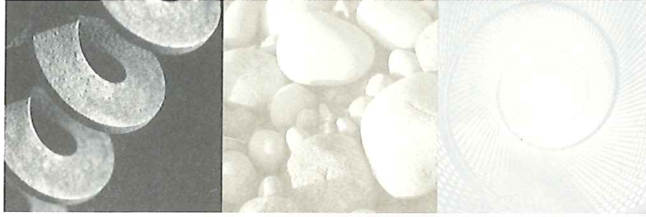

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GEI Consultants

Geotechnical
Environmental
Water Resources
Ecological

Gowanus Canal Investigation Executive Summary Report

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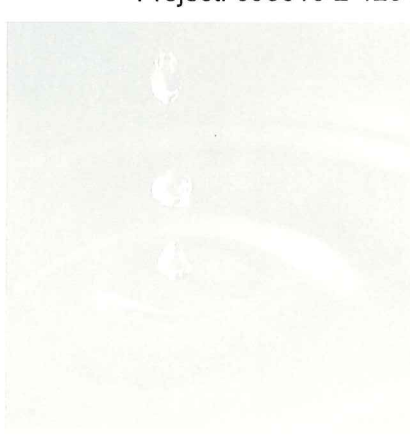

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1. Introduction

On behalf of KeySpan Corporation (KeySpan), GEI Consultants, Inc. (GEI) conducted an investigation to assess the environmental conditions within the Gowanus Canal. This document is an executive summary report presenting the key findings and conclusions of the investigation. Accompanying this document are technical reports prepared by GEI and NewFields Environmental Forensics Practice (NewFields). The GEI technical report documents the investigation methods, findings, results, and our evaluation of the ecological conditions in the Canal. The NewFields report discusses the investigation methods, results, and findings from an environmental forensic evaluation of the source and genesis of hydrocarbons found in the sediments of Gowanus Canal.

KeySpan undertook this work in response to a New York State Department of Environmental Conservation (NYSDEC) Order on Consent and Administrative Settlement (Index # A2-0523-0705) [Settlement Agreement], which was finalized after completion of the field investigations. The Settlement Agreement acknowledges that while KeySpan's predecessors formerly operated three manufactured gas plants (MGPs) on the Gowanus Canal, there are other parties that have contributed to the degraded environmental condition of the Gowanus Canal, beyond impacts potentially related to the former MGPs.

The three MGPs operated by KeySpan's predecessor, Brooklyn Union Gas Company, include Fulton Former MGP, Carroll Gardens/Public Place [former Citizens Gas Works] and the Metropolitan Former MGP Site (Figure 1). The MGPs were historically operated to produce gas for former business, industry and the community surrounding the Gowanus Canal from the late 1800s until the 1950s.

In addition to potential MGP-related contamination, the investigation was also performed to evaluate potential impacts to the Gowanus Canal from the numerous former industries that lined the canal as well as current and former urban discharges to canal. As a result, GEI evaluated sediments, surface water quality, and outfall samples along the entire length of the canal (Figure 1). We also reviewed, interpreted, and utilized biological data collected by previous investigators on behalf of the United States Army Corps of Engineers (USACE).

Other sources of ongoing contamination to the canal include discharges from New York City Combined Sewer Overflows (CSO) and other outfalls that discharge to the canal. On January 15, 2005, the New York City Department of Environmental Protection (NYCDEP) and the City of New York (City) entered into an administrative consent order (ACO) with the NYSDEC to address Clean Water Act (CWA) and State Environmental Pollution Discharge

System (SPDES) violations related to the CSOs that discharge to the canal. In addition, a number of other voluntary environmental cleanups of contaminated former industrial properties are being performed on properties adjacent to the Gowanus Canal; these sites also pose the potential to impact the canal's environmental condition.

GEI's investigation was performed between October 2005 and August 2006 and included the following components:

- Bulkhead and outfall reconnaissance and mapping
- Bathymetry survey
- Surficial sediment sample collection and analysis
- Sediment coring and sediment sample collection and analysis
- Sediment coring and age dating of accumulated sediments
- Surface Water and outfall sample collection and analysis
- Subsurface soil boring installation, sample collection and analysis
- Environmental forensic analysis of hydrocarbon impacts in the sediments
- Evaluation of the ecological conditions in the canal and assessment of the sources of sediment toxicity

1.1 Key Investigation Findings

GEI's investigation of the environmental conditions of the canal has revealed the following key findings.

- The upper sediments (conservatively, the upper 3 feet) are widely considered to represent the biologically active zone
- Sediments in the upper 3 feet beneath the canal are dominated by fine-grained organic-rich accumulations of sewage and CSO outfall materials. These materials are impacted by the presence of multiple chemical stressors (pesticides, polychlorinated biphenyls [PCBs], metals, polycyclic aromatic hydrocarbons [PAHs], and benzene, toluene, ethylbenzene, and xylene [BTEX])
- Physical observations and environmental forensic analyses and indicate that the hydrocarbons (including PAHs) in the upper 3 feet of sediments are largely derived from petroleum sources. Only in the middle reach of the canal, where barge traffic appears to have scoured accumulated sediments do the hydrocarbons and PAHs appear to be mostly related to MGP derived tar
- Tar is present at depths below the accumulated sewage/sediment in the native sand materials

- Gowanus Canal sediment and water quality appears to be adversely impacted by multiple chemical and physical stressors largely unrelated to contaminants associated with the former MGPs.
- Canal sediments were toxic to sediment dwelling organisms in controlled laboratory exposures, with sewage-related contaminants, including ammonia, being the drivers of the toxicity.
- Ecotoxicological analyses indicated the current canal benthic invertebrate communities are inherently impoverished due to the chemical stressors related to CSO discharges and other sources. As a result, the benthic communities consist of organic pollution tolerant organisms, the distribution of which seems to be driven by physical habitat variability.
- Isotopic age dating of the sediments has established that the upper 3 feet of sediments post-date the operation of the last former MGP, which was decommissioned in the early 1960s. Therefore, any potential historic releases from the three former MGPs have been buried by the rapidly accumulating organic-rich sediment/sewage.
- The rate of CSO-derived sediment accumulation is particularly relevant if a restoration plan were to be considered for the canal. Until the CSO discharge/sedimentation rate can be dramatically curtailed, any remedy posed for the canal would simply be inundated by ongoing siltation.

The remainder of this executive report is organized as follows:

- Section 2 presents a summary of the Gowanus Canal History and Setting.
- Section 3 summarizes the physical findings of our investigation.
- Section 4 discusses and presents the findings from our ecotoxicological assessment.
- Section 5 presents the findings of the environmental forensic study of hydrocarbons and PAHs in the canal sediments.
- Section 6 is a list of cited references.

2. Gowanus Canal History and Setting

The history of the Gowanus Canal is intertwined with the industrial development of Brooklyn and the byproducts of development including industrial waste and sewage discharges.

The Gowanus Canal was authorized in 1848 by State of New York for the dual purposes of draining the wetlands of South Brooklyn and to open the area to development. The Gowanus Canal was constructed between 1853 and 1869 and was designed as a conveyance channel for barges. The canal enabled easy transportation and storage of bulk materials such as coal, petroleum, asphalt, and lumber to support the rapid growth of industry in Brooklyn and surrounding areas. Consequently, the land use adjacent to the canal reflected this. The canal continued to be a primary route of transportation for goods and materials into the area until the completion of the Gowanus Expressway in 1951 (New York City Department of City Planning, 1985).

The historic land uses adjacent to the canal are summarized in the Historical Study of the Gowanus Canal completed by GEI on behalf of KeySpan (GEI, 2003). Historic land uses potentially contributing impacts to the canal included the following groups.

- Oil and petroleum storage
- Coal Yards
- Manufacturing
- Chemical/fertilizer/plastics manufacturing

The Gowanus Canal has also served for the conveyance of sewage and industrial wastes as part of the development and industrialization of the area. During the canal construction, the City of Brooklyn constructed sewers emptying into the Gowanus Canal as early as 1858. The confined nature of the canal and limited tidal exchange resulted in sedimentation and water quality issues shortly after construction. Accumulations of sludges and sediments in the canal became problematic as early as the late 1800s as a result of sewage discharges to the canal. In 1889, the waters in the Gowanus Canal waters were impacted by sewage and industrial discharges that they were considered a public health hazard and a hazard to travel in the canal. At that time, the state commission suggested that filling the Gowanus Canal was the best solution to the poor water quality conditions (Hunter Research, Inc., 2004). In an effort to flush the canal, the City of Brooklyn constructed storm sewer outfalls that drained the Fort Greene section of Brooklyn at the top of the canal in 1899; however, the effort was unsuccessful and only added additional pollution to the Canal.

In 1911, the Gowanus Canal Flushing Tunnel was constructed to pull the less polluted waters of Gowanus Bay into the Gowanus Canal while discharging polluted water at the head of the Canal to the Buttermilk Channel via a propeller and underground tunnel. The Flushing Tunnel infused approximately 300 million gallons of water into the canal and operated from 1911 until 1960 when mechanical failure from a manhole cover that was dropped into the flushing tunnel propeller shaft rending the pump inoperable. With the flushing tunnel inoperable, siltation of the canal occurred and canal water quality returned to its heavily polluted state.

In efforts to reduce the sewage discharge to the Gowanus Canal, the City of New York built the Gowanus Canal Pump Station at the head of the Canal in 1947 and the Owl's Head sewage treatment plant in 1952. However in 1984, the Gowanus Canal contained 13 sewer related outfalls: Nine CSOs and 4 continuous dry weather sewer discharges which discharged the 16.6 million gallons (MG) of raw sewage and 4 MG of combined sewer overflows into the canal on a daily basis (Stone & Webster Engineering Corporation, 1984). The CSO discharges to the Gowanus Canal resulted in the buildup of sludges and sediments not removed by tidal cycle and flushing. Sewage discharge to the Gowanus Canal was reduced but not eliminated after the construction of the Red Hook Treatment Plant in 1987. In 1999, the Gowanus Canal Flushing Tunnel was reactivated and currently pumps approximately 150 million gallons per day of water down the Gowanus Canal. CSO discharges to the canal continue today (USACE, 2006).

The canal is currently used as a conveyance channel for commercial barge traffic and navigation. In 2004, the Gowanus Canal was used to transport 350,000 short tons petroleum products and aggregate materials. The Gowanus Creek Channel, that area below the bottom Hamilton Avenue was used to transport 1,298 short tons of cargo. Together the Gowanus Canal and Gowanus Creek Channel account for 1% of all the cargo shipped in New York Harbor (USACE, 2004).

The Gowanus Canal is surrounded by under-utilized industrial and commercial buildings that are zoned for manufacturing uses. In areas along the southern portion of the canal, big box commercial redevelopment has occurred at the Lowes and Home Depot properties on the eastern side of the Gowanus Canal and Creek Channel.

There are currently ten NYCDEP permitted CSOs that discharge 293 million gallons of CSO waters and two NYCDEP permitted storm water discharge 59 million gallons of stormwater annually to the Gowanus Canal (NYCDEP, 2005). The CSO discharges are permitted under the state SPDES permits for the Owls Head and Red Hook WPCPs in Brooklyn.

There are three NPDES/SPDES permitted industrial charges within the Gowanus Canal: Bayside Oil Fuel Depot and Universal Fixture Corporation in the middle reach of the canal and Amerada Hess Corporation Brooklyn Terminal in the Lower Reach of the canal. A canal reconnaissance performed by GEI as part of our investigation revealed approximately 200 un-permitted outfall pipes daylighting through the canal bulkheads and banks.

As a result of its long-polluted history, the Gowanus Canal is classified as a saline Class D (SD) water body by the NYSDEC. The SD classification is the most degraded saline water body classification that is not suitable for primary secondary contact recreation such as boating or fish propagation According to the NYSDEC, SD waters best use is for fishing and fish survival. The Gowanus Canal was included by the NYSDEC on the Final 2004 New York State Section 303(d) list of impacted waters and was included within the New York Station Section 305 (b) report as required by the Federal Clean Water Act.

3. Physical Findings

This section presents a summary of GEI's sampling and investigation between October 2005 and August 2006. The sediment discussion focuses on the upper three feet of sediment because this zone conservatively represents the biologically active zone in the canal. Detailed discussion of the findings for the deeper sediments is provided in the appended GEI technical report. Overall, physical observations substantiated by forensic analyses indicated that the majority of MGP-related impacts are present in deeper native sands underlying the accumulated sediments and the biologically active zone.

For ease of presentation, the findings are discussed relative to three areas of the Gowanus Canal and Gowanus Creek Channel as described below.

Area of Gowanus Canal	Description
Upper Reach	Area at the head of the Gowanus Canal at Butler Street southward to the vicinity of the intersection of 2nd Street. This area includes Transect A through Transect G. This area includes the former Fulton MGP site.
Middle Reach	Area at the intersection of 2nd Street southward to the in the vicinity of the Hamilton Avenue Bridge/ BQE including the 4th Street, 6th Street, 7th Street and 11th Street Basins. This area includes Transect H trough Transect V and Transect BB. This area includes the Carroll Gardens/Public Place (Former Citizens Gas Works) Site and the former Metropolitan MGP site.
Lower Reach	Area to the south of the Hamilton Avenue Bridge/ BQE within the Gowanus Creek Channel. Transect V through Transect AA are located in this area.

The study area reaches are depicted on Figure 2 along with a recent aerial photographic base illustrating the current land use surrounding the canal. Figure 2 also shows the locations of GEI's transects along which sediment cores and surface water samples were collected.

3.1 Sediment Findings

The sediment in the biologically active zone (upper 3 feet) consists of fine grained organic-rich sewage deposits throughout the upper, middle and lower reaches of the canal. These findings are consistent with the findings from the USACE Site Investigation in 2003. The organic-rich sediment is described as low plasticity organic silts and clays with varying amounts of sand. The sediments contained elevated fecal coliform and total organic carbon levels. The figure below depicts a cross-section through the Gowanus Canal showing accumulations of organic-rich sewage deposits over ten feet at the head of the canal adjacent to the Gowanus Pump Station outfall.

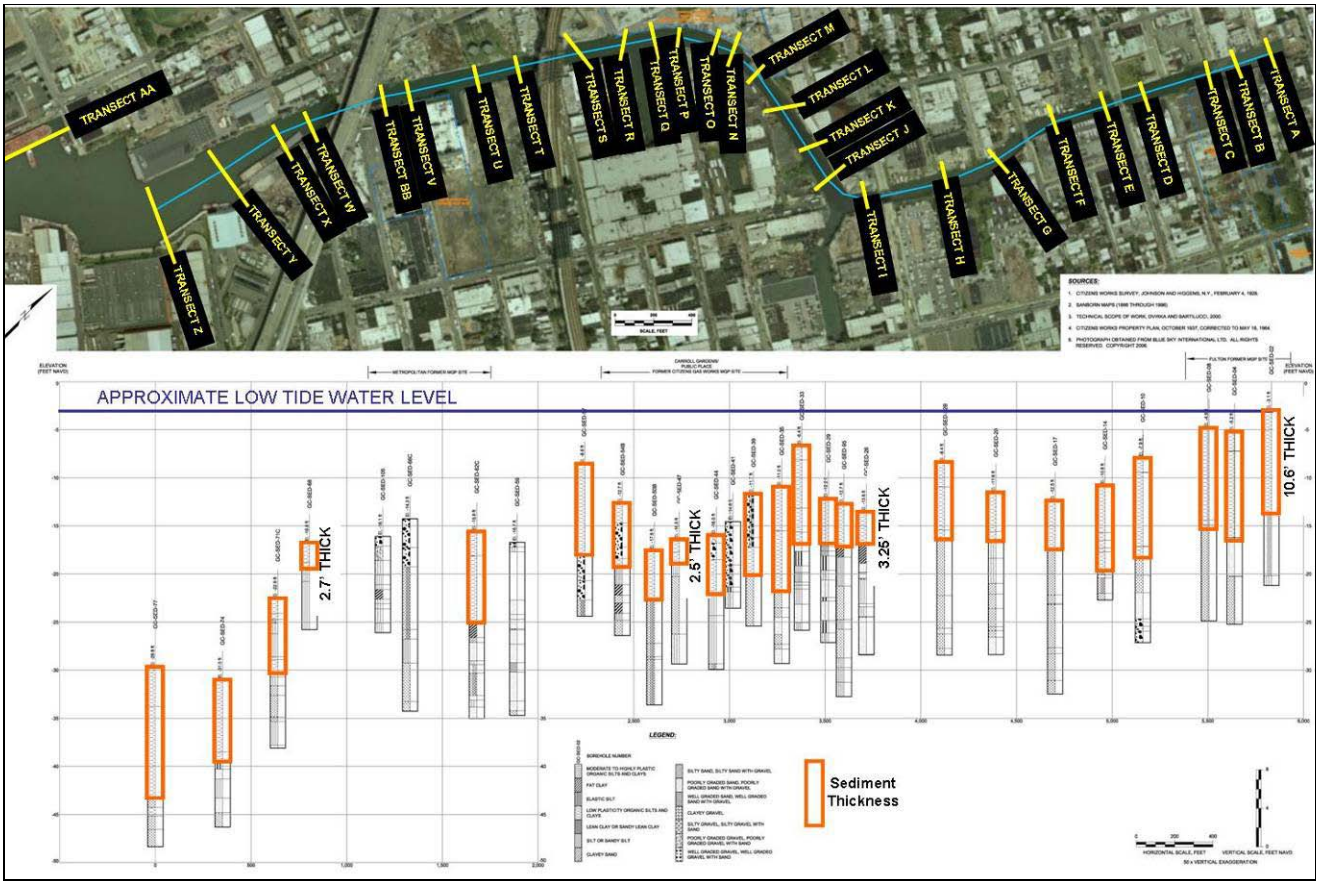

Figure 3. Accumulated organic-rich sediment thickness along longitudinal cross section of Gowanus Canal Sediments.

Thinner accumulations of organic-rich sediments in the vicinity of the former Carroll Gardens/Public Place site and Metropolitan MGP sites in the middle reach of the Gowanus Canal. This area of the canal is subject to barge traffic which has likely disturbed the organic rich sediment accumulations. This is evident at the Carroll Gardens/Public Place site where the organic rich sediments have been scoured and aggregate gravel overspill were encountered adjacent to the on-site concrete plant operations (Transects N through Q, above).

Isotopic age dating of the top 3 feet of sediments revealed sediment accumulation rates of 2.5 to 6.2 cm/year in the canal with the highest rates near CSOs locations and in turning basins. These measured sediment rates are nearly an order of magnitude higher than the range of the 7 to 9 mm per year estimated by the USACE within its mathematical model of the Gowanus Bay and Gowanus Canal watershed. Sediments within the top 3 feet are all very recent and only dated as far back as the 1960s. The age dating and sediment accumulation rates indicate that the upper sediments represent the sewage and CSO accumulations for the time period that the Flushing Tunnel was not in operation and accumulations prior to the Red Hook

Sewage Treatment plant coming on line in 1987. Age dating also indicated some sediment accumulations from the past five years.

The determination of sedimentation rates and the recent age of the upper sediments are specifically relevant to the potential for MGP-era impacts to be affecting the biologically active zone sediments in the canal. The last former gas plants that operated along the Gowanus Canal (Citizen's Gas Works) was decommissioned and demolished in the early 1960s. Therefore, any potential historic releases from the three former MGPs have been buried by the rapidly accumulating organic-rich sediment/sewage since the last of the MGPs shut down.

The rate of CSO sediment accumulation is also particularly relevant in considering any possible restoration plans for the canal. Until the incoming CSO/sediment rate can be dramatically curtailed, any remedy posed for the canal would simply be inundated by ongoing siltation.

The remaining discussion of physical findings will discuss the physical observations observed in canal sediments and the associated chemical concentrations by reach of the Canal and referenced to the former MGP locations. As depicted in Figure 4 below and as discussed in the following text, physical observations coupled with forensic analyses indicate that MGP-tar related impacts are for the most part present below the biologically active sediment zone and, petroleum impacts are present within the upper accumulated sediments that are accessible to the biota in the canal.

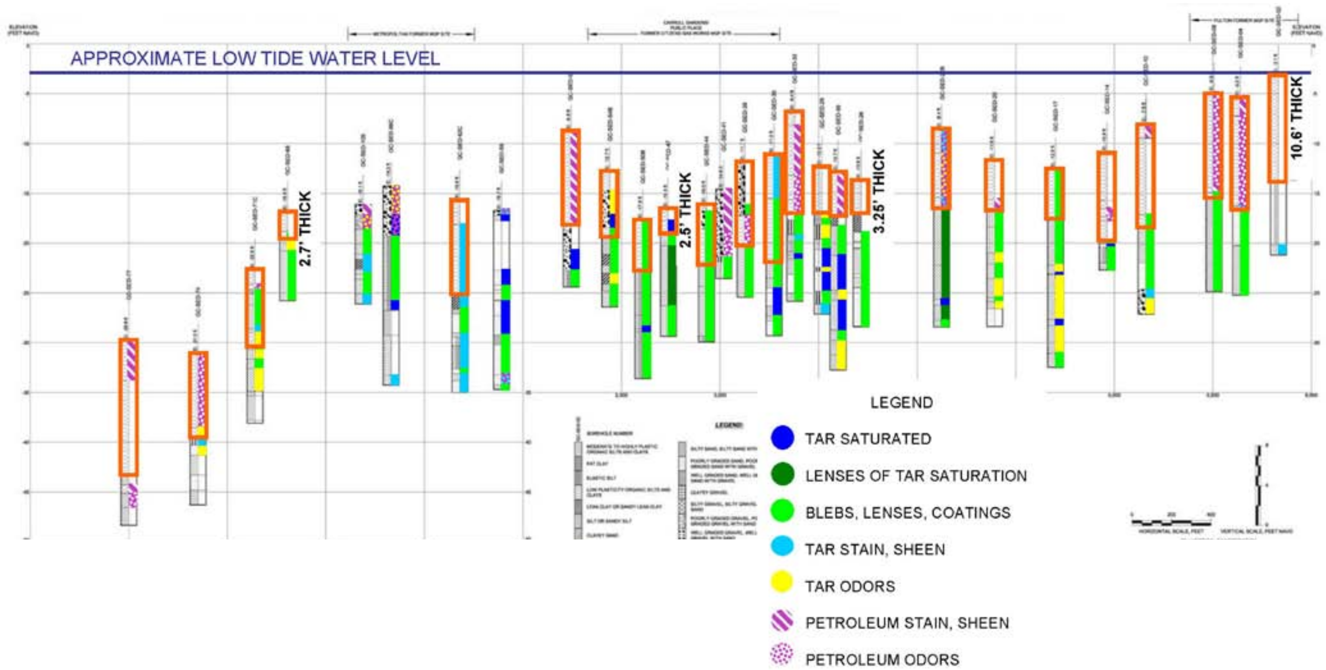

Figure 4. Depiction of environmental impact observations along longitudinal cross section of Gowanus Canal Sediments.

Upper Reach of the Gowanus Canal

The upper 3 feet of sediments within the upper reach of the Gowanus Canal exhibited spotty sheens and petroleum odors. Blebs (isolated sphericals) of dense non-aqueous phase liquid (DNAPL) tar were observed at one core in Transect F to the south of the Fulton Former MGP. Concentrations of volatile organic compounds (VOCs) and PAHs were associated with the petroleum impacted sediments. Forensic analysis of the sediment within the upper reach of the Gowanus Canal indicates that PAHs are primarily associated with petroleum. Sediments in this area also contained concentrations of PCBs, metals, and pesticides at concentrations that exceeded established acute NYSDEC sediment screening criteria.

Middle Reach of the Gowanus Canal

The upper 3 feet of sediment within the middle reach of the Gowanus Canal exhibited spotty sheens and petroleum odors from Transect H to Transect L in the vicinity of Bond Street and within the 4th Street Basin to the west and north of the Carroll Gardens/Public Place Site. Residual DNAPL tar was observed in Transect H in the vicinity of 2nd Street and Transect L in the vicinity of Bond Street. Lower concentrations of VOC and PAHs were associated with the petroleum impacted sediments. Forensic analysis of the sediments indicates that PAHs are primarily associated with petroleum in this area.

Adjacent to the Carroll Gardens/Public Place Site, sediments with patchy sheens and petroleum odors were generally observed adjacent to the eastern and western bulkheads of the Gowanus Canal and within 7th Street Basin. Forensic testing of sediments within the 7th Street Basin indicates that impacts are related to petroleum. Residual tar impacts including tar blebs and coated grains and tar odors were observed at Transect O through Transect R. An isolated black viscous tar-like NAPL material was observed between these transects however, forensic testing indicates that the material was a mixture of tar and petroleum. Residual tar and petroleum impacts were also encountered in Transect T and U below the 9th Street Bridge crossing.

Adjacent to the Former Metropolitan MGP, petroleum and tar impacts were encountered within the top 3 feet of the accumulated sediments. Sheens with petroleum odors were observed in sediments in the 11th Street Basin, Transect V and Transect BB. Sediments within Transect V and BB adjacent to the Metropolitan MGP also exhibited tar saturated lens and residual tar impacts.

Sediments in the middle reach of the Gowanus Canal above, adjacent to and below the former MGP sites also contained concentrations of PCBs, metals, and pesticides at concentrations that exceeded established acute NYSDEC sediment screening criteria.

Lower Reach of the Gowanus Canal

The upper 3 feet of accumulated sediment in the Lower Reach of the Gowanus Canal is characterized with physical observations of spotty sheens with petroleum-like odors were encountered in sediments in Transect W in the vicinity of the Hamilton Avenue Bridge and within Transects Z and AA at the southern boundary of the study area. Forensic analysis revealed that impacts were attributable to a petroleum source. Sediment exhibited naphthalene odors and tar blebs and sheen were observed in Transects W and X below the Hamilton Avenue Bridge/BQE. Heavily tar stained sediments were also encountered within Transect X adjacent to the current New York City asphalt plant.

Sediments in the middle reach of the Gowanus Canal also contained concentrations of PCBs, metals, and pesticides at concentrations that exceeded established acute NYSDEC sediment screening criteria.

3.2 Gowanus Canal Surface Water Findings

The Gowanus Canal surface waters were sampled at each of the sediment coring transects and within turning basins. Samples were collected from the surface and bottom of water column at each transect and each basin in the summer of 2006 during a dry period. The surface water sampling is considered representative of a base flow condition with the Flushing Tunnel in operation.

Upper Reach of the Gowanus Canal

Spotty and iridescent sheens were noted in surface and bottom samples collected from Transects above and below the Fulton Former MGP site. Sheens and NAPL blebs were previously observed during the outfall reconnaissance and sediment sampling activities in the vicinity of the Bayside Oil-Bond Street Terminal and near outfall RH-039 above the Union Street Bridge. Forensic testing of a NAPL bleb near RH-039 indicates a mixture of tar and petroleum.

Chemical analysis revealed the highest concentrations of VOCs generally occurred in bottom water samples above the Union Street Bridge. The bulk of the VOC concentrations in these samples consisted of bromoform which is a by-product of chlorination of public water systems and is likely attributable to the CSOs for the Gowanus Canal Pump Station (RH-034 and RH-035). Elevated fecal coliform concentrations above Union Street and downstream of the outfalls indicate that the CSOs are affecting the water quality in this area of the canal. Concentrations of petroleum-related VOCs, specifically BTEX and methyl-tert butyl ether (MTBE), were detected at the highest concentrations within the canal surface waters within Transect A adjacent to the Gowanus Pump Station outfalls (RH-034). MTBE is a fuel additive typically found in petroleum products and is not related to MGP wastes. Elevated BTEX and MTBE concentrations were also noted in Transect D across from the Bayside Fuel – Bond Street Terminal and
Transect F adjacent to the current Verizon property. These concentrations were below established NYSDEC water quality criteria for an SD water body.

Middle Reach of the Gowanus Canal

Spotty, iridescent, and platy sheens of varying intensity were noted on the surface of the Gowanus Canal and Basins. Sheen and NAPL blebs were periodically noted during sediment investigation activities in the vicinity of Transects N and O adjacent to the Carroll Gardens/ Public Place Site. Fecal matter was observed within these transects and the 7th Street Basin. Particulates resembling emulsified oil and blebs of NAPL were noted in some samples within the 6th and 7th Street Basins. Spotty surface water sheens were observed in the 11th Street Basin and Transect BB just before the Hamilton Avenue Bridge.

Chemical analysis revealed the elevated bromoform and fecal coliform in the surface water in Transects H through K, indicating that CSO discharges from the outfall of OH-007 at 2nd Avenue are affecting surface water quality in this reach of the canal. The VOCs of BTEX and MTBE were typically co-detected indicating that they are associated at least in part with petroleum sources. Elevated BTEX concentrations were also detected at Transect P, Q, and R adjacent to the Carroll Gardens/Public Place Site and to the southeast below the 9th Street Bridge within Transect T and U adjacent to Bayside Oil Depot. Elevated total cyanide concentrations were detected adjacent to the Carroll Gardens/ Public Place Site and the Metropolitan MGP. PAHs were detected in surface waters, however these concentrations were elevated because surface sheens present were inadvertently entrained within the laboratory samples and the results do not represent true dissolved concentrations. PCBs were detected in surface samples below the 9th Street Bridge. Pesticides were detected above water quality standards within surface waters within the middle reach of the canal.

Lower Reach of the Gowanus Canal

Few occurrences of platy sheen were observed within Transect W adjacent to the NYC asphalt plant near outfall RH-602. No other physical observations of sheen were noted within the Lower Reach of the Gowanus Canal.

Chemical analysis revealed the pervasive concentrations of BTEX and MTBE within the lower reach of the Gowanus Canal. The highest concentrations of these compounds occurred in Transect X adjacent to the New York City asphalt plant. Elevated fecal coliform concentrations were noted in the lower portion of the study area that is not serviced by the NYCDEP sewer system. All concentrations are within NYSDEC established standards for an SD waterbody. The only excursion of NYSDEC surface water quality standard occurred for pesticides in Transect Z in the lower portion of the study area.

3.3 Gowanus Canal Outfall Findings

Two hundred and fourteen outfall pipes were identified during the Gowanus Canal remedial sediment investigation. The status of the vast majority of these pipes is unknown. Many of them may drain stormwater and other effluents from landside facilities and others may be disconnected pipe remnants. Of these outfalls, 13 actively flowing outfalls and 48 submerged outfalls were sampled. In addition, accumulated sediments in ten dry (not flowing) outfall pipes were sampled. The results for the active outfalls and outfalls with accumulated sediments will be discussed below by reach of the Canal. Although a relatively small sample set, the outfall water and sediment samples results show that many chemical concentrations in the Gowanus Canal waters and sediments are also found in waters discharging to the canal.

Upper Reach of the Gowanus Canal

Two outfalls were flowing and therefore sampled within the upper reach of the Gowanus Canal. Concentrations of fecal coliform were detected near Transect B above the Fulton

Former MGP site. At the bottom of the Reach, a sample contained sheens and petroleum-like odors and detections of PAH, MTBE, fecal coliform, and a pesticide (Alpha –BHC).

Accumulated sediments from four non-flowing outfalls were sampled within the upper reach of the Gowanus Canal. Outfall sediments contained concentrations of PAHs, PCBs, metals, and pesticides.

Middle Reach of the Gowanus Canal

The remaining 11 outfall water samples and five outfall sediment samples were collected within the middle reach of the Gowanus Canal. The samples were located above and adjacent to the Carroll Gardens/Public Place MGP site and within the 4th, 6th and 7th Street basins. The outfall waters and outfall sediments within the middle reach contained concentrations of PAHs, metals, PCBs pesticides and/or fecal coliform.

4. Ecotoxicology

The purpose of GEI's ecotoxicological investigation was to evaluate the water and sediment quality to determine if the impacts from sources such as CSOs, industrial permitted discharges, overland runoff from properties on the canal, etc., that may be adversely affecting the aquatic resources in the canal. To perform this task we analyzed and interpreted the relationship between biotic and abiotic variables from current GEI sampling and previous studies conducted on the Gowanus Canal. Our ecotoxicological findings were the following:

1. Gowanus Canal sediment and water quality appears to be adversely impacted by multiple chemical and physical stressors largely unrelated to contaminants associated with the former MGPs.
2. Canal sediments were toxic to sediment dwelling organisms in controlled laboratory exposures, with sewage-related contaminants, including ammonia, being the drivers of the toxicity.
3. Current canal benthic invertebrate communities are inherently impoverished due to the chemical stressors related to CSO discharges and other sources. As a result, the benthic communities consist of organic pollution tolerant organisms, the distribution of which seems to be driven by physical habitat variability.

4.1 Finding 1

Gowanus Canal Sediment and water quality are adversely impacted by multiple chemical and physical stressors.

We evaluated the potential impacts to the aquatic community by comparing water and sediment quality data collected by GEI to Class SD water quality standards or guidance values and sediment ecological screening benchmarks. Potential sediment contamination sources, such as permitted and un-permitted outfalls, were evaluated as well.

4.1.1 Evaluation of Potential Ecotoxicological Impacts – Sediment Quality

For many contaminants, low and median toxic effect estimates derived from field studies across the nation were used to as surrogate sediment screening benchmarks. Effects estimates have been established to indicate levels of sediment contamination that can be tolerated by the majority benthic organisms. In our screening analysis of Gowanus Canal sediments, Effects Range-Median (ERM) guidance values for marine and estuarine sediments were used as toxicity benchmarks.

For contaminants without ERM values, sediment thresholds were calculated according to the NYSDEC's contaminated-sediment screening technical guidance document (NYSDEC 1999). Therefore, within the framework of New York State water quality regulations, sediment criteria were derived according to the primary levels of protection for Class SD waters. As these calculated sediment criteria are tied to sediment organic carbon data, they can be considered site-specific sediment criteria (SSSC).

Exceedance analyses for these sediment thresholds were evaluated two ways. First, we determined how often the thresholds were exceeded; i.e., the frequency, or percentage of values over the threshold. The second approach was based on the magnitude of sediment benchmark exceedances based on the ratio of the measured values to the threshold, also called a "Toxicity Quotient" or TQ. TQs > 1 would be predictive of toxicity (i.e., measured concentrations are greater than the threshold). Because aquatic biota are only expected to be exposed to surficial sediments, only sediment quality data from samples collected within the top three feet of sediment cores were evaluated in our analysis.

Twenty-six ERM values were available to develop 26 ERM TQs. Fourteen Class SD water quality standards, 7 guidance values, and 3 default sediment screening values were available to calculate a total of 24 SSSC TQs for this analysis. In total, 50 specific contaminants or contaminant class totals (i.e., total PCBs) TQs were modeled with respect to transect results.

Of the 50 contaminants in which a criteria benchmark was available, only eight were found in Gowanus Canal sediments at levels below respective benchmarks or detection limits. In contrast, 18 contaminants were above the benchmarks in 100% of the samples. Most of these 18 contaminants were PAHs, PCBs, and pesticides. As noted previously, the majority of hydrocarbons (including PAHs) encountered in the upper 3-feet of sediments are generally related to petroleum sources. All transects exceeded at least 20 sediment toxicity benchmarks. Figure 5 presents the Transect specific benchmark exceedance rates with all contaminants combined. No clear-cut patterns of exceedances were noted among transects and results indicated that sediments in all areas of the Gowanus Canal are potentially toxic to aquatic life.

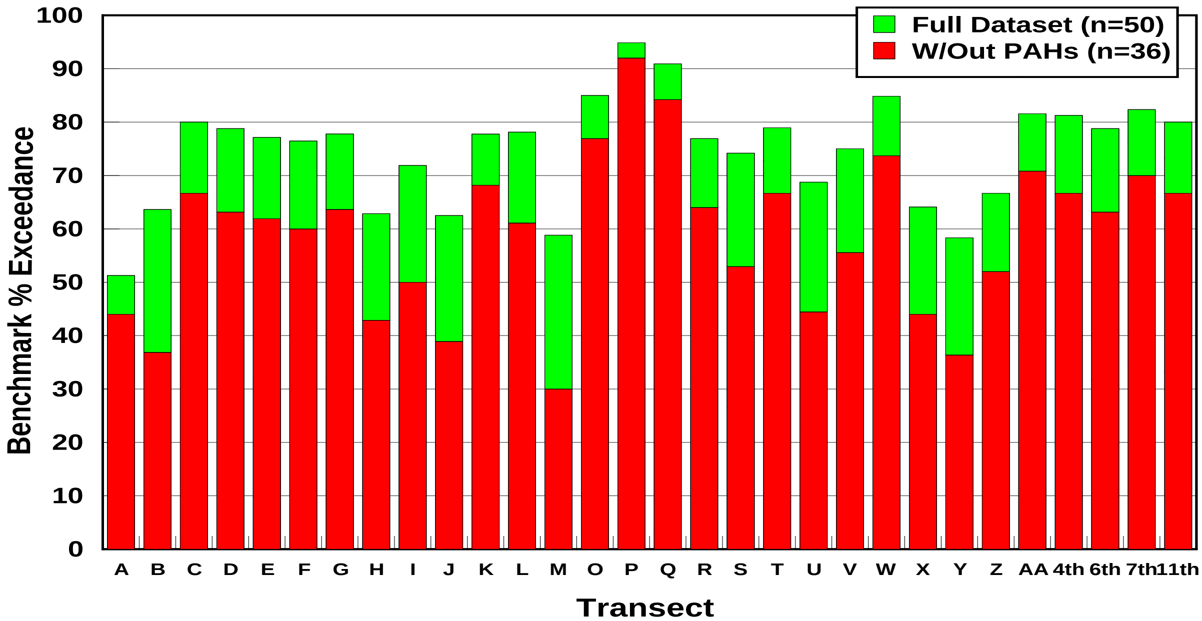

Figure 5. Cumulative sediment criteria benchmark exceedance rates for each transect. Exceedance rates derived using the full dataset contained 50 contaminants. Exceedance rates derived using the full dataset minus PAH contaminants contained 36 contaminants.

To explain the influence of PAHs in exceedance rates we removed the 14 PAHs and re-analyzed the data (Figure 5) for the remaining 36 contaminants (including semivolatile organic compounds [SVOCs], VOCs, PCBs, pesticides, and metals). It is clear there are a significant percentage of exceedances, with a minimum of 30% exceedance and most transects exceeding sediment quality benchmarks greater than 50% of the time, even with PAHs removed.

To investigate the magnitude of sediment benchmark exceedances we derived cumulative TQs for each contaminant category and transect (Figure 6). From this analysis it can be seen that cumulative PAH, PCB, pesticide, and metal TQs are greater than one (zero on the log10 scale) for every Transect in the canal. Cumulative VOC TQs, including cumulative BTEX, were greater than one in just over a third of all of the Transects. The greatest cumulative TQs were derived for PAHs. These results indicate that sediment quality is greatly impacted by multiple contaminant stressors. Additionally, the cumulative impact of all non-PAH contaminants is at least similar to PAH impacts.

In summary, Gowanus Canal sediments are greatly impacted by multiple chemical stressors from multiple sources including sewage and CSO discharges. When analyte results were compared to sediment screening benchmarks, high exceedance rates and TQs were derived for each transect.

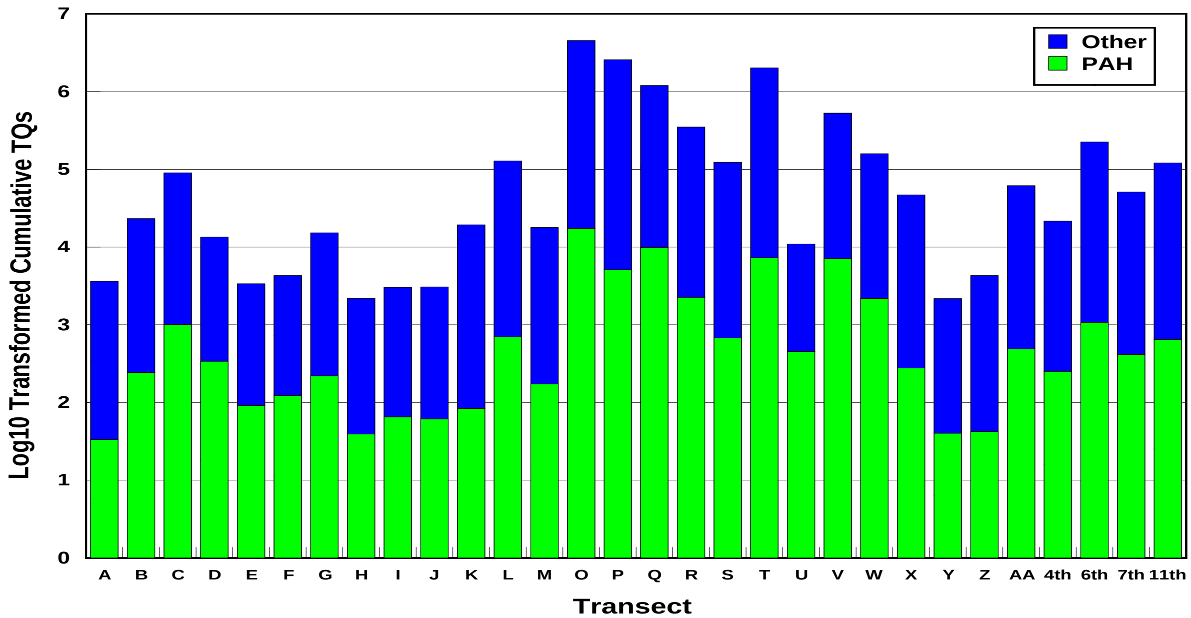

Figure 6. Cumulative log transformed sediment benchmark TQs for PAHs, and other compounds, which included PCBs, pesticides, metals, and VOCs, such as BTEX.

4.1.2 Evaluation of Potential Sediment Contamination Sources

We identified active outfalls as a significant potential source of the surficial sediment contamination within the canal. To identify these potential sources of contaminants, active CSOs and other outfalls discharging unknown effluents were sampled by GEI. Collected effluent samples were analyzed for similar contaminants as performed in sediment analyses. Paired effluent quality-to-sediment quality data were separated into contaminant classes and regressed (Figure 7).

Based on these paired contaminant class data, there was a significant relationship found between effluent quality and sediment contamination for metals and combined pesticides, PCBs, and VOCs. No relationship was noted between PAH concentrations in effluents and sediments within the same transect. These results indicate that outfalls are a potential source of sediment contamination in terms of metals, pesticides, PCBs, VOCs, and to a lesser extent BTEX.

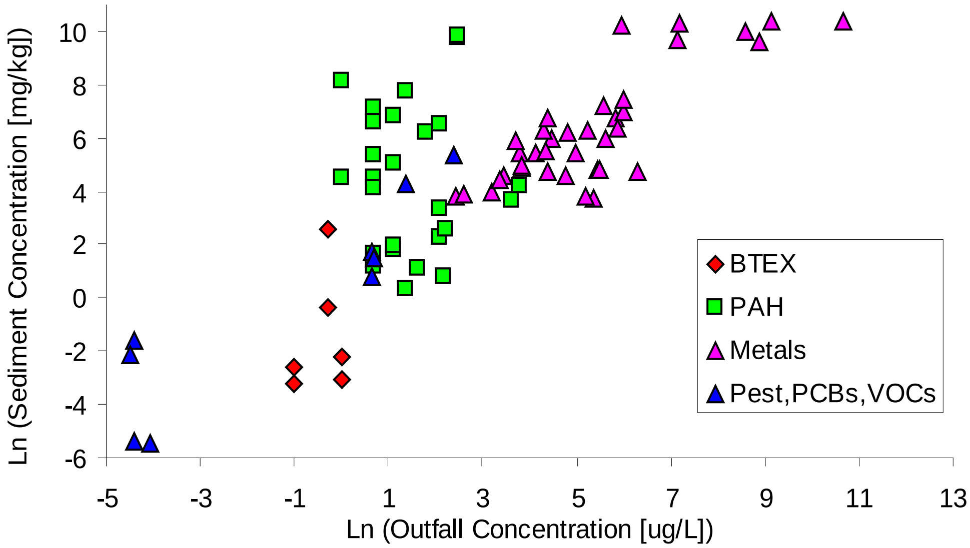

Figure 7. Scatter plot of paired effluent/sediment contaminant results. Paired contaminant results were plotted according to contaminant categories. The contaminant categories included BTEX, PAHs, metals, pesticides (PEST), PCBs, and VOCs.

Similar to water and sediment quality analyses we also predicted the toxicity of active outfall effluents using the same TQ approach. Figure 8 shows the cumulative log transformed outfall-specific TQs for PAHs, PCBs, pesticides, and metals. Analysis of respective TQs showed that active outfalls throughout the Gowanus Canal are discharging potentially significantly toxic concentrations of several contaminants. It is important to note that TQs derived for VOCs, which included BTEX, and dissolved oxygen were less than one, indicating that during outfall sampling these contaminants were not being discharged at potentially toxic levels.

The large PAH cumulative TQ identified in outfall sample number 100 was almost entirely due to benzo[a]pyrene (BAP). This compound was also found in surface water samples near this outfall. Interestingly, the Transect that this outfall was discharging into (Transect H) had the greatest BAP water column analyte results at concentrations that were roughly five fold that of the next greatest measurement, indicating this outfall as the source.

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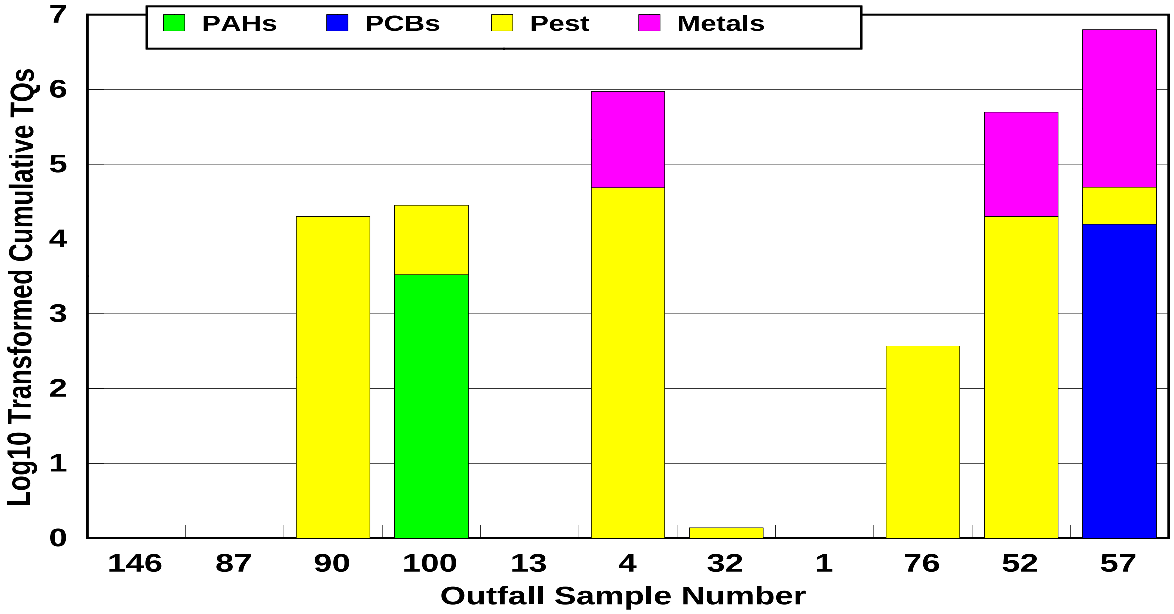

Figure 8. Cumulative log transformed active outfall effluent TQs for PAHs, PCBs, PEST, and metals.

4.1.3 Evaluation of Potential Ecological Impacts – Water Quality

Water quality data were also evaluated using a toxicity benchmark or criteria screen. Class SD water quality standards or guidance values served as toxicity benchmarks and were used to predict potential ecological harm when compared to measured contaminant values. New York State defines water quality standards with respect to classification of surface waters. Gowanus Canal is classified as Class SD saline surface water; therefore, canal waters should be suitable for fish survival or "no acute toxicity." It is important to note that Class SD waters are not intended to protect for more sensitive chronic toxicity endpoints such as fish propagation. For water quality screening purposes, 15 Class SD standards, 10 guidance values, and four narrative standards were compared to measured water column analyte concentrations. From these comparisons the frequency and magnitude, measured as TQs, of exceedances were developed as above.

Of the 25 contaminants in which a standard or guidance value was available, 11 contaminants were found at levels below respective criteria benchmarks or detection limits. In 11 other contaminants, 100% of measured values were found above respective criteria benchmarks, most of which were pesticides (Figure 9).

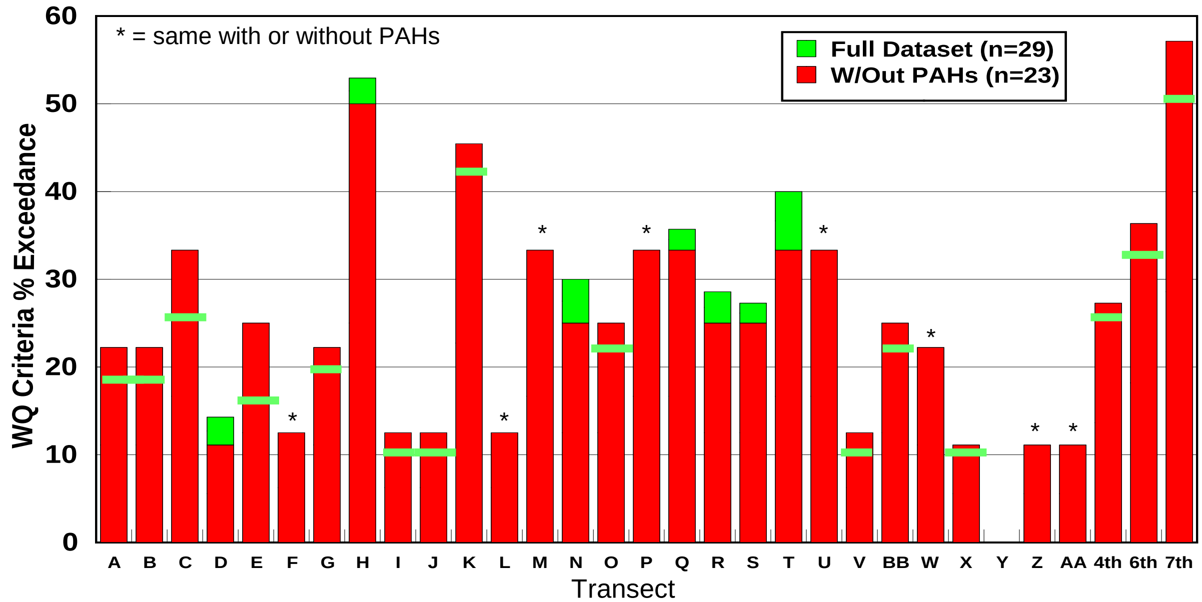

Figure 9. Transect specific Class SD water quality (WQ) standard, guidance value, and narrative standard exceedance rates for the full dataset and the full dataset without PAHs.

Four narrative standards were also assessed in conjunction with numeric criteria. There were no notable differences in dissolved oxygen (D.O.), odor, or floatables narrative standard exceedances between surface and bottom collected samples. The D.O. Class SD criterion (3 mg/L) are not meet in 35% of the surface sampled transect results and 39% of bottom sampled results. The "No residue attributable to sewage, industrial wastes or other wastes, nor visible oil film nor globules of grease" standard was exceeded in 81% of the surface and 68% of the bottom collected samples. Most of these had a patchy or platy iridescent sheen on the sample surface.

To investigate numeric and narrative exceedance rates with respect to PAHs we analyzed results with and without PAHs. Figure 9 presents exceedance rates for the two datasets. The minimal difference between each dataset for most transects, and increased rates in many others, indicates that PAHs are not appreciably contributing to the respective total water quality exceedances in the canal.

To investigate the magnitude of Class SD WQ criteria exceedances we derived cumulative TQs for each contaminant category and transect (Figure 10). The PAH category represents cumulative TQs for each PAH contaminant, except BAP. BAP was removed from the water quality TQ analysis due to the being measured at concentrations greater than the aqueous solubility and a low Class SD standard to protect human consumption of fish. Although

BTEX compounds were measured at each transect, results were far below respective benchmarks; thus, TQs were less than one and are not presented.

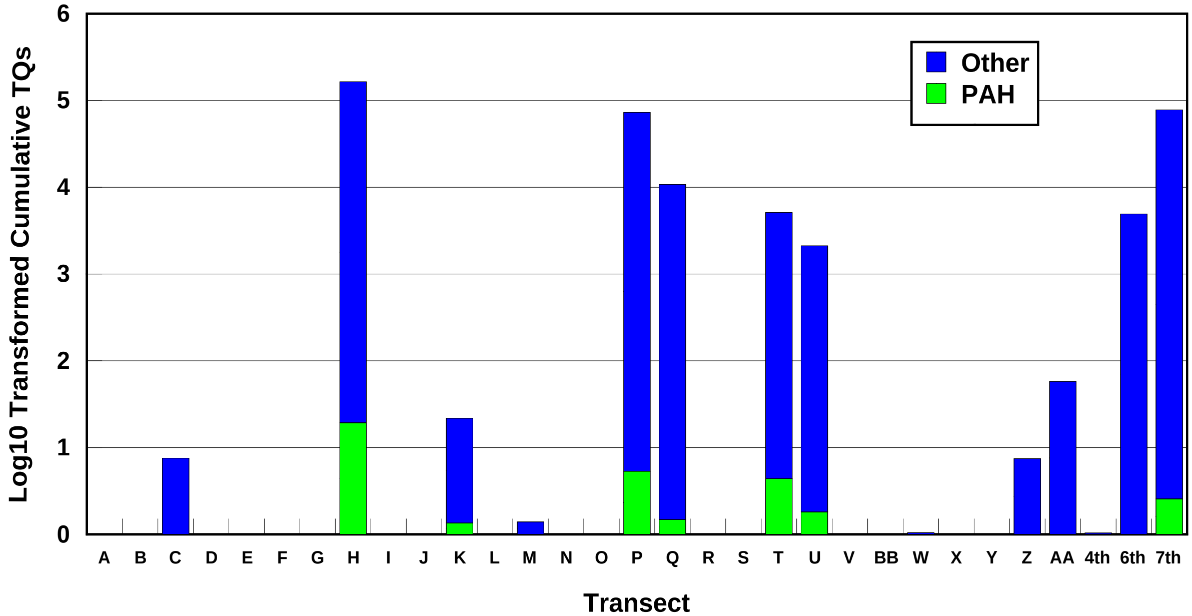

Figure 10. Log10 transformed cumulative water column TQs. The "other" category represents the cumulative TQs for four contaminant categories; pesticides, metals, PCBs, and BTEX. The PAH category represents cumulative TQs for each PAH contaminant, except BAP (see text).

When measured above the detection limits; total PCBs, chlordane, and heptachlor results were greater than screening criteria. D.O. was below the minimum criteria to protect fish survival in over 40% of the Transects and aesthetic narrative standards were not met at most sites due to oil surface sheens.

These results indicate that multiple contaminants might be contributing to the degraded water quality condition of the Gowanus Canal, even when PAHs are removed from the analyses.

4.2 Finding 2

Canal sediments were found to be toxic to sediment dwelling organisms in controlled laboratory exposures.

Since comparisons to sediment benchmarks only *predict* potential toxic effects in aquatic biota, it was important to follow up our analyses with results from recently conducted sediment toxicity testing. The USACE conducted sediment toxicity tests using a sensitive benthic invertebrate species exposed to canal sediments (Aqua Survey, Inc. 2005; DMA, Inc.

2006). Results showed significant sediment toxicity to the test organisms after 10 day exposures (Table 1). Additional data provided in toxicity test results included pore water ammonia concentrations for each sediment sample. Ammonia is potentially toxic to invertebrates and a relationship was found between both initial pore water and test ammonia concentrations and mortality in the test (although not statistically significant). The source of ammonia in test sediments was likely due to the decay of nitrogenous organic matter from the CSOs.

Table 1. Summary of the amphipod *Ampelisca abdita* sediment toxicity test results, initial test sediment pore water ammonia concentrations, and test water ammonia concentrations. Test water ammonia concentrations were the geometric mean of the initial and final ammonia concentrations. Percent survival results are an average of replicate tests.

Nearest transect	Percent mortality	Pore water ammonia conc. (mg/L)	Toxicity test ammonia conc. (mg/L)
A	30%	109	9.5
E	100%	--	8.9
H	5%*	70.6	3.5
J	35%	57.5	8.6
L	100%	42.8	8.4
R	100%	44	9.1
U	22%	59.3	4.1
4th Street basin	1000%	68.4	5.6
6th Street basin	81%	109	5.3
7th Street basin	96%	72	2.6
Control	1%	--	<0.5

* = Not statistically different from control

In addition to toxicity testing, USACE also chemically analyzed a subsample of toxicity test sediments. When analyte concentrations were compared to toxicity test results (Fig. 11), a significant relationship was found between concentration and percent mortality for many contaminants, none of which were PAHs (Table 2). Compared to their respective ERMs, copper, lead, nickel and zinc were found at potentially toxic concentrations, with average TQs ranging from 1.89 for copper to 859 for lead.

Table 2. List of 2005 sediment contaminants that demonstrated a statistically significant positive relationship between natural log transformed concentration and sediment toxicity test percent mortality.

Contaminant (natural log transformed)	p value	Contaminant (natural log transformed)	p value
Bis(2-ethylhexyl)phthalate	0.0356	Copper	0.0332
Total PCBs	0.0430	Lead	0.0261
Arsenic	0.0497	Nickel	0.0318
Cadmium	0.0377	Zinc	0.0414
Chromium	0.0386		

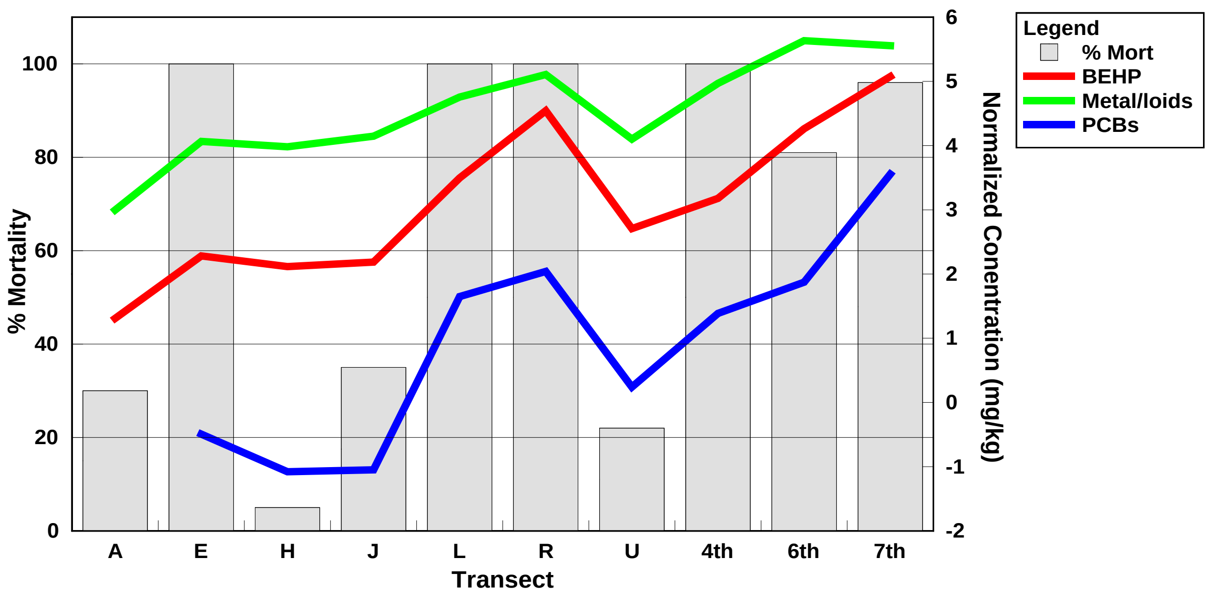

Figure 11. Summary of the amphipod *Ampelisca abdita* sediment toxicity test results, with comparisons to contaminants showing significant relationship to organism mortality.

After predicting that the Gowanus Canal sediments were toxic using comparisons to toxicity benchmarks, toxicity testing confirmed that the sediments are, indeed, toxic to a standard test organism. The parameters found to be significantly correlated with toxicity test mortality are common municipal waste water contaminants and, in the previous section, were found to have a positive outfall-to-sediment relationship. Additionally, the high ammonia pore water concentrations, measured in toxicity test sediments, also support CSOs as a source of acute ammonia toxicity in canal sediments.

4.3 Finding 3

The benthic invertebrate community is impoverished due to the chemical stressors and consists of organic pollution tolerant organisms, the distribution of which seems to be driven by physical habitat variability.

Biological data were used to further characterize the extant Gowanus Canal benthic community with respect to sample/transect location within the canal, local reference conditions, sediment contamination, and physical habitat. Results indicated that the current ecological condition is characterized as being stressed by multiple chemical and physical stressors. Pollution tolerant organisms dominated the invertebrate community. Species richness was lower than nearby stressed New York Harbor communities, which included sewage impacted sites. Although no clear cut chemical/invertebrate community metrics relationships were found, physical habitat characteristics such as sediment particle size, temperature, salinity, and D.O. seemed to drive the distribution of the stressed invertebrate community within the canal.

A total of 29 Gowanus Canal and Bay benthic macroinvertebrate sampling sites were established by the USACE and sampled in April 2003 (USACE 2003). Latitude/longitude coordinates from the study were used to identify site locations to match the USACE sites with 15 of the GEI transects.

Benthic data provided a robust dataset that was used to investigate relationships within and between transects with respect to local reference conditions and sediment contamination. Invertebrate population metrics used to evaluate community condition included species richness and percent pollution tolerant taxa. These metrics were also compared to New York/New Jersey Harbor Estuary reference conditions, based on United States Environmental Protection Agency's (U.S.EPA's) Regional Environmental Monitoring and Assessment Program (REMAP) data (Adams et al. 1998). Three sites were available for comparisons. These sites included upper and lower New York Harbor and the Jamaica Bay (Adams, 1998). It is important to note that these are not pristine reference condition sites, but sites with potentially similar stressors as the Gowanus Canal, in terms of CSOs. Although the benthic samples and GEI sediment collections were temporally disconnected, correlations between benthic macroinvertebrate abundances and contaminant concentrations were also investigated.

To identify the different types of benthic invertebrate communities within the canal, cluster analyses were performed. Clustering was performed on a presence/absence basis to determine the relative similarity of the species composition of the benthic invertebrate communities. The cutoff for designating a "cluster" of benthic samples, matched to transects, was set at 55% dissimilarity. Once clustered transects were identified, community metrics were compared to GEI collected sediment data and water quality parameters recorded during the benthic sampling.

Overall, the benthic invertebrate community strongly represents an estuarine community that is highly tolerant of organic pollution, with most taxa preferring mesohaline environments. A few species which can exist in freshwaters were found and included nematode worms, oligochaeta worms, and flatworms (i.e., Platyhelminthes). Nematoda, which were abundant throughout the canal, are ubiquitous in their distribution and catholic in their ecological preferences and pollution tolerance. Likewise, the Oligochaeta and Platyhelminthes are ubiquitous in their distribution, and as a group prefer soft substrates and are fairly tolerant of high levels of organic matter.

There are notable difference between Gowanus Canal species richness and REMAP reference sites (Fig 12). It is apparent that the sediment contamination noted earlier results in a Gowanus Canal invertebrate community that is very limited. The greatest number of species in canal sites was roughly three fold lower than that seen in the nearby reference sites.

In contrast, when the relative numbers (percent) of the taxa considered "pollution tolerant" are compared to REMAP sits (Figure 13), Gowanus Canal is quite similar to reference conditions. Together these results indicate that, while the number of species in the Gowanus invertebrate community is very low when compared to local impaired communities, the species present have similar pollution tolerance patterns.

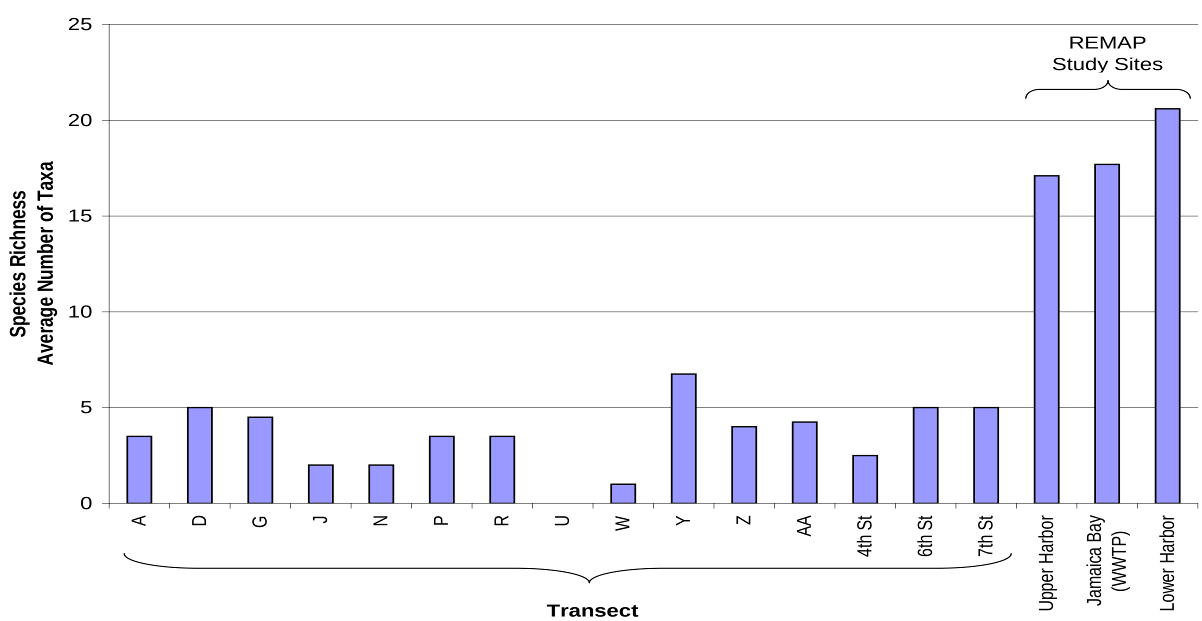

Figure 12. Gowanus Canal Transect specific average number of taxa compared to local communities. The upper New York Harbor, lower New York Harbor, and Jamaica Bay Wastewater Treatment Plant (WWTP) data from the U.S. EPA's REMAP study (Adams et al., 1998).

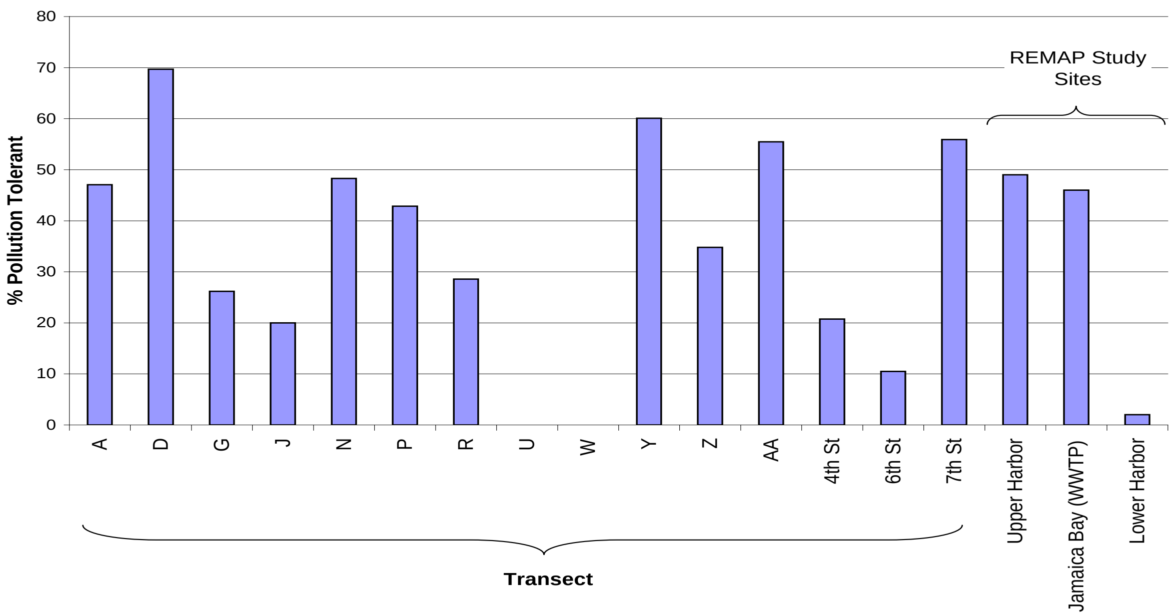

Figure 13. Gowanus Canal Transect specific percent pollution tolerant taxa compared to local communities. The data for upper New York Harbor, lower New York Harbor River, and Jamaica Bay where 26th Ward Street WWTP is located from the U.S.EPA's REMAP study (Adams et al., 1998).

To investigate trends in the extant invertebrate community with respect to chemical stressors, invertebrate metrics were compared to GEI sediment data. No biologically significant conclusions could be made when invertebrate metrics were compared to GEI sediment data. Because non-impaired communities were not found in the canal, a reference community was not available to evaluate causal relationships between sediment contamination and benthic community metrics.

Extant invertebrate communities within the canal were dominated by sewage/organic pollution tolerant organisms such as worms. However, REMAP identified non-impaired benthic communities in the NY Harbor system. They determined that 3 benthic metrics: abundance (decrease), species richness (decrease), % pollution tolerant species (increase) could be correlated to sediment chemistry when 6 or more chemicals exceeded NOAA ERMs. This was observed throughout the entire NY harbor system and each of 3 subbasins

(Upper Harbor, Lower Harbor, Jamaica Bay). This relationship was most often found for three contaminants: chlordane, PCBs, and mercury.

To further investigate trends within the extant invertebrate community, a cluster analysis was performed. Our analyses were performed on community species composition (presence/absence) data. Results effectively demonstrate that the benthic invertebrate community can be broken into 5 distinct clusters, with dissimilarity between clusters $\geq$55% (Figure 14). These five clusters were further evaluated to determine if additional trends within the invertebrate community could be identified.

Cluster 1 contained only one transect. No invertebrates were found in samples from Transect U; therefore, it was the least diverse of all clusters. Cluster 2, which included transects N, J, and W had few freshwater worms (Nematoda and Oligochaeta), with no other species. Cluster 3 contained more transects than any other cluster. Transects A, D, G, P, R, 4th St, and 7th St and had more Nematoda and Oligochaeta than Cluster 2, but included *Capitella capitata* (marine worm or Polychaete) and three species of amphipods, which were not identified at any other transects. This was the second most diverse cluster. Transect Z and the 6th Street basin was represented in Cluster 4. Cluster 4 was dominated by Nematoda, Oligochaeta, and Polychaeta (multiple species). More Nematodes and Oligochaetes were identified in Cluster 4 transects than any other cluster. Cluster 5 was most diverse; when Transects Y and AA were condensed 15 taxa were identified. Most of these taxa were Nematoda, Oligochaeta, and Polychaeta, but a few Mollusca (mussels/snails) and Decapoda (crabs) were also found.

Interestingly, Mollusca and Decapoda have been shown to be an indicator of high organics and low petroleum hydrocarbons in the New York Harbor contaminated sediments (Gallager and Keay 1998). In summary, transects were grouped (clustered) with respect to increasing species or taxa richness.

Using the clustered invertebrate communities with the increasing trend in species richness referenced above, we investigated trends in chemical and physical datasets that matched the grouped transects (Fig. 15). As seen in earlier 2006 sediment data comparisons, no clear cut relationships were identified between cluster condensed metrics and chemical stressors. This is not surprising given the already limited community comprised mostly of tolerant taxa noted above.

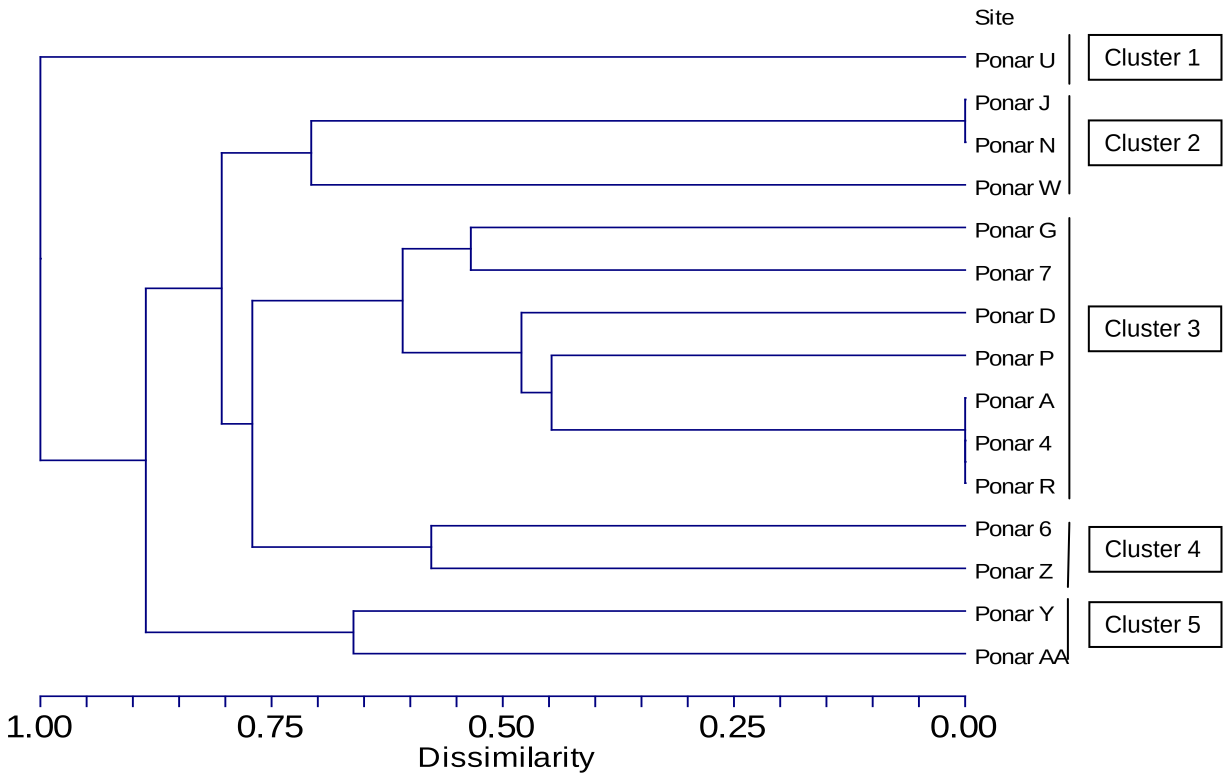

Figure 14: Cluster analysis, based from benthic invertebrate presence/absence data, of transects from Ponar samples collected in Gowanus Canal. Five distinct clusters were identified with respect to dissimilarity between clusters ≥55%.

Clustered results did seem to be correlated with physico-chemical conditions, such as temperature, salinity, dissolved oxygen, and substrate particle size (Fig. 15). These data were collected concurrently with invertebrate sampling and best reflect the physical condition of the Gowanus Canal when invertebrate communities were sampled. Lower temperature, higher salinity, and higher D.O. were all associated with greater species richness. Clusters 3 and 5 which had the greatest species richness also contained gravel-sized particles, while Cluster 1, which had no species present, had high percent silt and clay relative to more diverse sites.

In total, these results indicate that within the impoverished, pollution tolerant invertebrate community able to inhabit Gowanus Canal; physical habitat condition has more of an influence on resulting species richness than the presence of toxic chemicals in sediments

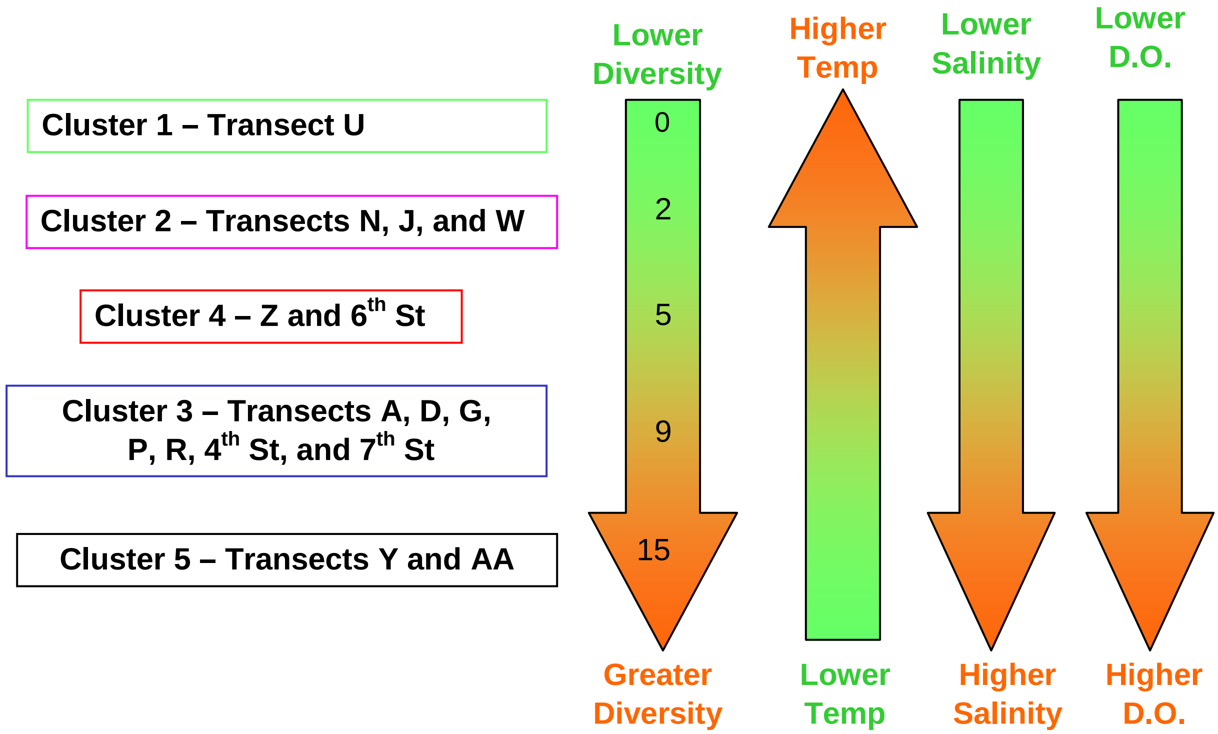

Figure 15: Comparison of species richness (combined number of taxa) of cluster analysis groupings with concurrently based water quality data.

Overall, the benthic invertebrate community represented by the benthic samples appears to be composed of estuarine organisms that are generally tolerant of organic pollution and chemicals. When the Gowanus invertebrate community was compared to local impaired communities, lower species richness was evident and the species that were present were identified as pollution tolerant. When species richness trends within the canal were investigated, physical habitat such as grain size, temperature, salinity, and D.O. seemed to be more influential than toxic chemicals in sediments for this already stressed invertebrate community.

4.4 Ecotoxicology Conclusions

The results from this study support that sediments are toxic due to multiple chemical stressors. These stressors include metals, PCBs, pesticides, and to a lesser extent PAHs, (forensic analyses and physical observations generally attribute the hydrocarbons and PAHs in the upper 3 feet of sediment to petroleum sources). Using water quality standards and sediment benchmarks, established to protect fish survival, we were able to identify the frequency and predict the magnitude of toxicity of canal water and surficial sediments to sediment-dwelling organisms. PAHs had little impact on water quality and the magnitude of potential impacts in sediments from non-PAH chemicals were substantial. Outfall effluents were also identified as a potentially significant source of sediment contamination from metals, pesticides, and PCBs.

The predicted toxicity of canal sediments was validated in laboratory toxicity testing, with clear relationships seen between test organism mortality and non-PAH contaminants.

Analyses investigating invertebrate abundance and richness metrics with respect to reference sites, sediment contamination, and habitat revealed that the Gowanus Canal invertebrates are severely limited by a combination of chemical contamination, organic (sewage) pollution, and poor physical habitat, much of which could be artifacts of CSO effluent impacts.

5. Environmental Forensics of Hydrocarbons

NewFields conducted an environmental forensic study of hydrocarbons and PAHs in the Gowanus Canal in Brooklyn, New York to assess the source and origin of hydrocarbons and PAHs in sediments. The full forensics report prepared by NewFields is appended to this executive report. The technical approach for the forensics investigation involved the collection of sediments from multiple strata within the Gowanus Canal in additional to accessible source area samples. The source samples included tar from the former Citizens MGP, tar from the former Witco/Barrett tar products facility, some regional pavement, and adjacent subsurface soils. Advanced chemical analyses were performed on the field samples. These results generated the following conclusions:

- Many landside sources of hydrocarbons and PAHs exist around the Gowanus Canal. The following landside source materials were consistent with the chemistry of sediments from the Gowanus Canal: middle distillate diesel and fuel oil, abraded pavement, tars near the former Witco and Barrett facilities, and tar from the former Citizens MGP. Other PAH sources are likely, but presently unidentified.

- The shallow sediments (upper 3 feet) were generally deposited after 1950 and contained predominantly petroleum products mixed with combustion or tar derived PAHs. Lower concentrations were generally observed in these surface sediments than in deeper sediments.

- The sediments deeper than 3 feet below the bottom of the canal contained accumulated and native sediments deposited before 1950. These deeper sediments contained high PAH concentrations dominated by tar and lesser amounts of petroleum. The native sediments contained the highest concentrations of PAHs.

- The PAH signature of tars resembling the former Citizens MGP plant were observed in a limited number of sediment samples. Most of the samples containing tar derived PAHs did not resemble source samples from the Citizens Site. This finding suggested the significant role of multiple PAH sources in the Gowanus Canal.

- An allocation model demonstrated the relative amounts of petroleum and tar in each forensic sample. This model revealed the dominant presence of petroleum in shallow sediments and tar in deeper sediments. Most sediment samples contained PAHs from mixed petroleum, tar, and combustion sources, especially in the Middle Reach where surficial sediments appear scoured away. The sediment scouring was attributed to barge traffic.

In summary, the Gowanus Canal sediments contain a complex mixture of hydrocarbons from many sources. Petroleum products dominated the shallow sediments and tars dominated the deeper sediments.

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