Final Report

Holly Pond Sedimentation Study

Prepared for

Stamford Water Pollution Control Authority

July 2010

CH2MHILL

Executive Summary

> ***Restoring the health of Holly Pond and the Noroton River will benefit residents and businesses in Stamford and Darien.***

Holly Pond and the Noroton River discharge to Long Island Sound and are important natural resources to both the City of Stamford to the west and the Town of Darien to the east. The formation of a series of shoals at the head of Holly Pond where the Noroton River discharges has been a cause of concern in the community for many years. Sediments from bank erosion and stormwater runoff along the river are transported downstream, where they settle at the inlet to Holly Pond. These sediment deposits adversely affect inlet hydraulics, aesthetics, and aquatic habitat.

The purpose of this sedimentation study is intended to evaluate the sources, characteristics, and quantities of sediment entering the Noroton River. The study included bathymetry of the pond and preparation of a digital terrain map of the southern sections of the Noroton River in December 2008 and January 2009. To assess the feasibility of dredging the shoal, a limited sediment testing plan was implemented. A stream evaluation was conducted to ascertain the geormorphic conditions of the river, measure current velocities and flow conditions, and document areas of bank erosion that could be contributing to the sediment loading in Holly Pond.

After completing the sediment field work and testing, preliminary characterization of the shoal was presented to the Connecticut Department of Environmental Protection (CTDEP). Laboratory analyses of the sediments confirmed that elevated levels of metals, pesticides and polycyclic aromatic hydrocarbons (PAHs) were present in the sediments within Holly Pond. Discussions with CTDEP staff indicated that beneficial use of the sediment, either within the pond or at another location, was unlikely. This limited the disposal options to an upland landfill at costs that had previously delayed completion of a dredging program in Holly Pond.

Modeling was also completed to provide a basic understanding of the sources and sinks of solids in the Noroton River and Holly Pond system. The results indicate that there may be two main sources of sediment: erosion of stream banks in the tributaries to the Noroton River and historically deposited sediment in the stream beds of the tributaries and main stream.

During the course of the study, new grant opportunities became available through the American Recovery and Reinvestment Act (ARRA). After discussions with CTDEP, the Stamford Water Pollution Control Authority (SWPCA) completed a streamlined pond inlet restoration alternatives analysis and prepared a design concept for submittal. In completing this work, an alternative was developed to minimize both dredging and costs using a habitat restoration concept. This alternative compared favorably to the dredging alternatives proposed in previous studies in terms of costs and benefits.

When the ARRA grant funding was not awarded, the project focused on the completion of watershed characterization and analysis of potential improvements that could be implemented in 2010 using available funding from the State of Connecticut and Federal Highway Administration. Several stormwater management retrofits were considered, and design concepts were drafted.

When funding becomes available, the improvement design phase will include plans to remove the shoal in Holly Pond and for watershed improvements to reduce or eliminate sediment sources; minimize sediment deposition; and improve aquatic habitat.

The goal is to manage sedimentation of Holly Pond for the long-term in a sustainable and beneficial way.

The restoration o f Holly Pond and the Noroton River will maximize the creation and maintenance of jobs through the implementation of specific projects and will improve the long-term economic conditions in the area. The project will achieve the following:

- Create jobs through implementation of a tidal marsh restoration project and related river and watershed work.
- Improve the urban green space and aesthetics of Holly Pond to support recreational activity such as boating, angling, nature study, wildlife observation, walking, and picnicking.
- Provide critical habitat to support all life cycles of aquatic species.
- Reduce pollution of water and sediment.
- Address current flood risk and any impacts that might occur as a result of climate change.
- Improve property values around the pond and along the river.
- Improve business for the local restaurant adjacent to the pond.

Unmanaged, the sedimentation and deleterious water quality conditions will continue to occur in the Noroton River and Holly Pond, and the state of these natural resources will worsen. Aesthetics, property values, habitat, flood protection, and other benefits will further decline.

Taking action now to restore the Holly Pond inlet and make improvements in the Noroton River watershed will enhance the quality of life for residents in Stamford and Darien, increase property values, benefit local business owners, and create opportunities for healthful outdoor recreation in a safe urban environment. The restoration will promote better hydraulics, create vegetated wetlands, enhance habitat for bottom-dwelling plants and animals, and improve water quality for species that are dependent on the pond.

Taking action now is the best investment for the communities.

Urban river restoration is a multi-component process that takes place over many years. This project represents an opportunity for state and local leaders to demonstrate the benefits of multi-jurisdictional cooperation to optimize economic, environmental, and community outcomes.

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Abbreviations and Acronyms

BMP	best management practice
ConnDOT	Connecticut Department of Transportation
CTDEP	Connecticut Department of Environmental Protection
FHWA	Federal Highway Administration
GIS	geographic information system
HEA	habitat equivalency analysis
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
PAH	polynuclear aromatic hydrocarbon
SWPCA	Stamford Water Pollution Control Authority
TCLP	toxicity characteristic leaching procedure
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

SECTION 1

Background and Existing Conditions

Holly Pond and the Noroton River discharge to Long Island Sound and are important natural resources to both the City of Stamford to the west and the Town of Darien to the east. The ongoing formation of a series of shoals at the inlet to Holly Pond where the Noroton River discharges has been a cause of concern in the community for decades. Sediments from bank erosion and runoff along the river are transported downstream, where they settle at the mouth of the river. These sediment deposits adversely affect hydraulics, aesthetics, and aquatic habitat. Appendix A provides a location map of the Holly Pond inlet, which has experienced the most visible shoaling. Appendix B includes photos of the conditions of the inlet in 2008 and 2009.

The purpose of the Holly Pond Sedimentation Study is to perform a study that focuses on sources, characteristics, reduction, and remediation strategies to reduce or eliminate sedimentation in Holly Pond and improve water and sediment quality to support aquatic life.

Holly Pond and the Noroton River are listed on the 2006 List of Connecticut Water Bodies Not Meeting Water Quality Standards and do not support all designated uses. Restoration of Holly Pond will address current degradation, and watershed improvements will improve the long-term health of the river, pond, and sound.

1.1 Historical and Baseline Information

The first step in the sedimentation study was to construct a body of knowledge; gather relevant data and information for the river, watershed, and tides; and perform a gap analysis to determine what was lacking for comprehensive sediment management and watershed planning.

CH2M HILL requested and reviewed project-related documentation and studies previously prepared by the City of Stamford, Town of Darien, Town of New Canaan, Connecticut Department of Transportation (ConnDOT), U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), Federal Emergency Management Agency, and other readily available county, state, and federal agencies. A library was established for use by the project team. Appendix C includes a copy of the library index as of December 2009. A geographic information system (GIS) and relational database was created to organize relevant planning data and serve as the foundation for hydraulic, sediment transport, water quality, and habitat analyses. A gap analysis was submitted to the Stamford Water Pollution Control Authority (SWPCA). This memo guided additional data collection efforts, including recommendations for the field program. Below is a summary of key historical information obtained from this effort.

The history of Holly Pond is not unique, as described by the Connecticut Department of Environmental Protection (Dreyer and Niering, 1995):

> The conversion of tidal coves and embayments into millponds began in the 1700's, primarily in central and western Long Island Sound where the greater tidal range provided more tidal energy for the mill operation. Sherwood Mill Pond, Holly Pond, and Sluice Creek are each examples of former millponds. The inlets to these coves were modified through the installation of tide gates which allowed tidal flow into the cove but closed at high tide. Water was returned to the Sound through a narrow channel called a sluiceway, which contained the waterwheel for the mill. In many places the gates caused prolonged flooding of areas of salt marsh, contracting the once extensive vegetation to a narrow fringe along the elevated borders of the millpond… The reduced tidal flows to these sites often cause water quality problems and increased sedimentation.

The first dam is thought to have been constructed at Holly Pond for a mill in 1796 at 3.5 feet above mean sea level (msl). The dam was breached in the 1938 hurricane. In 1960, a new dam was constructed with flap gates installed to allow quick flushes of sediment. The design was based on estimates that siltation was occurring at an average rate of 1 inch per year in the pond. In 1966, "guillotine" gates were installed to allow for sediment flushing, but there is no documentation that these have ever been operated.

Numerous studies relating to sedimentation and other concerns in the pond have been conducted since 1935. In 1995 the City of Stamford and the Town of Darien applied for a permit to remove and dispose of sediment in the northern inlet of Holly Pond. The permit was approved, but contamination in the sediment limited disposal options. The project was not completed because of budgetary concerns.

Interviews conducted during the course of the study indicated that the following types of commercial/industrial users were in operation along the Noroton River throughout the 20th Century:

- Landscaping companies
- Heavy industrial and commercial
- Plating
- Rock crushing
- Phillips Milk of Magnesia

The interviews indicated that historical land uses may have been a source of contaminants discharged to the Noroton River.

Additional information on historical documentation is provided in Appendix D. The *Summary of Holly Pond Historical Documents* memorandum was prepared in February 2009 for the use of the CH2M HILL project team during the course of the sedimentation study.

The State of Connecticut's impaired waterbody list (303[d]) indicates that the Noroton River is impaired as habitat for fish, other aquatic life, and wildlife from Post Road (Route 1) upstream to the US Route 15 Crossing in New Canaan. Holly Pond is not assessed for habitat, but the 303[d] list indicates that the pond is impaired for commercial shellfish harvesting due to fecal coliform. Probable causes are numerous, including urban stormwater discharges and waterfowl. Sedimentation is among the factors that indicate the declining use of these waterbodies as aquatic habitat.

1.2 Field Investigations

The goals of the field investigations were to conduct a monitoring and assessment program to fill in the data gaps identified in the review of historical and baseline information. Primarily, the field investigations updated and supplemented previous studies to provide an understanding of current conditions. CH2M HILL developed a monitoring and assessment work plan, which included investigations of the river and the pond. The investigation of Holly Pond consisted of a bathymetry study, sediment sampling and analysis, and biological assessment. The watershed investigations consisted of a visual assessment to identify where typical channel conditions (channel stability, sinuosity, slope, etc.) change significantly and to define boundaries of assessment reaches according to those changes. Additional components of the watershed investigation included physical, geomorphic, hydrological, water quality, biological, and habitat assessments. Topographic survey of the river was also completed. Appendix E includes a copy of the final report on the bathymetric study, flow monitoring, and sediment sampling.

1.2.1 Holly Pond Sediment Investigations

The CH2M HILL team conducted bathymetric mapping, sediment core collection, and physical and chemical sediment analyses on sediment samples to examine the existing conditions of the pond. An aquatic biologist made biological observations, generally equivalent to a U.S. Environmental Protection Agency Level I Rapid Bioassessment Protocol, at several representative locations and documented habitat around the pond. Appendix F includes the *Holly Pond Sediment Investigation – Field and Analytical Data Report.* The data collected as part of these investigations provides a framework for developing sediment management strategies. The findings are summarized below:

- ***Aerial and vertical extent of the shoal.*** The November 2008 bathymetry of Holly Pond indicated that sediment surface elevations range from about 2 to 14 feet (North American Vertical Datum of 1988 [NAVD88]). These bathymetry data were used to define the lateral and vertical extent of the shoal in the inlet, to approximate the volume of material comprising the shoal, and to guide the selection of sampling locations for the physical and chemical characterization. During the field work, the shoal was exposed throughout the tidal cycle, except for a very brief period at high tide.

- ***Soft sediment thickness***. The sediment thickness increases southward ranging from 0.2 feet near the Route 1 Bridge to 7.8 feet at the mouth of the Noroton River inlet to Holly Pond.

- ***Sediment grain size***. The average particle size decreases from north to south. The northern end of the shoal is dominated by very coarse sands, gravel, and small cobbles; in the southern samples, the material is dominantly silty sand. The material throughout the shoal was strong enough to support the sampling crew walking out onto the shoal without sinking.

- ***Chemical analyses.*** Laboratory data indicate that the sediments are moderately contaminated with PAHs, metals, and pesticides. This limits the possibilities for beneficial use of material and disposal options. Polynuclear aromatic hydrocarbons (PAHs) range up to nearly 200 times ecological screening criteria. Several PAH compounds are also above State of Connecticut Industrial Fill screening criteria. Chlordane was also detected at all locations at levels above ecological screening criteria. Arsenic, mercury, chromium, copper, lead, nickel, zinc, and cadmium were present at detectable concentrations in a number of samples. Typically, the constituents listed above are associated with the fines component of the material.

- ***Benthic community assessment.*** The bottom substrate at the majority of sampling stations in Holly Pond was soft silt. The exceptions included the northern end of the Noroton River inlet to Holly Pond, which had a firmer sand-gravel bottom; the southwestern corner of the pond, which had a sand-gravel bottom; and north of the dam, which had a cobble, gravel bottom. Benthic biota were generally observed to be sparse in Holly Pond. The dominant organisms observed were estuarine and included mud snails (*Nassarius obsoletus*) with patches of a branching red algae (possibly *Gracilaria sp.*) and sea lettuce (*Ulva lactuca*). Other organisms observed in lesser number included American oysters (*Crassostrea virginica*), crabs, shrimp, amphipods, a juvenile horseshoe crab (*Limulus polyphemus*), trumpet worms (*Pectinaria sp.*) and two unidentified bivalve species. A few oyster beds were observed on the southeastern shore of Holly Pond on sand bottom.
- ***Reference wetland.*** The upper and lower limits of Common Reed (*Phragmites australis*), the lower limit of the low salt marsh at the extent of Saltmarsh Cordgrass (*Spartina alterniflora*), and the upper limit of high salt marsh at the extent of Marsh Elder (*Iva frutescens*) were obtained.
- ***Salinity*** at the southern end of Holly Pond was measured at 20 parts per thousand.

1.2.2 Noroton River Investigations

CH2M HILL performed field investigations in the Noroton River and its watershed to characterize geomorphic, hydrological, and water quality conditions. Field investigations included a full survey and assessment of the main stem of Noroton River to Camp Avenue and rapid assessment of the remainder of the main stem and additional tributaries to identify primary erosion areas that could be sediment sources. Appendix G includes the *Holly Pond River Assessment – Field and Analytical Data Report.*

The field investigations included the following:

- Water Quality Investigation
- Hydrology Investigation
- Hydraulics Investigation
- Sediment Supply Investigation
- Sediment Transport and Storage Investigation
- Riparian Vegetation
- Topographic Survey

The new data from the investigation included streamflow data from a gage location; water quality analyses, including total suspended solids, suspended sediment, and nitrogen parameters; channel bed sediment grain size distribution; and digital terrain mapping. Qualitative components of the investigation included documentation of channel bank erosion locations; documentation of riparian and floodplain vegetation characteristics;

channel, riparian, and floodplain hydraulic roughness estimates; channel, riparian, and floodplain habitat conditions; and other relevant observations regarding river morphology, hydrology, sediment transport, and vegetation. The data were incorporated into the project GIS, as needed.

1.3 Sediment and Watershed Characterization

Historical information and field data were used to characterize hydrology and pollutant loadings and to link sediment sources in and around the Noroton River to shoaling in Holly Pond.

1.3.1 Holly Pond Sediment Shoal Characterization

CH2M HILL completed an initial comparison of characterization results with the Connecticut Department of Environmental Protection (CTDEP) and USACE criteria for open water disposal, upland management options, and beneficial use determinations. The dredging envelope was calculated, including the depth and aerial extent of the shoal. These determinations also included estimates of removal volumes.

Below is a summary of the discussions held with CTDEP regarding the results of the Holly Pond sediment investigation (at the Noroton River inlet) with respect to potential management options and next steps. The elements of the discussions that contributed to the alternatives analyses are also reiterated in the next section of this report.

Analytical Results for Sediment Chemistry

The chemical analyses performed, although not consisting of an exhaustive list of parameters, indicated that the sediments are moderately contaminated, as highlighted below, and this will limit the possibilities for beneficial use.

- PAHs are up to nearly 200 times ecological screening criteria.
- Several PAH compounds are also above State of Connecticut Industrial Fill screening criteria.
- Chlordane was also detected at all locations at levels above ecological screening criteria.

Typically, the constituents listed above are associated with the fines component of the material. Appendix H includes a benchmark comparison.

Sediment Removal Options

The estimated removal volume was calculated to be approximately 16,000 cubic yards of material from an area of approximately 24,000 square yards. This volume was approximated using a removal elevation of 0.0 foot NAVD88. The following assumptions were noted:

- The proposed removal elevation of 0.0 foot NAVD88 was selected to bring the sediment surface down to an elevation similar to that observed in the northern portion of the pond (at the end of the Noroton River inlet where the pond widens).
- The proposed removal only focused on the two shoals visible in the Noroton River inlet area.

- The planned removal depth, which accounts for 1 foot over dredge allowance (the need for overdredging is discussed further below), would range from 1.75 to 2.25 feet.
- Selection of a deeper removal depth would result in a greater volume of material and possibly an expansion of the footprint.
- The dam maintains the water surface at approximately +1 foot NAVD88. Removal to an elevation of 0.0 foot would:
  - Remove the visible portion of the shoal.
  - Not create a gully or trench in the upper reaches of the Noroton River inlet area, which could affect sedimentation rates and hydrodynamics.
  - Result in approximately 1 foot of water depth at low tide.

CTDEP indicated no concerns with the proposed elevation. There was no stated expectation that a defined channel would need to be created (e.g., deepening the existing channel in addition to removing the visible shoal material).

CTDEP would require additional testing (at depth) to characterize the sediment that would be exposed at the dredge-cut surface. CTDEP provided additional guidance, as follows:

- Analytical requirements would include semivolatile organic compounds and volatile organic compounds, pesticides, polychlorinated biphenyls (as Aroclors), metals (current metals list was acceptable), and GS/TOC.
- Bulk sediment data could be used to approximate toxicity characteristic leaching procedure (TCLP) concentrations.
- CTDEP cited the need to potentially over dredge and backfill with up to two feet of clean material for ecological protection.
- The U.S. Environmental Protection Agency and USACE guidance would need to be cross-referenced on this issue.

If over dredging can be avoided, then there is the potential for substantial cost savings. If over dredging and backfilling is required, the type of backfill material would need to be determined using modeling of stream flows (or by an approximation based on what is currently present).

There were a number of concerns raised with respect to the 1994 dredging plan that was not implemented, including:

- The vertical extent of the walls on either side of the Noroton River inlet area was called into question after the permit was reviewed. (Note: The 1994 plan also called for removing a greater thickness of sediment in the Noroton River inlet area.)
- The staging area previously selected was in Gerli Park as well as within the Noroton River inlet area itself. There is very limited working area in these locations. Gerli Park could still be used to stage one piece of equipment (e.g., crane or excavator), but more area would be required. The only other realistic option would be to use the privately owned property behind Giovanni's Restaurant. A November 1994 letter from Mr.

Michael Pavia (at that time, the Stamford Department of Public Works Director) indicated that the property owner had previously offered use of the property for drying of sediment. Use of the property for equipment staging and sediment dewatering would need to be confirmed with the owner.

Other items noted with regard to removal included:

- Based on the composition of the material, odors are unlikely to be problematic.
- Removal could be completed within one construction season, but removal work could not occur from June 1 to September 1 because of shellfish spawning.
- Any noise or traffic congestion would be noted no matter where the staging area is placed.
- The staging area could be resurfaced or returned to original conditions after implementation.
- The *phragmites* established on the eastern side of the cove constitutes a tidal wetland and is subject to all the protective measures required for wetlands. If there was interest in restoring that area to contain native plants, CTDEP can advise.
- Discharge water could be under a general permit if discharged to the sewer. This would be the best option for flows under 50,000 gallons per day. The salinity levels would likely require a special permit from the receiving treatment plant. If there would be run-back, elutriate testing requirements are likely. Barge dewatering, solubility, and odor concerns were also discussed.

Materials Separation Options

If the sands and gravels and fines were separated during removal, the disposal costs could be substantially reduced. Initial estimates (including the over dredge allowance) indicate that approximately 15,650 cubic yards (about 23,500 tons) of material will be removed. Based on particle size distribution data from the 2008 sampling event, it is estimated that slightly over 60 percent of this material is composed of sands and gravels. If the dredge material is separated by particle size, the sands and gravels could be used as fill material. The remaining fines (clay/silt component) will require disposal in an appropriate upland facility.

The topic of separating the material resulted in the following discussion points:

- Even with the separation, the material might still not pass as “clean fill.”
- Given the relatively small volume of material, it might be more feasible to dispose of all the material at an upland facility.
- There are several other facilities in the region that have sorting operations; it was unclear whether any of them would be permitted to accept this material, including:
  - The nearby asphalt/aggregate plants might be able to use some of the gravel-sized material if it could be screened appropriately (salinity of the sediments may make this infeasible).

- McVac in New Haven was cited as a possible resource for sorting; however, it was not certain if its permit would allow for processing of dredged material.
- The City of Stamford also has a separator for road sweepings.
- The City of Torrington has a sand washing/sorting mechanism that has been very successful.

Beneficial Use and Disposal Options

Alternatives incorporating beneficial use of the removed material would be extremely challenging as described below:

- There were some early suggestions regarding potentially using the material to create a park area along the shoreline in another area of the pond. Any actions that result in creation of more usable open space along the shoreline (i.e., expanding a park area) create adverse impacts on wetlands areas and flood storage. CTDEP confirmed that filling any areas of the shoreline (e.g., bulk-heading) would not be permitted. All regulations with respect to the tidal marsh areas focus on protection and preservation; any action contrary to that would not be permitted.
- Because the fines component of the material contains elevated chemical concentrations, the potential for remobilization of those parameters would need to be considered (e.g., any type of open space created may require engineered barriers to prevent leaching or sediment mobilization, thus requiring an operations and maintenance schedule and budget).
- The material is not suitable for beach nourishment because of the chemical concentrations and grain size distribution.
- Given the high PAH concentrations, use of all the material for industrial fill would be questionable, even if a suitable location could be identified.

Beneficial use of the fines component (or all of the material if not separated) is highly unlikely. Based on the initial chemistry data, this material would require additional CTDEP permitting, and a specific approved destination would need to be identified prior to removal. Additional testing to specify disposal options will be necessary (i.e., elutriate testing).

CTDEP indicated that the material is likely to be considered a special waste requiring TCLP testing and a special waste permit. The frequency of TCLP testing required would be dependent upon the selected landfill, but generally one sample per approximately 4,000 cubic yards is acceptable. Manchester or Windsor landfills may accept this material; the tipping fee was approximated at $70 per ton (about 1.5 cubic yards). Several other in-state and out-of-state locations were discussed.

Ocean disposal was also discussed as summarized below:

- Requires toxicity testing based on bulk chemistry.
- If this disposal were permitted, the material would have to go to the disposal area off of New Haven/East Haven.

- Material would likely require a cap; this would require teaming with a larger (i.e., federal) project occurring at the same time that is disposing of cleaner material.
- Material would be handled at least twice to load it onto the barge to get it out to the disposal area.

Dam Impacts

The dam was also discussed with CTDEP, as follows:

- The condition of the dam is still in question. It may still leak even though repairs were recently made.
- Any action taken with respect to altering the dam must not restrict the tidal exchange that is currently happening.
- Increased tidal flushing of the pond is still considered beneficial if the tide gates were to be restored to operable conditions.

Habitat Restoration

Habitat restoration in the inlet has been discussed as part of a solution to decrease materials disposal. A habitat restoration plan would need to address all of the same issues discussed above.

1.3.2 Hydrology, Hydraulics, and Sediment Transport Characterization

The material causing the shoaling in Holly Pond is derived from a number of sources. To evaluate the sources and fate of sediment within this system, a conceptual level "box model" for Holly Pond was constructed. Each source, sink, and process is illustrated as a box or an arrow transferring material between boxes. The purpose of the model is to demonstrate the relative order of magnitude of the various sources to the pond and the fate of the solids once they reach the pond. This information can then be used to concentrate future efforts on the most significant sources of sediment loading and the key processes affecting shoaling.

Box Model Development Approach

The box model was developed by first determining the potential sources of solids to Holly Pond using the results of the pond and watershed investigations. The site-specific determination of sources was supplemented by review of reports and published articles for similar systems where shoaling and sediment impacts are a concern. The primary reports reviewed are listed in the references section.

This approach identified a number of primary sediment sources to Holly Pond. There are other sources, such as aerial deposition, but they are considered minor and are not included in this order of magnitude box model. The major sediment sources to the pond are as follows:

- Runoff and erosion from land in the watershed
- Erosion of stream and river banks and beds
- Biologically mediated generation of solids within Holly Pond

- Influx from Long Island Sound on the incoming tide

A similar approach was used to determine the fate of solids once they entered Holly Pond. Two processes, which balance the input of solids to the pond, were identified: deposition in Holly Pond and flushing into Long Island Sound with the outgoing tide. Storage of sediments in stream banks and beds could be considered a fate of solids originating in the watershed. However, it is just a temporary fate, and over time, especially during periods of high precipitation, these solids will reach Holly Pond.

The next step in developing the model was to estimate the relative quantities of sediments from each source and sink on an order of magnitude scale. No direct measurements were made; the estimates were developed using simple modeling exercises and similar situations reported in the literature. The purpose of this characterization was to identify the primary sources of solids to the pond and the key processes affecting the solids fate and transport within the system in order to focus future efforts; therefore, relative contribution of various sources is the focus of the box model.

The final step was to construct a model that balances the sources and sinks of solids to Holly Pond. Each of the sources and potential fates of solids to Holly Pond are discussed in the following sections. This section concludes with the discussion of the resulting Holly Pond Box Model.

Erosion and Runoff from Land in the Watershed

A pollutant load characterization (PLOAD) model was used to estimate the contribution of solids from the land surface to Holly Pond. Calculations were performed on the watershed using land use, percent impervious, and event mean concentration data within each of the subwatersheds delineated by the State of Connecticut. The land use for the Holly Pond watershed was obtained from the State of Connecticut in the form of GIS data. The most recent land use data available from the state is from 2002, and it is assumed that the Holly Pond watershed has seen little land use change in the past 8 years. The land use data has four main categories: agricultural, urban, water, and wooded.

The PLOAD model uses historical rainfall data to determine the volume of water running off from the watershed into the Norton River and other tributaries of Holly Pond. The acreage of each land use type is also input into the model. The mass of solids from each acre is based on such factors as soil characteristics and percent impervious surface. Percent imperviousness and event mean concentrations for land use categories were determined from review of state data summaries, nearby watershed studies, and other guidance from the literature. See Table 1-1 for the values used in the model.

Although urban land accounts for only 27 percent of the acreage, over 80 percent of the solids input from watershed sources is generated from highly developed or urban lands, as shown in Table 1-2.

Erosion of Stream and River Banks and Beds

As noted in the *Holly Pond River Assessment – Field and Analytical Data Report (*see Appendix G), the river appeared generally stable from Holly Pond to Camp Avenue. Isolated areas of significant erosion and scour were recorded, and a few reaches appeared to be particularly dynamic. Bank stabilization (primarily stone walls) along the assessed reaches is fairly

TABLE 1-1
Land Use Percent Impervious Values and Event Mean Concentrations

Land Use	Imperviousness (percent)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
Agricultural	2	104.4	3.42	1.02
Urban	70	61.9	1.86	0.32
Water	100	3.1	1.25	0.11
Wooded	2	39.3	0.86	0.11

TABLE 1-2
Contribution of Solids to Holly Pond by Land Use Type

	Agricultural	Urban	Water	Wooded	Total
Acreage in Holly Pond Watershed	476	1,910	43	4,622	7,051
Total (tons per year)	15	360	<1	55	430

common in residential areas and industrial areas, mainly consisting of rock walls and steel/concrete retaining walls. Several failing walls were observed that could be supplying a moderate level of larger bedload to the channel. The field report made a preliminary statement that the sediment load from streambanks did not appear to account for the volume of sediment in the Holly Pond shoal.

Nevertheless, generation of solids from the banks and beds of rivers and tributaries are reported nationally as one of the largest and most significant sources. These sediment sources are also one of the most difficult to quantify. The quantification must take into consideration soil type, stream velocity, slope of stream and bank, channel morphology, channel stability, general topography, past history of runoff in the watershed, and other site-specific factors. Because of this complexity, data-intensive, site-specific studies are needed to directly estimate sediment quantities originating from the stream banks and beds, and these have been done in only a few locations nationwide.

Where these data-intensive studies have been completed, there is some consistency in the relative quantities of solids from stream banks and beds. The solids from these sources are consistently between 67 percent and 85 percent of the total sediment load for the system (USGS, 2003 and Gwinnett County, Georgia Department of Water Resources, 2005). The studies note that highly urbanized areas tend to have higher percentages of the total sediment load from bank and bed erosion. There is speculation that this occurs because most of the urban areas were developed prior to modern methods and requirements for control of erosion during construction. Thus, there was significant runoff of solids during this period, and much of the sediment load was and is temporarily stored in stream banks and stream beds. The studies also found that it takes many decades for sediments stored in the stream banks and stream beds to erode, and it is likely that much of the sediment from construction in the 20th Century continues to contribute to sedimentation in downstream areas like Holly Pond. Additionally, the hydrology of urban areas becomes altered as a result of impervious surfaces thereby increasing the peak flows and volume of runoff. This change in hydrology increases stream velocities and promotes further erosion of stream banks.

For the Holly Pond Box Model, the upper end of the reported range of contribution from river and tributary banks and beds (85 percent) was used because the highly urbanized watershed was largely developed prior to modern stormwater and construction runoff management methods and requirements. Applying this contribution factor to the results from the PLOAD model yields an estimate of approximately 2,890 tons per year of bank and bed solids.

Biologically Mediated Solids within Holly Pond

A small embayment in an urbanized watershed, like Holly Pond, is typically rich in nutrients that support growth of plant and animal material. The production of this material incorporates not only carbon, but inorganic compounds such as calcium (animal shells) and silicon (phytoplankton cells). This material can contribute to the total solids load. Typical production rates (Maughan, 1993; USGS, 2005) for enriched coastal embayments were used to estimate primary production, and these rates were adjusted for respiration and secondary production by animals. This yielded an estimate of approximately 320 tons a year of solids generated by biota in Holly Pond.

Exchange with Long Island Sound

During each tidal exchange, approximately 700,000 cubic meters of water from Long Island Sound enters Holly Pond. This volume carries with it suspended solids, which include eroded material from throughout the sound’s watershed and material biologically generated within the Long Island Sound. The concentration of solids in the water entering from the sound was assumed to be the lower end of the range of suspended solids measured as part of this sedimentation study. This yielded an average annual load of approximately 1,200 tons of solids entering Holly Pond on incoming tides.

There is also a relative large mass of solids leaving the sound with the outgoing tides. The mass was estimated as the solids associated with the return of sound water entering on the flood tide plus the solids associated with the flow generated within the Holly Pond watershed. The concentration of solids in the Holly Pond watershed flow was assumed to be the mid-range concentration from this sedimentation study. Applying these estimates to the flow leaving Holly Pond yields an export of approximately 1,230 tons per year.

Holly Pond Sediment Box Model

Table 1-3 lists the estimates of solids inputs to Holly Pond that could contribute sediment to shoaling.

The Box Model is depicted graphically in Figure 1-1. These solids represent an estimate of the annual sedimentation that contributes to the shoaling and infilling in Holly Pond. Most

TABLE 1-3
Holly Pond Sediment Box Model Summary

Major Solids Inputs and Exports	Estimated Quantities (tons per year)
Erosion and Runoff from Land in the Watershed	430
Erosion of Stream and River Banks and Beds	2,890
Biologically Mediated Solids within Holly Pond	320
Input from Long Island Sound	1,200
Export to Long Island Sound	-1,230
Sediment Deposition in Holly Pond	**3,610**

of these solids result from erosion of stream banks and beds in the Norton River and smaller tributaries throughout the watershed.

Summary

Based on the field investigations and historical data, the Holly Pond Box Model provides a basic understanding of the sources and sinks of solids in the Noroton River and Holly Pond system. The estimated solids runoff from the land represents only a relatively small portion of the solids that are deposited in Holly Pond. Using the available information, there may be two main sources of sediment: erosion of stream banks in the tributaries to the Noroton River, and historically deposited sediment in the stream beds of the tributaries and main stream. It is possible that during large runoff events, the sediments in these stretches are flushed downstream. This flushing of in-stream sources is supported by the literature and anecdotal information provided by residents. The water quality analyses indicated high concentrations of suspended solids (greater than 30 milligrams per liter [mg/L]), which indicate that solids are still being transported and settling in Holly Pond.

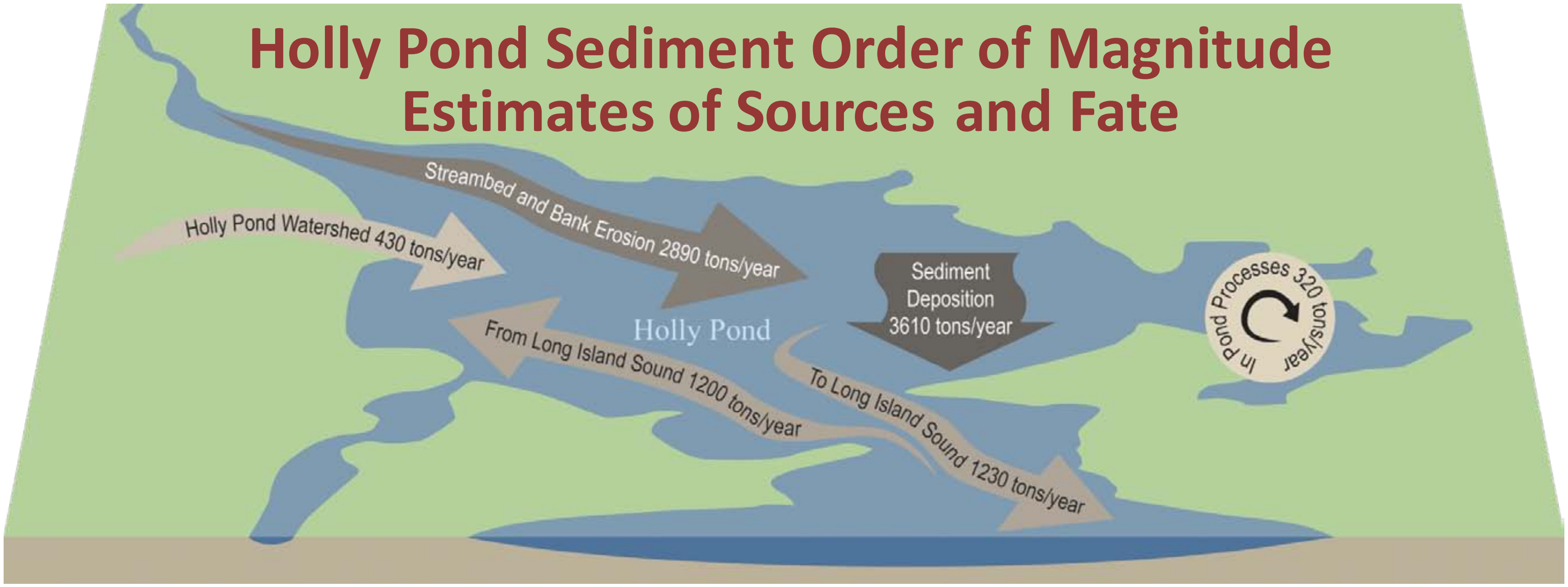
Other specific sources of sediment were discussed during the sedimentation study:

- Winter sanding of highways and local roads - Available information suggests that ConnDOT and municipalities now use salt-only solutions on winter roads.
- Gravel operation at Camp Avenue – Closed; now condominiums.
- Municipal/ConnDOT maintenance and storage facilities – Should be adhering to recognized best management practices (BMP) for stormwater management.

While these sources could have contributed to sediment loading, and in some cases might still be contributors, it is likely that in-stream sources are currently the primary source of solids being transported downstream. Additional analyses to confirm these findings could include the use of pollen layer dating or carbon dating to measure sediment deposition rates.

More detailed survey and calculation of bank and bed erosion, particularly in the upstream tributaries, could be completed if it would be beneficial in evaluating future alternatives. In fact, the sediment generated from erosion of tributaries in the upstream watershed may be

FIGURE 1-1
Holly Pond Sediment Order of Magnitude Estimates of Sources and Fate



	Source	Input Tons/yr	Export/Retain Tons/yr
1	Streambed and Bank Erosion	2,890	
2	Holly Pond Watershed	430	
3	Import From Long Island Sound	1,200	
4	In Pond Processes	320	
5	Sediment Deposition		3,610
6	Export to Long Island Sound		1,230

the primary source given the relative stability of the Noroton River observed during field reconnaissance efforts. There are many analytical methods for estimating sediment supply from in-stream sources including repeat measurements of channel shape through time (e.g., cross sections and longitudinal profiles), hydraulic and sediment transport analysis (e.g., excess shear stress calculations relative to a representative particle size), hydraulic models (e.g., one- and two-dimensional), and bank stability analysis. While these methods have been used successfully to predict sediment yield, these approaches require a significant amount of stream data, which are not currently available for all stream segments within the Holly Pond watershed. These methods are also difficult to verify without proper calibration data such as measured sediment yield, both on an annualized and storm event basis.

SECTION 2

Alternatives Analysis

This section contains a summary of the alternatives analyses completed for the sedimentation study, leading to the design concepts and management strategies for restoration and sustainability that are presented in the final section of this report.

2.1 Holly Pond

Several remedial and management options were considered and discussed with CTDEP. Much of the discussion is presented as part of the characterization in the previous section of this report. Elements of the discussion that contribute to this alternatives analysis are highlighted below.

The focus of past studies and permits has been on sediment removal by dredging. Currently, it is estimated that approximately 16,000 cubic yards of sediment would need to be dredged from the inlet to result in a sediment elevation similar to that in the adjacent area (0.0 foot NAVD88). Removal to this depth would result in approximately 1 foot of water depth at low tide. The sediment sampling of the shoals indicated the presence of PAHs, chlordane (a pesticide), and metals. As noted previously, this level of contamination makes beneficial use of dredged sediment unlikely. In addition, over dredging and backfill with clean fill may be required to mitigate exposure of buried contaminants exposed by sediment removal. As a result of these challenges, CH2M HILL focused on solutions that minimize the cost and implementation challenges of sediment removal.

Maintaining a completely open channel in the inlet is likely not sustainable without aggressive reduction of sediment sources. While reduction of sources is also a focus of the overall project, it would pose a significant challenge to prevent sedimentation and shoaling indefinitely. Nevertheless, several options related to the dredging option were reviewed. A review of alternatives is provided below.

2.1.1 Removal with Beneficial Use of Sediment

The level of contamination limits beneficial use options. Because the fines component of the material contains elevated chemical concentrations, the potential for remobilization of those parameters would be considered (e.g., any type of open space created may require engineered barriers to prevent leaching or sediment mobilization, thus requiring an operations and maintenance schedule and budget).

2.1.2 Removal with Sediment Processing

If the removed material is separated by particle size, the sands and gravels could be used as fill material. The remaining fines (clay/silt component) will require disposal in an appropriate upland facility. Space constraints adjacent to the dredging site make implementation of a processing alternative expensive. Also, processing the material might not necessarily produce a product that would qualify as clean fill.

2.1.3 Removal and Disposal

Based on discussions with CTDEP, any sediment removed will require upland disposal, which adds significant costs to the project. Given this, the intent is to minimize the amount of sediment removed and find other ways to make the project cost-effective and sustainable. While some amount of dredging will occur on the project, the project team investigated alternatives to reduce the cost and inconvenience of dredging while providing other benefits.

2.1.4 Tidal Marsh Restoration

As an alternative to sediment removal alone, this alternative proposes to restore 8 acres of the historical tidal marsh habitat with grading and planting to create small "islands" of low tidal marsh habitat surrounded by open channels for river and tidal flows. This project aligns with CTDEP's successful long-term tidal marsh restoration program. The goal of this alternative is to establish the pre-disturbance characteristics of the site to the extent practicable, including plant and animal species, structure, function, and habitat values. While the full tidal range has been restricted because of the presence of the dam, the process of sedimentation that is occurring in this system can be used as a benefit to restore tidal marsh while maintaining flood storage. In particular, this alternative provides the following advantages:

- ***Threatened/endangered species and species of concern:*** Marshes and stands of marsh grass are habitat to numerous species of concern including birds, mammals, and aquatic species. Improving hydraulics and creating vegetated wetlands will prevent degradation of benthic communities resulting from intense deposition of eroded sediments. It will also reduce suspended solid concentration and improve habitat quality for pelagic species.

- ***Diadromous fish habitat:*** Sustainable maintenance of the river/inlet channel with suitable depth, substrate, and shading will facilitate migration of anadromous (those that breed in freshwater and mature in saltwater) and catatromous (those that breed in saltwater and mature in freshwater) species. This applies to migration of adults and juveniles. Improving the substrate physical and chemical quality creates critical benthic habitat to support primary food sources for migratory fish. Unmanaged sedimentation limits the area and time period (i.e., only high tide) providing depths suitable for migration. This can significantly reduce the spawning success and juvenile survival rate of the species.

- ***Shellfish habitat:*** Most of Holly Pond sediment is mud with a few isolated areas of pebbles. Providing areas of clean and coarser sediments through sediment restoration and hydraulic controls will provide a higher diversity of shellfish habitat.

- ***Coastal wetlands:*** Addressing Holly Pond sediment issues through hydraulic modifications will improve connections to existing wetlands. This will allow wetland expansion to other areas through movement of seeds and wetland fauna. Also, stabilizing sediments will encourage establishment of rooted aquatic plants and improve the quality and quantity of coastal wetlands.

- ***Climate change and sea level rise***: The CTDEP has reported that sea level rise could be altering the zonation of plant communities in Connecticut and that marsh systems could be drowning without room for migration (Dreyer and Niering, 1995). The project proposes to restore low marsh and associated habitat at the current elevations in Holly Pond, which are slightly higher than historical levels as a result of sedimentation. This anticipates sea level rise and supports the pond's ability to adapt and provide healthy habitat at a higher elevation for habitat migration. As sea levels rise, the restriction of tidal range because of the dam will become less significant. The restored bathymetry can be configured to support the species and aquatic communities that would otherwise be rare as a result of climate change.

Community benefits from the Holly Pond inlet restoration would include the following:

- Minimizing costs associated with current and future handling and disposal of contaminated sediment to maintain an open channel.
- Habitat for birds, fish, shellfish, invertebrates, and other aquatic species.
- Increase in Connecticut's coastal wetlands as part of the Long Island Sound Estuary.
- Increase in urban green spaces.
- Angling opportunities through improved fish habitat.
- Nature and wildlife observation.
- Signage placed around restored areas for the dual purpose of public education and protection of sensitive areas.
- Employment opportunities as part of construction.
- Adaptation to climate change and sea level rise.
- Enhanced property value near the pond.
- Improved business for Giovanni's Restaurant adjacent to the Holly Pond inlet.

2.1.5 Other Alternatives

Other alternatives that could be considered in Holly Pond are additional sediment removal or habitat restoration, as well as modified operation of the dam to improve low tide flows and flushing of the pond. These alternatives are not considered feasible in the near future unless significant funding becomes available for evaluation and implementation.

2.2 Noroton River and Watershed

It is important to address the sources of sediment and pollution since the ability to control these sources will help to avoid additional costly restoration efforts in the future. The program should continue to identify watershed management approaches to sustain the ecological and aesthetic benefits. These improvements can and should begin immediately and continue as funding becomes available.

The enhancement allocation awarded under the Federal Highway Administration (FHWA) Enhancement Program administered by ConnDOT has been held for Holly Pond since the mid 1990s. The focus for many years has been on the sediment removal project in Holly Pond, the cost of which far exceeds what is available from the FHWA. With the realization that the City of Stamford is seeking funding for Holly Pond restoration, ConnDOT indicated that the enhancement money set aside for construction must be obligated as soon as possible and advised the SWPCA to identify a smaller project that could be implemented in 2010. In 2009, discussions resumed on how to use the FHWA allocation and the following ideas were evaluated:

- Retrofit catch basins with BMP technology that would capture sediment and reduce pollution.
- Prioritize bank erosion areas for improvement.
- Construct forebays/riprap weirs between stormwater discharges and the Noroton River/Holly Pond.
- Implement a catch basin labeling program.

2.2.1 Noroton River Improvements

Based on the results of the Holly Pond Box Model, it is clear that sediment loading from in-stream sources must be addressed. Management alternatives include restoration of stream banks to reduce erosion as well as in-stream sediment capture features (e.g., forebay or weirs) that would require periodic maintenance.

Implementation of any improvements in the Noroton River will require close cooperation among Stamford, Darien, and New Canaan. Property ownership of the stream banks along much of the Noroton River is private, and municipal programs to assist homeowners in embankment maintenance and restoration can be pursued. Homeowner permission/agreements to facilitate large-scale municipal restoration of the stream are also an alternative.

Such improvements to the river would qualify for the ConnDOT funding. Because the available ConnDOT funding would not be enough to complete meaningful improvements in the Noroton River, these alternatives were not evaluated in detail during the course of this study.

2.2.2 Stormwater Retrofits

Stormwater retrofits are also an important part of reducing sediment loading. For the Holly Pond and Noroton River system, retrofits should focus on mitigating the urbanization of the watershed and restoring a more natural hydrologic cycle. This will reduce stormwater impacts on the Noroton River.

Catch basin BMPs can be implemented and then monitored to ensure they meet certain performance measures. BMPs would also help Stamford and Darien meet stormwater permit goals (i.e., Stamford’s Phase 1 permit requires documentation of catch basin maintenance and improvements). The SWPCA stated that interlocal agreements between

Stamford and Darien are currently under negotiation, and such a program can be included to ensure Darien's commitment to catch basin maintenance.

The steps would be:

1. Identify potential catch basins connected to the Noroton River. Stamford mapping was available. Dye testing may be required on the Darien side. The goal would be to select catch basins having the most impact on Holly Pond.
2. Establish baseline for sediment and pollutants entering the Noroton River through catch basins.
3. Complete a desktop analysis of technology/approaches and select most appropriate for installation.
4. Develop performance specification and design based on "approved equal" to meet ConnDOT design review requirements.
5. Obtain ConnDOT design review. Obtain permits as needed.
6. Construct project(s).
7. Monitor performance.

An urban stormwater retrofit project was selected as the most appropriate use of the funding because the project(s) could be scaled to fit the available funding and still be beneficial to the overall goals. The goal of a retrofit project is to remove stormwater pollutants, minimize channel erosion, and help restore stream hydrology. A streamlined alternatives analysis of stormwater retrofit approaches was conducted with the goal of using available FHWA funding for the project.

Potential Technologies and Approaches

The following qualitative summary of the potential technologies and approaches that could be included in an urban stormwater retrofit project is based on Chapter 6 of the *2004 Connecticut Stormwater Quality Manual* (CTDEP, 2004). Primary treatment practices meet the standards of a minimum of 80 percent total suspended solids and 80 percent floatable removal. Secondary treatment practices do not meet this standard.

- ***Shallow Marsh Pond Retrofit*** – a Primary Treatment Practice. An existing dry detention pond is converted to a shallow marsh. Dry ponds are sometimes considered a secondary treatment practice because studies have found that sediment can pass on through the system.
- ***Raingarden/Bioretention*** – a Primary Treatment Practice. An existing untreated storm outfall would have the first flush diverted to a retrofit bioretention area. Alternatively, an untreated parking lot can sheet flow into a bioretention cell retrofit along the side or into landscaped islands.
- ***Catch Basin Inserts*** – a Secondary Treatment Practice and Innovative / Emerging Technology. A number of suppliers are available. Low cost per installation would mean more installations for the available funding.

- ***Proprietary Manufactured BMP Systems*** – Two categories, hydrodynamic separators and media filters, are considered innovative / emerging technologies. A number of suppliers are available.

Shallow marsh ponds and proprietary BMPs were culled from the list because of space and siting limitations at the outfalls on the Noroton River. Proprietary systems also require a rigorous review and approval process by ConnDOT. ConnDOT completed a separate review of the project area in early 2010 and also determined that there were no suitable locations for these technologies. The remaining two approaches were discussed with ConnDOT in more detail, as summarized below.

Catch Basin Inserts

Catch basin inserts can treat stormwater runoff from small, highly impervious sites. If used without pretreatment, they consume no land and have few site restrictions. Adequate pretreatment to prevent premature filter clogging and ensure retrofit longevity requires additional space and maintenance. These filters will provide water quality benefits if properly maintained, but will not address other stormwater management objectives, such as groundwater recharge and channel protection.

Catch basin inserts are considered by CTDEP to be an innovative/emerging technology. A number of suppliers and technologies are available and the specific technologies vary in terms of target pollutants. The pros and cons of implementing catch basins include the following:

- Pros: Can be low cost, can be incorporated in a variety of locations; some technologies can be fit into existing catch basins (see Figure 2-1).

FIGURE 2-1
Installation of Smart Sponge ® Catch Basin Inserts
Photo courtesy of Abtech Industries

- Cons: Might require additional space or components depending on technology and design requirements (e.g., the product shown on Figure 2-1 is not designed for sediment loads without pretreatment); regular maintenance inspections and cleaning is required; must be designed for full design flow bypass; disposal requirements must be determined (if pollution is present); does not enhance natural hydrologic regime of watershed.

Bioretention

Bioretention is a landscaping feature adapted to treat stormwater runoff. It provides moderate to high pollutant removal and can become an attractive landscaping feature with high amenity value and community acceptance. In the right landscape setting, bioretention can be a cost-effective and flexible retrofit option with minimal maintenance requirements.

The technology is based on the same premise as a "rain garden." An existing untreated storm outfall would have the first flush diverted to a retrofit bioretention area.

Alternatively, an untreated parking lot can sheet flow into a bioretention cell retrofit along the side or into landscaped islands (see Figure 2-2). Bioretention can also be incorporated along sidewalks, curbs, and medians as part of a "green streets" program. This approach is included in the CTDEP stormwater manual (CTDEP, 2004).The pros and cons of using bioretention include the following:

FIGURE 2-2
Bioretention in a Parking Lot

- Pros: Low cost; small area required; low maintenance once established; can be incorporated in a variety of locations; "green" solution helps to restore natural hydrologic regimes by decreasing impervious surface and promoting infiltration to the soil; visible surface location encourages proper care and maintenance; excellent public education opportunity; adds more of a park-like feel to an urban area.
- Cons: Need property owner engagement; some sites not suitable; should be incorporated into regular stormwater maintenance program.

Stormwater Retrofit Alternatives Analysis

The best alternative for sediment removal and restoration of natural hydrologic regimes that reduce erosion in the stream would be to divert the first flush of a storm event to a bioretention basin at an outfall. Along the Noroton River, this most likely requires installation on private property. The best alternative for siting on municipal property in the drainage area is the parking lot bioretention option.

The best use of catch basin inserts is to install in areas of low sediment and leaf litter (to minimize pretreatment and maintenance requirements) to focus on removal of other water quality pollutants (e.g., hydrocarbons).

Bioretention was the recommended approach and ConnDOT agreed in 2009 that bioretention is the preferred option if appropriate sites can be identified.

2.2.3 Other Alternatives

In general, watershed improvements can include the following:

- Volunteer programs such as stream cleanups to engage the community.
- Catch basin labeling programs, such as "Don't Dump – Drains to Long Island Sound."
- Stream and channel restoration to reduce erosion.
- Low impact development, such as site design and stormwater controls that minimize and filter runoff.

Individual projects can be sized from as small as $100,000 each to millions, depending on the scope and goals. Cost and benefits can be evaluated as part of an adaptive implementation approach. The implementation of watershed improvements should continue over the long term. As improvements are implemented, monitoring and modeling are used to evaluate watershed-wide effects. The watershed management plan is adapted over time as incremental improvements are made.

SECTION 3

Basis of Design

The primary purpose of this task was to establish project design criteria for the alternative recommended during the alternative analyses. Design objectives, procurement policies, regulatory agencies, and other permitting requirements were integral to the preparation of these concepts.

3.1 Holly Pond

While previous studies have focused on sediment removal only (e.g., "dredging"), the Holly Pond inlet restoration was recommended to restore approximately 8 acres of historical tidal marsh habitat. This alternative compared favorably in terms of cost with previously proposed dredging programs and was the most feasible alternative to reduce dredging volumes and associated disposal costs. The restored inlet would effectively manage sediment and nutrients while providing critical aquatic habitat for feeding, breeding, and migration. Controlling sediment and pollution in the watershed would ensure that the health of the river and pond are sustained for decades to come. The information on the tidal marsh restoration design concept is based on a grant application that was prepared and submitted to NOAA in April 2009.

3.1.1 Design Concept

The design of this recommended alternative includes the following features:

- An open-water perimeter channel constructed along the edges of the low marsh area and in areas that would otherwise be adjacent to *Phragmites*-dominated marsh (located on the east side of the pond) to provide 1) tidal cycling and flushing of the marsh to maintain sufficient salinity to prevent the spread of *Phragmites* to the disturbed marsh and mitigation areas; and 2) inundation to prevent the spread of *Phragmites* rhizomes and leaders across the channel. The 10-foot-wide open-water channels will be constructed to a depth to maintain continued inundation.
- Selection of vegetation and planting specification.

Appendix I includes information and conceptual sketches of the design concept, including the preliminary cost estimate.

The long-term maintenance and management of the Holly Pond Project will be under the direction of the City of Stamford in cooperation with the Town of Darien, CTDEP, and neighborhood representatives, such as the Cove Neighborhood Association. The concept has received endorsement from the Stamford legislative delegation including Connecticut State Representative Carlo Leone, Senator Andrew McDonald, and Connecticut State Representative Gerald Fox; former Stamford Mayor Dannel P. Malloy; former Darien Selectwoman Evonne M. Klein; the Cove Island Wildlife Sanctuary; and adjacent business owner Gabriel Giovanni (see Appendix J).

3.1.2 Permitting

Key required permits for this alternative would include the following:

Federal Permits: 404 Wetlands by USACE; Coastal 401 Water Quality Certification Diversion/401 to be obtained in conjunction with CTDEP applications. National Environmental Policy Act requirements have been reviewed and would be incorporated into the future work, as needed.

State Permits: CTDEP Office of Long Island Sound Programs– Structures, Dredging and Fill and Tidal Wetlands and 401 Water Quality Certification.

3.1.3 Project Benefits

The project is intended to provide an overall benefit to the environment and minimize the potential for adverse impacts. For example, the project area is listed as Essential Fish Habitat for Atlantic Herring and Pollock juveniles and adults; all life stages of Red Hake and Window Pane Flounder, and Winter Flounder; and potentially Ocean Pout adults. The restoration of trophic levels will benefit to these species, and construction impacts will be minimized.

A tidal marsh restoration plan would provide justification and a path forward for wetland mitigation activities. This implementation plan, along with construction drawings, would provide the necessary details of the wetland mitigation activities. Habitat equivalency analysis (HEA) would be used to quantify the changes in wetland ecological services associated with impacts and mitigation. HEA determines the present value of ecological services provided by a habitat over time.

HEA views a habitat as a stock or an asset that provides a flow of services over time. HEA requires that service flows from the injured habitat and service flows from the mitigation project be characterized with a common metric. For the majority of HEAs conducted, this metric is an acre-year or service-acre-year, where one fully functioning acre of a habitat will provide 100 percent of ecosystem services for 1 year. If that 1 acre of habitat lasts 2 years, the acre will provide 2 acre-years of services, and so on.

The project would confirm the baseline level of services over the 8.3-acre restoration area and the projected change in functionality under “with project” and “without project” conditions to measure the incremental benefit as a result of implementing the project. The uplift in ecological services generated in future years would be discounted to determine the net present value of the environmental benefit in units of discounted service acre-years. The ecological metric developed for estimating functionality would be the indicator for the primary ecosystem services that are provided by tidal marsh ecosystems (e.g., habitat quality for benthic communities, pelagic species, diadromous species, and shellfish). This approach toward quantifying the value of ecological services from restoration projects is similar to the method that NOAA (NOAA, 1995) and other federal agencies (i.e., U.S. Department of Interior, U.S. Fish and Wildlife Service, and National Park Service) and states use as a valid approach for quantifying impacts and benefits of ecological services associated with various restoration actions. These tidal marsh ecosystem benefits would be estimated during the construction period and will be verified during the monitoring phase of the project.

The tidal marsh restoration plan would build on the design concept and present more detailed design features, vegetation, and planting specifications.

All other project benefits stem from the success of the restoration of the historical tidal marsh and aquatic habitat and ensuring optimum flow patterns for tides and freshwater flows. The result would provide an aesthetic and natural amenity for the community. The additional long-term benefits to the community include the following:

- Improved angling opportunities within the 8-acre inlet and the Noroton River. Additional stream miles would also benefit from restoring Holly Pond upon completion of separate restoration projects within the river. Currently, the public has access to the shoreline along the west side of the pond and from a community park on the northern end of the pond. Boat access is provided by a rudimentary (publicly accessible) boat launch on the east side of the inlet.
- Nature study and wildlife observation would be enhanced by the restoration project. Signage will be placed for the dual purpose of further educating the public on the benefits of the restoration and protecting sensitive areas from inadvertent trampling.
- The restoration would complement the planned improvements to the community park, including landscaping and a gazebo to facilitate outdoor gatherings and enjoyment of the natural setting in an otherwise urban environment.
- Approximately 24,000 direct labor hours of employment were estimated for the tidal marsh restoration in Holly Pond. This includes jobs in heavy construction and civil engineering; engineering services; nursery stock wholesalers; and remediation services. This estimate was provided as a minimum based on direct labor expended on the project and did not include labor hours associated with providing materials, equipment, or other areas. It also does not include any of the other phases of work, which would also generate significant labor needs in similar categories. The project is likely to meet stated employment targets as the estimates are based upon similar projects that are in various stages of implementation.
- Property values adjacent to the pond and within the viewshed could be enhanced by the restoration.

Information obtained from readily available sources including state fisheries experts, other knowledgeable local sources, and the empirical environmental economics valuation literature would be used in a benefits transfer analysis to assess the short- and long-term economic benefits of the proposed restoration project.

In addition, Holly Pond's innovative approach will serve as an example to communities nationwide. Consideration of habitat restoration as an element of a sedimentation project is still often overlooked in favor of dredging and disposal.

3.1.4 Implementation Schedule

The Holly Pond tidal marsh restoration would be undertaken by the City of Stamford in cooperation with the Town of Darien. This inlet restoration is an essential aspect of the overall watershed improvements that will demonstrate visible progress and engage community support for future phases.

The restoration would occur in stages over a 24-month period with up to 5 years following construction to monitor the wetland plantings and wildlife.

Year 1

First steps would include conducting first year monitoring for baseline (existing conditions) assessment. The assessment would include detailed habitat assessment; identification and documentation of reference wetland; and supplementary sediment sampling to confirm final disposal classification and provide detailed information to the dredging contractor. The reference wetland would be selected based on similarity to the project site in terms of hydrologic characteristics and landscape position; it would serve as a model for the proposed hydrologic regime and plant community of the planned wetland. Baseline vegetation surveys would be conducted in the reference wetland to determine the vegetative species composition and percent cover of vegetation in this healthy, well-established wetland system to serve as a model for the restoration. Detailed micro-topographic surveys would be conducted in the reference wetland to confirm the elevation data to be used to replicate optimal hydrologic conditions. The project team would use first year monitoring information to confirm layout, elevations, grades, and planting scheme using the project digital terrain map and hydraulic and sediment transport modeling. By the end of the first year, required permits would be obtained and construction contracts awarded based on a competitive bid process.

Year 2

Construction activity begins with development, review, and approval of the project submittals. The contractor would mobilize to complete grading operations as weather and permitting requirements dictate. Initial activities would include site-specific safety training; preconstruction bathymetry of project area; installation of erosion control around upland work areas; site preparation and construction of access to Holly Pond site; and implementation of tidal/turbidity controls. Tidal/turbidity controls may occur with an aquabarrier, turbidity curtain, and/or pumping/piping. River and tidal flows would be accommodated as the work progresses.

Sediment removal would be conducted per design. Sediment would be handled and disposed of in accordance with project documentation and permits. Staging would be designed to minimize the footprint; the park on the west side of the inlet and the private property on the east side provide limited space. It is assumed that contamination levels would require 1 foot of over dredge and coverage with clean fill (assume clean sand; heavier materials may be required depending on anticipated flow velocities) on all disturbed areas. Site management would also include traffic control, construction surveys, and geotechnical/chemistry testing. Planting and construction of any required protective elements would be completed. Planting in the spring would ensure the longest growing season, the best chance for plant survival, and the best project outcomes. Protection mechanisms may include elements to dissipate high energy river flows to allow establishment of vegetation (e.g., riprap, vanes, and bioengineering practices) and goose fencing. The contractor would repair or rebuild any damaged retaining walls and restore all disturbed upland areas used for staging and construction purposes. Demobilization would be completed.

Vegetative monitoring data would be collected in the fall after the first growing season following the planting of the site. A metric would be chosen to represent the percent cover that would be expected in a young, healthy wetland system in the early stage of development compared with a well-established, vigorous system (i.e., such as the reference site). The careful matching of elevations and plant species found in the reference wetland should optimize the likelihood that this criterion will be met. Percent cover and species composition would be monitored using the same methods used for data collection in the reference wetland (i.e., fixed 1-meter square quadrants). A minimum number of monitoring stations would be surveyed at representative locations in each habitat type. Native and non-native or nuisance plant species would be listed and their percent cover would be quantified. These data would be used to guide vegetation management measures. Observations of wildlife occurrence and use would be noted during each site visit. If, at the time of the post-construction monitoring, it is determined that vegetative cover at the site does not meet the criterion, then appropriate action would be taken to improve vegetation establishment (e.g., supplemental planting). A contingency plan would be implemented to execute the appropriate corrective action, and its success will be evaluated at the end of the next growing season.

After the monitoring event, a data summary report would be prepared documenting plant species cover. The report would include information such as composition of established vegetation (including both native and non-native species), wildlife observations, descriptions of significant conditions, and photographs of the created wetland. If contingency measures are determined necessary and are implemented, then a report will be prepared that discusses those measures, and subsequent reports will include a discussion on the success of the implemented actions.

3.1.5 Monitoring and Maintenance

The adaptive implementation approach includes a monitoring and maintenance plan that will guide the work of the City of Stamford in the establishment of the native tidal marsh community. Successful restoration of tidal wetlands is contingent upon the monitoring and maintenance of these created resources. To establish viable tidal marsh for the purpose of maximizing ecological services, the following success criteria would be monitored:

- Establishment of planted vegetation. The monitoring program would assess the plant species composition, percent cover, and general health and vigor of the individuals of each planted species compared with conditions observed in the reference wetland, as described above. The presence and percent cover of non-native and nuisance plant species (e.g., *Phragmites*) would be quantified to assess the need for invasive species control measures in the wetland.

- To assess how well the wetland is providing ecological services in the form of wildlife habitat, it would be monitored for wildlife usage. The occurrence of wildlife species that can damage marsh vegetation during wetland development, such as geese, would also be monitored to assess the need for control measures for nuisance wildlife species.

The design and tidal marsh restoration plan would present site-specific hydrologic and ecological design considerations that provide reasonable assurance that the wetland will be self-maintaining. Nevertheless, because wetlands are inherently unique expressions of their hydrologic and ecological setting, conditions could vary from those anticipated. As a preventive measure, monitoring of the wetland would indicate the need for implementation of corrective measures for unanticipated site developments.

Vegetative monitoring data would indicate whether established wetland vegetation is developing along a normal trajectory. If the vegetative monitoring data point to an unanticipated problem, appropriate solutions will be developed, reviewed, and implemented.

Potential challenges relating to the sustainability of vegetation may include the following:

- Intrusion of invasive plant species
- Herbivory by waterfowl, muskrats, or turtles
- Plant diseases or infestations
- Plant mortality caused by weather or flow conditions

Should these challenges occur, they could be managed as follows:

- Invasive plant species can be controlled by removal of individual plants, mowing, or herbicide prescriptions. Herbicides may be applied to individual plants, or used on a larger scale, depending on the degree of invasion.
- There are a number of ways by which herbivory can be addressed, including additional exclusion fencing, population reductions (i.e., through trapping, hunting, or the attraction of herbivore predators), and chemical deterrents.
- Mortality caused by plant disease or infestation can be mitigated by identifying the disease or insect and using an appropriate pesticide to control the problem.
- Plant mortality resulting from weather or flow conditions might require the replanting of the wetland to restore proper vegetative cover and diversity, depending on the severity of the damage to the wetland. It might also require an adjustment to the design to protect plants from future damage.

These examples illustrate the utility and importance of the monitoring results in guiding the long-term growth and development of the wetland and in addressing unanticipated problems. The information collected during this period will be used to assess other improvements for the Noroton River and Holly Pond.

3.2 Noroton River Watershed

3.2.1 Bioretention

As discussed in the alternatives analysis section, a bioretention approach was selected for further development with the intent to use the ConnDOT funding in 2010 if possible. The design was advanced as described in this section.

Watershed reconnaissance

Conference calls with stakeholders and a half-day site reconnaissance with the SWPCA established the following objectives and standards for the project design work:

- ***Design objectives***: Confirmed the overall purpose of the proposed project to ensure that all parties have the same understanding.
- ***Procurement policies:*** Bidding/procurement requirements and restrictions. Use of FHWA funding involves decisions regarding rights-of-way/easements and adherence to ConnDOT procurement policies.
- ***Regulatory Agencies:*** Confirmed the regulatory agencies with jurisdiction for this project and specific contact people.
- ***Civil Design Requirements:*** Coordinated with SWPCA on restrictions as they pertain to the proposed project; permitting requirements; local public work standards as they pertain to the work; and existing floodplain restrictions.

CH2M HILL reviewed aerial maps of Stamford and Darien to identify prospective locations for bioretention. Viable sites have to be in the Noroton River watershed (not only at the outfall) to be considered promising for bioretention and contribute to stormwater management goals for the watershed. Because of funding limitations to obtain easements on private property, municipal and state properties were identified. The ConnDOT Rest Area on I-95 in Darien and several local schools were included in the initial screening.

Hydrologic Analysis and Conceptual Design

Following the site visits, the ConnDOT I-95 Rest Area in Darien and a local Stamford school were selected as the two most promising sites.

The project team discussed the I-95 Rest Area as a potential site with ConnDOT. Initial sizing calculations and concept plans were prepared. Subsequently, ConnDOT confirmed that the rest area was undergoing preliminary design of a reconstruction. The revised layout provided in February 2009 did not provide much landscaped area on the downhill end of the car parking lot for a bioretention area of sufficient size to meet CTDEP requirements. Adjustments to the layout could address this. For example, a few parking spaces could be replaced with bioretention islands. Green roof and pervious pavement options could also be considered. Unpaved areas at the north and east ends of the site could also be considered for bioretention. A revised conceptual design was prepared using the new site layout. A request to meet with the ConnDOT and the site designers was made to determine the feasibility of incorporating the concepts into the final design. The reconstruction is scheduled for fall 2010. Conceptual sketches for both layouts, as well as a general schematic of bioretention design, are included in Appendix K.

The school site was also evaluated in terms of hydrology and water quality. The site consists of a large impervious area, such that the resulting bioretention size needed to meet CTDEP requirements does not fit into the available downhill landscaped area. Similar adjustments as considered for the rest area site could be considered for the school site.

Maintenance

Construction of stormwater retrofits on ConnDOT property – whether it is at the rest area or adjacent maintenance property, bioretention, or other technology – would require some maintenance. ConnDOT and the municipalities would need to make an agreement as to the responsibilities and ownership. Stormwater retrofits on municipal property would be the responsibility of the municipality.

SECTION 4

Public Outreach

Watershed improvements are sustainable only if they accommodate the values of the stakeholders and promote the community's vision of its future. Integrating the technical work with a stakeholder process enables the project results to build on a platform of community goals, evaluation criteria, and prioritized values. Investments can be made with confidence of enduring results.

Public involvement is important to help members of the community connect their behaviors, lifestyles, and activities to the health of the ecosystem. Working with stakeholders on the range of possibilities helps them grapple with the impacts of the alternatives and understand that tradeoffs will have to be made and differing opinions will have to be accommodated.

The City of Stamford and its consultant, CH2M HILL, have been in contact with the community throughout the project, including meetings and discussions with Connecticut State Representative Carlo Leone; Congressman Jim Himes; Stamford Mayor Dannel Malloy; Darien Town Manager Karl Kilduff; Stamford City Representative Eileen Heaphy; several town employees in Stamford, Darien, and New Canaan; the adjacent landowner in Darien; and the Cove Neighborhood Association in Stamford (at the Soundwaters Coastal Education Center). The project team also submitted an update to the online quarterly newsletter from the Mayor of Stamford.

CH2M HILL presented at the Cove Neighborhood Association Meeting in March 2009 along with the SWPCA and Connecticut State Representative Carlo Leone. CH2M HILL also presented at the Sustainable Stamford Expo in May 2009 with an exhibit highlighting the Holly Pond project and as a speaker on municipal stormwater management. Appendix L includes some of the materials prepared in public outreach efforts.

The final marsh restoration project will include upland restoration of affected staging areas on the Stamford and Darien side, which is of interest to landowners and the public. Interpretive signage on the habitat restoration would be placed for educational purposes.

Meetings and dialogue with the public would continue throughout the implementation process to build support and interest, including financial support for ongoing restoration activities in Holly Pond and Noroton River. The formation of a supportive community group to help promote the importance of the Noroton River watershed would be a strong asset in moving the Holly Pond improvement projects forward. The group could help to organize many volunteer activities that would connect the residents and business owners of Stamford, Darien, and New Canaan with this historic and environmentally important waterway. Such an organization is also of benefit when seeking funding.

The restoration of habitat in the Holly Pond inlet is part of the initial steps needed to begin work on improving the health of the Noroton River and Holly Pond. This project will improve the quality of life for residents in Stamford and Darien, increase property values, benefit the adjacent business owner, and create opportunities for healthful outdoor recreation in a safe, urban environment.

SECTION 5

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Appendix A
Project Location Map

Appendix B
Holly Pond Inlet Existing Conditions Photos, 2008-2009

Appendix C

Project Library Index, December 2009

Appendix D

Summary of Holly Pond Historical Documents, February 2009

Appendix E

CR Environmental, Inc. Bathymetric and Sediment Mapping Surveys, Vibracore Sampling, and River Stage/Flow Measurements at the Noroton River and Holly Pond, Stamford, CT, March 2009. Also Response to Comments, June 2009.

Appendix F

Holly Pond Sediment Investigation - Field and Analytical Data Report, February 2009

Appendix G

Holly Pond River Assessment – Field and Analytical Data Report, December 2009

Appendix H
Holly Pond Sediment Data
Benchmark Comparison

Appendix I

Holly Pond Tidal Marsh Restoration Design Concept and Preliminary Cost Estimate

Appendix J

Letters of Support for the NOAA Grant Application, April 2009

Appendix K

Bioretention Concept Sketches for I-95 Rest Area
Existing and Proposed Layouts

Appendix L
Public Outreach Materials