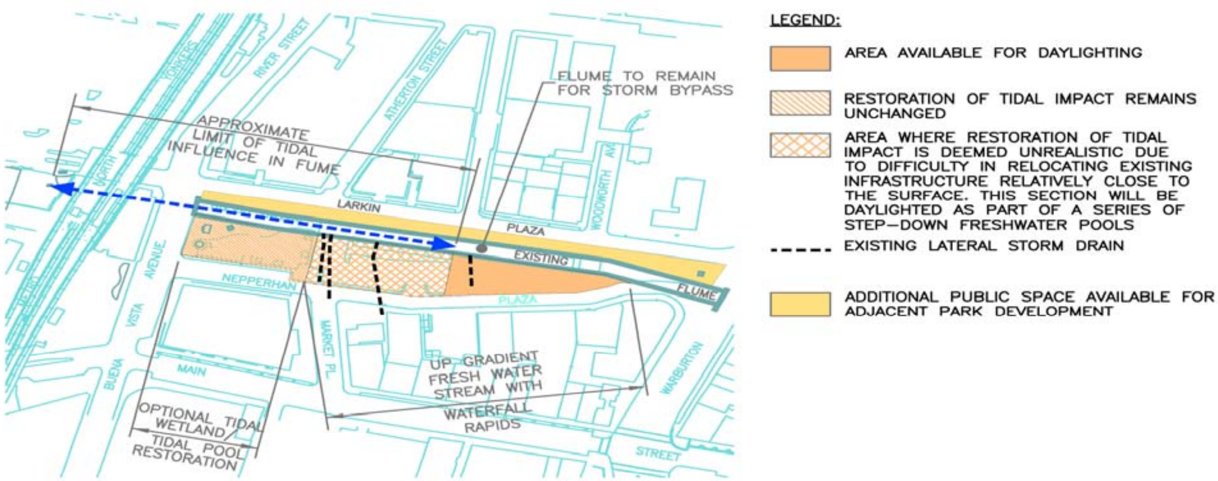


Exhibit 8
Plan view of Larkin Plaza and surroundings, highlighting portions of the plaza and the Hudson River after the conclusion of the design process. The intertidal potential of the site as shown in Exhibit 2 could not be fully realized due to underground utilities that could not easily be moved. As a result, the non-tidal freshwater portion of the daylighting project increased significantly.

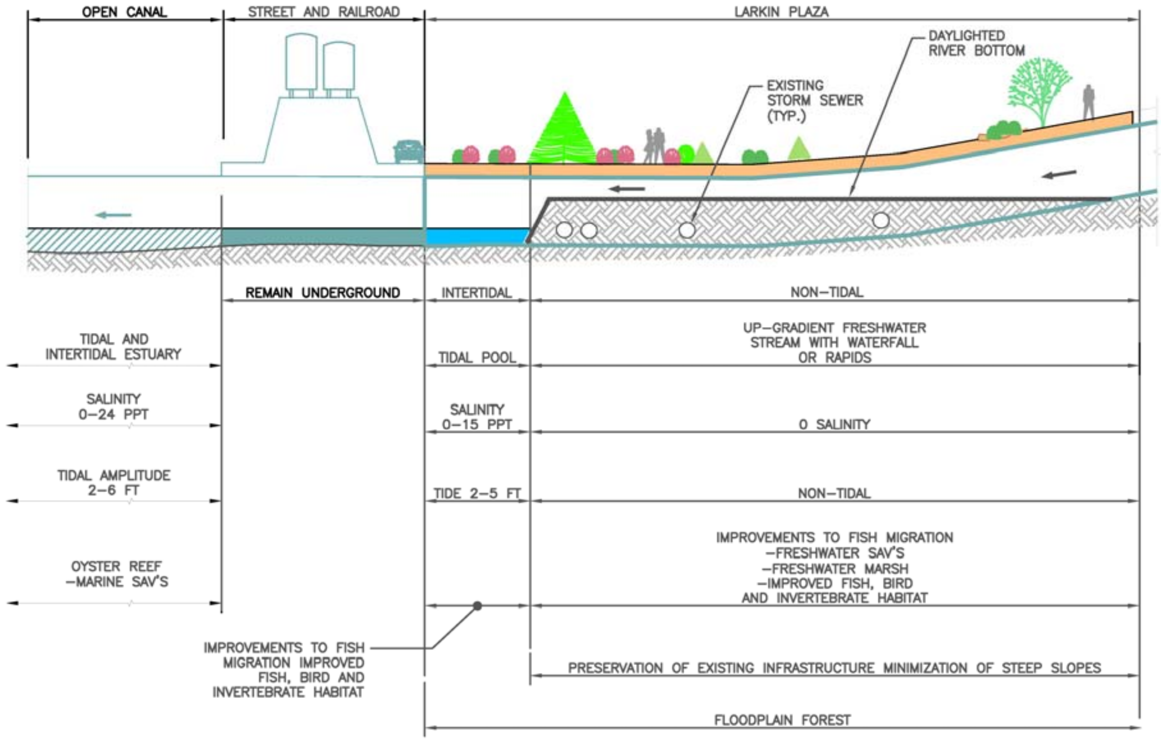


Exhibit 9
Schematic cross section through Larkin Plaza and the mouth of the Saw Mill River referencing and complementing Exhibit 8. The diagram differs from the theoretical restoration potential as shown in Exhibit 3. When compared side by side, the intertidal pool inside Larkin Plaza shrunk dramatically due to existing storm sewer infrastructure (see white circles with call-out).

Monitoring and Adaptive Management

Just as the implementation of individual TECs may prompt research and development, as is the case with an oyster reef and with the establishment of brackish SAV beds, so must the installation of other TECs prompt flexible maintenance and monitoring, also known as “adaptive management”.

Adaptive management will hold an important, if not the key position, in the successful establishment of biological diversity and ecological functioning of the daylighting project. As this is an unprecedented project, there are no known prototypes or comparison sites to refer to for design, construction and operation of the new stream channel and its features. The design recommendations that found their way into the construction documents are purely based on our knowledge of the preferences of various biological resources – not however on prior experience in a comparable situation. The best-laid plans often need tweaking and outright changes. Most notably, our current lack of knowledge of future water temperatures during the summer, may prompt the need to look for improvements, if temperatures would reach so high, that they were to imperil the various biological resources by depriving them of oxygen (the higher the water temperature, the less oxygen dissolves in it). Adaptive management in such a case would mean that engineering solutions, alternative shoreline planting plans, perhaps auxiliary tree plantings or other ways of shading, aeration or better flushing would have to be discussed and suitable solutions implemented. Once implemented, monitoring would determine if the chosen solution(s) solve(s) the problem. If still unsatisfactory, further adaptive measures would be taken and in term results monitored, until the desired ecology will be achieved. It is not sufficient to simply identify the problem; the project management MUST include the funds and flexibility to take corrective action should ecological targets not be met.

First and foremost the population of the American eel must be protected. This requires good baseline information and follow-up counts of migrating individuals each year beginning prior to and following for several years after the construction of the bypass. Monitoring of migrating eels requires consistency of methods and dedication to the task for a recommended time of at least 5 years past construction. Should the monitoring counts show a decline in the number of passing eels, or should it show that the eels do not enter into and through the daylighted section, corrective actions and in this case, specifically designed eel ladders, may be called for. Similarly fish counts in special traps at the end of a fish ladder may provide insight into the success of other species. Plant establishment is commonly jeopardized by predation and may require re-planting or temporarily protective fences to sustain a target population. Weeds may invade the site and threaten the projected and desired target trajectories. Erosion, trash accumulation, vandalism, unexpected environmental agents, such as oil or salt, siltation – all need to be monitored and if necessary remedial action must be implemented.

Over time – typically at least 5 years – the integrated approach to monitoring and management actions will produce a more or less self sustaining ecology. Ideally, this ecology will be as was originally planned, but as often is the case with living systems, unanticipated factors may force adjustments to be made that could not be or were not foreseen.

Monitoring reports should be filed yearly and should report at the very minimum the following data and recommendations to remedy problems:
- Eels counts (upstream migration, density if at all possible)
- Alewife counts and spawning
- Other fish migration and utilization of the daylighted river
- Invertebrate characterization of the daylighted river
- Reptilian, mammalian and bird use of the daylighted river
- Plant survival and voluntary establishment
- Weed infestation and removals
- Unusual environmental disturbance, vandalism
- Significant predation of plants by animals
- Rudimentary water quality data, such as salinity in the tidal section, temperature, dissolved oxygen, etc.

Documentation

1) Baseline Information:

Reporting on pre-project conditions provides a powerful baseline against which to measure the project targets. For the daylighting project of the Saw Mill River two basic fish surveys have already been conducted and a specific count of migratory eels will be conducted in 2010 prior to construction. Groundwork Hudson Valley also commissioned a water quality survey of the Saw Mill River independent of this project. Those data may be helpful if water quality questions arise in the future.

2) Construction Monitoring:

Documentation should continue during the construction phase to monitor adherence to plans and to record inevitable changes. Structural changes may force changes in the planting plan or they may have effects on location and construction details of fish ladders for example. Changes during the construction phase must be accessible to the monitors to properly evaluate the success of any restoration or re-introduction project.

3) Monitoring Reports:

Monitoring reports - or a summary of various separate research reports and counts as listed above – should be provided on a yearly basis for at least 5 years following the end of all construction activities. The monitoring reports should be precise and thorough in assessing the success of the TEC's that have been built. As part of the report, a discussion of successes and failures and their potential "drivers" should result in recommendations for future management and corrective actions (see Adaptive Management). Monitoring reports shall include photographic documentation and sketched maps as necessary.

4) Management Logs:

Routine management actions, such as trash removal, mowing or fence repair shall be documented in a management log at a predetermined location or as separate logs if various maintenance entities are involved. At least once yearly this/these record(s) shall be summarized and made available to the entity performing the monitoring.

5) Final Assessment:

At the end of the monitoring and adaptive management period (presumably 5 years) a final assessment of the success in achieving the project targets should be performed and summarized in a Final Assessment Report. This report should document the baseline information, constructed measures, recorded outcomes of targeted ecosystem components, management's actions taken, and projections of future developments. Where trends are obvious, or where new insights have been developed, recommendations for improvements in the daylighted river as well as beyond should be given.

References

Christie, Rod & *Feller*, Natara. Benthic Macroinvertebrate Analysis for the Saw Mill River, Westchester County, NY, 2002. Internal Report Saw Mill River Coalition.

Jackman, George, *Larson*, Marit, and *Ruzicka*, Victoria. American Eel Passage Enhancement Plan for the Bronx River, 2009. New York City Parks and Recreation Report.

Haro, Alex, *Franklin*, Abigail, *Castro-Santos*, Theodore, and *Noreika*, John. Evaluation of Nature-like Fish Pass Design for Passage of Alewife (*Alosa pseudoharengus*) and American Shad (*A. sapidissima*). Undated powerpoint presentation.

Machut, Leonard S., *Limburg*, Karin E., and *Schmidt*, Robert E. American Eel Dynamics (*Anguilla rostrata*) in Hudson River Tributaries, New York, 2004. Powerpoint presentation.

NYC Parks Department Press Release, April 09, 2009. Parks Finds Alewife In Bronx River For First Time Since 1600s. www.nyc.gov/parks.

New York Natural Heritage Program. www.acris.nynhp.org

Orvis, Curt. Example American Eel Specific Fishways. Undated slide presentation, US Fish & Wildlife Service.

Orvis, Curt. Fishways for River Herring. Undated slide presentation, US Fish & Wildlife Service.

Pappanttoniou, Tony. Longitudinal Distribution of the Fishes of the Saw Mill River Westchester County, New York, 2003. Special report commissioned by the Beczak Environmental Education Center as part of a study conducted by Groundwork Yonkers.

Rachelin, Joseph, & *Warkentine*, Barbara. Saw Mill River Final Report (a fish study), 2008. Special report commissioned by Groundwork Yonkers

Richardson, John E. CFD Saves the Alewife – Computer Simulation helps the Alewife return to its Mt. Desert Island Spawning Grounds, 2007. www.flow3d.com

Schmidt, Robert E. American Eel (*Anguilla rostrata*) in the Saw Mill River, 2008. Special report commissioned by Groundwork Yonkers.

Schmidt, Robert E. Migratory Fishes in the Mouth of the Saw Mill River, 2008. Special report commissioned by Groundwork Yonkers.

Smith, Lavett. The Inland Fishes of New York State, 1985. The New York State Department of Environmental Conservation, Albany, NY.

Solomon, David, and *Beach*, Michael. Manual for Provision of Upstream Migration Facilities of Eel and Elver, Science Report SC020075/SR2, 2004. www. environment-agency.gov.uk

Ziemer, G.L. Steeppass Fishway Development (Informational Leaflet No.12), 1962, Alaska Department of Fish and Game, Division of Engineering and Services.

Appendix: Tables

Table 1: Woody vegetation documented growing at potential reference sites for the "restoration" of the Saw Mill River at Larkin Plaza - Summary

Line	Scientific name	Common name
	Trees	
1	*Acer platanoides*	Norway maple
2	*Acer rubrum*	Red maple
3	*Ailanthus altissima*	Tree-of-heaven
4	*Celtis occidentalis*	Hackberry
5	*Fraxinus pensylvanica*	Green ash
6	*Liriodendron tulipifera*	Tuliptree
7	*Morus spec.*	Unidentified mulberry
8	*Populus deltoides*	Cottonwood
9	*Prunus serotina*	Black cherry
10	*Quercus rubra*	Red oak
11	*Robinia pseudoaccacia*	Black locust
12	*Sassafras albicans*	Sassafras
13	*Ulmus spec.*	Unidentified elm
	Shrubs	
14	*Amorpha fruticosa*	False indigobush
15	*Eleagnus umbellatus*	Autumn olive
16	*Euonymus alatus*	Burning bush
17	*Hammamelis virginiana*	Witch hazel
18	*Ligustrum vulgare*	Privet
19	*Lindera benzoin*	Spicebush
20	*Rhus typhina*	Staghorn sumac
21	*Rosa multiflora*	Multiflora rose
22	*Rubus allegheniensis*	Blackberry
23	*Rubus phoneniculasius*	Wineberry
	Vines	
24	*Celastrus orbiculatus*	Asiatic bittersweet
25	*Lonicera japonica*	Japanese honeysuckle

Table 2: Basic Species List from Seinings at the Beczak Environmental Education Center

Line	Scientific name	Common Name
	Fishes	
1	*Alosa aestivalis*	blueback herring
2	*Alosa pseudoharengus*	alewife
3	*Anchoa hepsetus*	striped anchovy
4	*Anchoa mitchilli*	bay anchovy
5	*Anguilla rostrata*	American eel
6	*Fundulus diaphanus*	banded killifish
7	*Fundulus heteroclitus*	mummichog
8	*Gobiosoma bosc*	naked goby
9	*Menidia menidia*	Atlantic silverside
10	*Microgadus tomcod*	Atlantic tomcod
11	*Morone americana*	white perch
12	*Morone saxatilis*	striped bass
13	*Paralichthys dentatus*	summer flounder
14	*Pomatomus saltatrix*	bluefish
15	*Pseudopleuronectes americanus*	winter flounder
16	*Syngnathus fuscus*	northern pipefish
17	*Trinectes maculatus*	hogchoker
	Invertebrates	
18	*Aurelia aurita*	moon jelly
19	*Callinectes sapidus*	blue crab
20	*Crangon septemspinosa*	sand shimp
21	*Ctenophora*	comb jellies
22	*Cyanea capillata*	lion's mane jellyfish
23	*Gammarus spec.*	amphipod
24	*Mya arenaria*	soft shell clam
25	*Palaemonetes* spp.	grass shrimp

Table 3: Target Ecosystem Characteristics (TECs) – Overview and Summary

TEC #	Title & Description	Sustainability
1	**Preserve American eel** Protection of existing migration routes (up- & downstream), Improvement of juvenile habitat **Scientific name:** *Anguilla rostrata* - American eel **Basic actions**: Identify barriers, specify substrate materials at barriers, prevent barriers to downstream migration, provide cavities and soft soils for shelter of juveniles, guarantee high water quality for high diversity of food sources.	Measurable increase in all size classes over 5 years, free of maintenance. **Potential hazards:** insufficient passages and unidentified barriers **Highly desirable**
2	**Enable fish passage** Maximize fish passage for multiple species **Scientific names**: *Catostomus commersonii* - white sucker, *Morone americana* - white perch, *Perca flavenscens* - yellow perch, *Micropterus dolomieu* - small-mouth bass. **Basic actions:** Avoidance of barriers, installation of structures (e.g. fish ladders, orifices, notches); design for controlled stream flow velocities and flow patterns.	Measurable increase in species diversity over 5 years, will require limited maintenance. **Potential hazards**: "unattractive" and "insurmountable" passages, insuffient sizing, clogging, lack of maintenance **Highly desirable**
3	**Freshwater SAV (Submerged Aquatic Vegetation)** Plant SAVs for structure and food in Larkin Plaza; **Scientific names:** *Vallisneria americana* - American eelgrass, *Elodea nuttallii* - Nuttall's waterweed, *Ceratophyllum demersum* - coontail, *Ludwigia palustris* - seedbox. **Basic actions**: Selection of suitable substrates and locations, installation of predator excluders.	Unknown; expected to be self-sustaining within 3 years, will require limited maintenance. **Potential hazards:** predators, extreme streamflow velocities **Highly desirable**
4	**Brackish SAV** Plant SAV at mouth of Saw Mill River, **Scientific names**: *Najas guadelupensis* - naiad, *Ruppia maritima* - widgeon Grass, *Stuckenia pectinata* - sago pondweed, *Ceratophyllum demersum* - coontail. **Basic actions:** Conduct feasibilty study; find donor sites.	Unknown, feasibility study is needed. **Potential hazards**: Limited commercial availability, turbidity, predators, wave energy, ice shear **Desirable**
5	**Alewife spawning runs** Introduction of alewife (a diadromous herring) spawning run; design of habitat features beneficial for early larval development; **Scientific name:** *Alosa pseudoharengus* - alewife. **Basic actions**: Provision of suitable passage structures, calm-water zones for larval retention, stocking program, monitoring .	Measurable results will be available 4 years after introduction into the SMR. **Potential hazards**: Insufficient larval retention time may prevent return of spawning adults **Desirable**
6	**Oyster reef** Restoration of an oyster reef at mouth of SMR; install prototype reef. **Scientific name**: *Crassostrea virginica* - oyster. **Basic actions**: Program development	Will require regulatory permit and constant maintenance. **Potential hazards:** Poaching, predators, disease **Desirable**
7	**Brackish intertidal marsh** Restoration of intertidal marsh. **Scientific names:** *Spartina alterniflora* - smooth cordgrass, *Juncus gerardi* - black needlegrass, *Iva frutrescens* - hightide bush, *Spartina cynosuroides* - giant cordgrass, *Spartina pectinata* - prairie cordgrass, *Scirpus americanus* - three-square. **Basic actions:** Selection of suitable substrates, locations and elevations, installation of predator excluders.	Self-sustaining within 5 years, will require limited maintenance. **Potential hazards:** lack of suffient salinity, predators, soil erosion, invasive weeds **Moderately desirable**

Table 3, continued:

TEC #	Title & Description	Sustainability
8	**Freshwater marsh** Installation of emergent marsh vegetation along the shores of the new river. **Scientific names:** examples only - *Pontederia cordata* - pickerel weed, *Juncus spp.* - various rushes, *Carex spp.* - various sedges, etc. **Basic actions**: Selection of suitable substrates and locations, installation of predator excluders.	Self-sustaining within 5 years, will require limited maintenance. **Potential hazards**: salinity from road maintenance, predators, soil erosion, trampling, invasive weeds **Highly desirable**
9	**Waterfall restoration** Establishment of waterfall or/and rapids; historic recreation, high dissolved oxygen content. **Scientific names**: not applicable **Basic actions**: Engineering review to allow for fish passage	Self-sustaining, maintenance-free **Low degree of desirability**
10	**Floodplain forest** Native riparian canopy of forest trees and shrubs for shading, nutrient recycling and habitat; **Scientific names**: *Acer rubrum* - red maple, *Fraxinus pennsylvanica* - green ash, *Platanus occidentalis* - Sycamore, *Hamamelis virginiana* - Witch hazel, *Lindera benzoin* - spicebush. **Basic actions:** selection of suitable substrates and locations.	Self-sustaining within 3 years, will require limited maintenance. **Potential hazards**: failure to establish enough of this TEC may result in overheated water in mid summer **Desirable**
11	**In-stream habitat complexity** Maximize biological diversity through creation of habitat variability. **Basic actions:** Establish riffles, rapids, calm zones (pools & ponds) for varied streamflow characteristics, varied soils/sediments from coarse (rock/gravel) to fine (sand/organic), varied structure from open to cavernous (overhangs) with snags/reefs and islands and varying side slopes from shallow to steep.	Immediately self-sustaining, will require limited maintenance (trash removal, etc). **Potential hazards:** sedimentation, erosion, dislocation. **Highly desirable**

Table 4: Basic Environmental Data
Source: Beczak Environmental Education Center

A) Salinity [ppt] in shallow Hudson River waters (Dec 2005-Mar 2010)						
Line	**Month**	**Average (Mean)**	**Most common (Mode)**	**Minimum**	**Maximum**	**Base data count**
1	January	4.6	0.2	0	16.9	2647
2	February	5.6	0.2	0	15.3	2773
3	March	4.8	0.2	0	12.8	3222
4	April	3.9	0.2	0	24.4	2879
5	May	5.4	3.0	1	22.8	2160
6	June	7.8	9.5	1	17.6	2374
7	July	9.7	10.5	1	17.5	1779
8	August	10.0	13.0	2	16.7	2063
9	September	11.1	12.3	3	16.8	2160
10	October	10.0	12.0	0	17.9	2289
11	November	5.8	6.3	1	16.1	2678
12	December	4.8	2.8	0	15.0	2959
	Total					29983
B) Temperature [^oC] in shallow Hudson River waters (Dec 2005-2010)						
Line	**Month**	**Average (Mean)**	**Most common (Mode)**	**Minimum**	**Maximum**	**Base data count**
13	January	2.6	0.1	0	11.4	2647
14	February	2.0	2.4	0	5.2	2773
15	March	3.8	3.3	0	13.6	3222
16	April	9.2	7.5	3	19.5	2879
17	May	15.7	15.2	10	22.8	2160
18	June	21.5	22.8	16.4	27.1	2374
19	July	25.0	24.7	20.7	29.2	1779
20	August	25.3	24.7	22.0	30.7	2063
21	September	22.6	24.2	19.0	26.4	2160
22	October	18.0	18.3	4.1	24.0	2289
23	November	11.5	11.7	3.0	18.1	2678
24	December	5.3	4.5	0.1	12.7	2959
	Total					29983