Data Evaluation Report No. 1: "Summary of Major Sediment and Water Investigations Conducted in the Lower Passaic River"

LOWER EIGHT MILES OF THE LOWER PASSAIC RIVER
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1 INTRODUCTION

This document is part of a series of data evaluation reports describing different aspects of the Lower Passaic River, which were prepared to support the Remedial Investigation (RI) and Focused Feasibility Study (FFS). Where necessary, data evaluation reports are cross-referenced to direct the reader to another report that contains further explanation. Topics discussed in this series include major sediment and water investigations conducted in the river, boundary conditions on the river, historical sediment contamination, surface sediment contamination, contaminant inventory calculations, and biota analysis. This report describes major sampling programs conducted on the river.

1.1 Overview of the FFS Study Area

The FFS Study Area is located within the Lower Passaic River Study Area (LPRSA), which is the 17-mile, tidal portion of the Passaic River from Dundee Dam [located at River Mile (RM[1]) 17.4] to the confluence with Newark Bay at RM0 and the watershed of this river portion, including the Saddle River (RM15.6), Third River (RM11.3) and Second River (RM8.1) [Figure 1-1]. During a comprehensive study of the Lower Passaic River, the sediments of the lower eight miles were found to be a major source of contamination to the rest of the river and Newark Bay. Therefore, the United States Environmental Protection Agency (USEPA) completed the FFS to evaluate alternatives to address those sediments in the lower eight-mile stretch from RM0 to RM8.3, near the border between the City of Newark and Belleville Township. The entire 17-mile Lower Passaic River is the subject of another Remedial Investigation/Feasibility Study (RI/FS) being implemented by the Cooperating Parties Group (CPG; a group of approximately 70 potentially responsible parties who signed an agreement with USEPA in 2007), under

[1] The FFS uses the "River Mile" (RM) system developed by the United States Army Corps of Engineers (USACE), which follows the navigation channel of the Lower Passaic River. The Data Evaluation Reports (Appendix A), Empirical Mass Balance (Appendix C) and Lower Passaic River-Newark Bay model (Appendix B) were initially developed at the beginning of the 17-mile Remedial Investigation and Feasibility Study (RI/FS), and thus follow a RM system developed for that RI/FS, which follows the geographic centerline of the river. RM0 is defined by an imaginary line between two marker lighthouses at the confluence of the Lower Passaic River and Newark Bay: one in Essex County just offshore of Newark and the other in Hudson County just offshore of Kearny Point. River miles then continue upriver to the Dundee Dam (RM17.4). The two RM systems are about 0.2 miles apart.

USEPA oversight. The Upper Passaic River watershed (the portion of the Passaic River located above the Dundee Dam) contributes solids, water, and contaminants that cross over the head-of-tide, which is represented by the Dundee Dam[2], into the Lower Passaic River.

1.2 Overview of the Major Sediment and Water Investigations Conducted in the Lower Passaic River

This report summarizes major sediment and water investigations conducted in the Lower Passaic River that yielded data considered for the FFS Study Area. Field investigations to characterize contamination in the Lower Passaic River and Newark Bay have been conducted from the 1990s up to the present by federal and state agencies, potentially responsible parties under USEPA oversight, such as the CPG and Occidental Chemical Corporation (with Tierra Solutions, Inc (TSI) performing the work), and academic institutions. All datasets are available on the project web site "ourPassaic.org".

The report is comprised of the following sections in addition to the introduction:

- *Section 2, Sediment Investigations*: provides a brief narrative describing historical and recent sediment investigations conducted in the Lower Passaic River and Newark Bay. These studies were evaluated to support the FFS.
- *Section 3, Water Investigations*: provides a brief narrative describing historical and recent water investigations conducted in the Lower Passaic River.
- *Section 4 Bathymetric, Geophysical, Geotechnical, and Hydrodynamics Investigations*: provides a summary of bathymetric, geophysical, geotechnical, and hydrodynamics surveys conducted in the Lower Passaic River.
- *Section 5, Acronyms*: defines the acronyms used in this report.
- *Section 6, References*: lists the references used in this report.

[2] The Dundee Dam represents a hydraulic boundary. The head-of-tide actual location is downstream of the dam because even though the tides can influence the water level near the dam, the upper-most extent of saltwater (*i.e.,* the salt front) typically stops several miles below the Dundee Dam (refer to Lower Passaic River System Understanding of Sediment Transport [HQI and Sea Engineering Inc, 2011] for further details on the salt front migration).

2 SEDIMENT INVESTIGATIONS

The following section briefly describes the major sediment investigations that were conducted on the Lower Passaic River and in Newark Bay, summarized in Table 2-1. The other data evaluation reports and the FFS also incorporate the results of these studies, as well as other historical and current datasets, to evaluate the nature and extent of contamination in the river. The results were also used to develop a contaminant fate and transport model. All data described herein are available on www.ourPassaic.org.

2.1 1991 and 1993 TSI Sediment Coring Program (Nature and Extent of Contamination)

Following the implementation of the interim cleanup plan at the former Diamond Alkali upland property in 1990, TSI conducted several sediment sampling programs in the estuary under USEPA oversight. Two prominent sediment sampling programs were the 1991 and 1993 sediment coring programs.

Field work conducted in November and December 1991 consisted of 26 sediment cores collected throughout the Lower Passaic River, Upper Passaic River, Hackensack River, and Newark Bay. One core was located in the Upper Passaic River in Dundee Lake; six cores were located in the Hackensack River and Newark Bay; and the remaining 19 cores were located in the Lower Passaic River with the majority of coring sites located below RM8. TSI conducted a similar sediment coring program in 1993 (consisting of two field programs: one occurred in March 1993 and the other occurred in July 1993) with 28 sediment cores collected in the estuary. Two cores were collected in Newark Bay; four cores were collected in the Kill van Kull and the Lower New York Harbor; and one core was collected in the Hackensack River. The remaining 21 cores were collected in the Lower Passaic River, including two cores located at the mouth of Third River and three cores at the mouth of Second River.

Sediment cores extended from 3 feet deep to about 20 feet deep, but were processed in a discontinuous fashion. A discontinuous core is defined as a sediment core where only

selected sediment horizons were sampled, instead of sampling continuously from core top to core bottom. For example, for the 1991 sediment program, one 2-inch sediment sample may have been collected at a depth 2 feet from the top of a particular core, with the next 2-inch sediment sample collected at a depth 3 feet from the core top, skipping the 10 inches of sediment between these two intervals. Each 2-inch interval was processed and shipped for chemical analyses. Additional, but separate, 2-inch intervals were also obtained from each core and were processed for radiological analyses; however, the chemical and radiological samples were not directly linked nor was there a discernable correspondence among sample intervals in different cores.

For both the 1991 and 1993 programs, a suite of chemical parameters was analyzed to characterize the sediment samples. These parameters consisted of polychlorodibenzodioxin/furan (PCDD/F) congeners, polychlorinated biphenyl (PCB) Aroclors, polycyclic aromatic hydrocarbon (PAH) compounds, pesticides, semivolatile organic compounds (SVOC), metals including mercury, total petroleum hydrocarbons (TPH), and total organic carbon (TOC). Volatile organic compounds (VOC) were only analyzed during the July 1993 sampling event, and butyltins were analyzed from selected samples during the 1991 and 1993 sampling program.

The data collected from the 1991 and 1993 TSI sediment coring programs have been used extensively. Specifically, these data have been used to characterize the following:

- Surface sediment samples (0-2 inches) provide a historical representation of surface sediment conditions in the river, including an early 1990s sample above the Dundee Dam.
- The very long sediment cores obtained during these studies provide important estimates of the depth of contamination as well as rough estimates of contaminant inventories. These long cores are particularly important as a basis to extrapolate sediment concentrations in shorter cores that were obtained in other programs but did not penetrate the entire depth of contamination.
- Radiological data [cesium-137 (Cs-137) and lead-210 (Pb-210)] provide affirmation that much of the contaminated sediment inventory was deposited after the 1940s,

although these radiological data are not sufficient in number and distribution to permit segment year assignments.[3]

2.2 1995 TSI Remedial Investigation Program (Nature and Extent of Contamination – RM1 to RM7)

Sampling in the Lower Passaic River continued in 1995 with a field investigation conducted by TSI under USEPA oversight as part of a remedial investigation. In contrast to the previous 1991 and 1993 TSI programs with sediment cores distributed at selected locations throughout the estuary, the 1995 RI program was designed to follow a systematic (*i.e.*, unbiased) sampling scheme. Sediment cores were collected from a portion of the river that was historically defined as the "Passaic River Study Area," stretching from approximately RM1 to RM7. A total of 97 sediment cores was collected in sets of three along transects spaced at quarter mile intervals. A pre-determined sampling program prescribed a 6-foot depth for most cores; however, one-third of the cores penetrated beyond 6 feet. Each core was divided longitudinally. One side of the core was designated for chemical analyses and segmented into continuous 1-foot intervals, except the core top, which was defined as the top 6 inches. The other side of the core was designated for radiological analyses and segmented in a discontinuous fashion.

Similar to the 1991 and 1993 TSI programs, a suite of chemical parameters was analyzed to characterize the sediment samples. These parameters consisted of PCDD/F congeners, PCB Aroclors, PAH compounds, pesticides, SVOC, VOC, metals including mercury, TPH, and TOC. Unlike the previous TSI investigations, herbicides were analyzed, but not butyltins. An executive summary prepared by TSI was submitted to USEPA; however, a formal report summarizing these data has not been published.

This dataset has proven to be very valuable because the sediment cores collected were continuous and radiological data are available. However, the pre-determined sampling

[3] Cs-137 and Pb-210 are particle-reactive radioisotopes (with different source terms) that are used to geochronologically date sediment cores. Refer to Data Evaluation Report No. 5 for further discussion.

depth did result in some limitations on data usability. The 1995 TSI dataset has been used to characterize the following:

- Surface sediment conditions (0 to 6 inches) provide a historical representation of surface sediment conditions in the Lower Passaic River (RM1 to RM7) as well as a possible characterization of the routinely resuspended surface materials.
- Some dated down-core profiles provide an estimate of contaminant loading over time; however, most cores are limited by the pre-determined depth and do not capture the full vertical extent of contamination in the river.
- Beryllium-7 (Be-7) was detected in about 15 percent of the sampling locations. Surface samples from these locations were examined to assess contamination levels in solids deposited *circa* 1995.[4]

2.3 1999 and 2000 TSI Environmental Sampling Programs (Risk Assessment Support)

To assess ecological and human health risks in the Passaic River Study Area, TSI conducted two environmental sampling programs under USEPA oversight. The fall sampling event occurred from September 1999 to October 1999 while the spring sampling event occurred in May 2000. In general, the fall 1999 event was more extensive than the spring 2000 event and resulted in a greater quantity of biological data.

During the fall event, surface sediment samples (0-6 inches) and co-located tissue samples were collected from 14 shoal areas in the Lower Passaic River between RM1 and RM7. The 14 locations that were sampled in the fall were re-occupied in the spring; however, fewer sediment and tissue samples were collected in the spring (co-located sediment samples were collected at only 4 of the 14 locations).

Sediment and tissue samples from both environmental sampling programs were analyzed for a suite of chemical parameters, including PCDD/F congeners, PCB Aroclors and

[4] Be-7 is a naturally occurring, particle-reactive radioisotope with a short half-life (53 days). The presence of Be-7 in surface sediments (0-1 inch) indicates that the associated solids were generally deposited on the sediment bed within the last 6 to 12 months (termed "recently-deposited surface sediments") prior to collection. Refer to Data Evaluation Report No. 4 for further discussion.

congeners, PAH compounds, pesticides, SVOCs including butyltins, metals including mercury, and herbicides. Sediment samples were also analyzed for TPH, TOC, pH, and ammonia. A formal report summarizing these data has not been published. Assessment of the usability of the 1999 and 2000 biological datasets indicates:

- Surface sediment samples (0 to 6 inches) provide a historical representation of sediment conditions in the shallow areas near the Mean Low Water (MLW) elevation in the Lower Passaic River (RM1 to RM7).
- Tissue samples from several species and trophic levels provide data on exposure levels to contaminated sediment for the local biota.

2.4 2005 Sedflume Testing (Sediment Bed Erosion Susceptibility)

The Sedflume is an apparatus designed to measure erosion rates with varying flow velocities for cohesive sediments. As part of the Lower Passaic River Restoration Project (a joint study conducted by the USEPA, United States Army Corps of Engineers [USACE] and New Jersey Department of Transportation [NJDOT]), sediment cores were collected at 14 sites (Stations 1 through 15 were proposed; however, only 14 could be completed) along the Lower Passaic River from May 17, 2005 through May 20, 2005. Two cores, considered replicate cores and differentiated by an "A" and "B" designation, were attempted at each location. Both cores were successfully obtained at all stations except Station 10. The material at this location consisted of a high viscosity fluid mud overlying an impenetrable coarse-grained material. A total of 28 cores were collected as part of this investigation, and the distance between replicate cores varied from 1 to 10 meters (3.3 to 33 feet).

Lexan core tubes (10-inch diameter) were manually advanced into the sediment bed to the maximum possible depth (*i.e.*, either to the entire core tube length or to refusal) to collect the cores. Where water depth precluded the use of the lexan tube alone, a box corer was used to obtain a sediment bed sample, and a lexan tube was used to core the material retrieved within the box corer. Core lengths ranged from 22.75 centimeters (cm) [9 inches] (Station 1B) to 65.5 cm [2 ft 2 inches] (Station 9A).

Once the sediment cores were collected, river water was decanted from the top. The cores were then stored in a 40-gallon barrel filled with cool water (on the sampling vessel) and with cool water and ice (onshore). Ice and water were replenished daily. Collected cores were then subjected to Sedflume testing to measure erosion rates with varying flow velocities down the length of the core. Sedflume testing was performed on the cores in a 24-foot trailer which housed a mobile laboratory and the equipment needed to perform the procedure. This mobile lab was based at the USEPA Passaic River field office during May and June of 2005.

In addition, physical properties were measured in each sediment core during the erosion tests at intervals of approximately 2 to 3 cm (0.8 to 1.2 inches). To accomplish this, the Sedflume procedure was paused, the apparatus drained, and a sample manually extracted from the sediment bed. Measurements included bulk density, grain size distribution, and organic content. The findings of the Sedflume testing are reported in the Erodibility Study of Passaic River Sediments (USACE, 2006) and the Lower Passaic River Sediment Transport Model Report in Appendix B.

2.5 2008 Sedflume Testing (Effects of Consolidation on Erodibility)

The purpose of the Sedflume Consolidation Analysis was to characterize the properties of deposited sediments during the consolidation process, and to determine the effects of consolidation on sediment density and susceptibility to erosion over time. Surface sediment was collected from a single location on the Lower Passaic River from May 16 to 20, 2008 by Sea Engineering, Inc. for USEPA and USACE. This location corresponded to the collection point of the Malcolm Pirnie, Inc. high resolution sediment core obtained at RM2.2 (see Section 2.7). A box core was used to retrieve 15 gallons of surface sediment from the top 15 cm of the sediment bed. This material was composited into a single sample and then re-constructed into four laboratory cores (as described below) that could be subjected to Sedflume testing to determine the effects of consolidation on stored sediments.

Collected sediments were composited with water at the Sea Engineering, Inc. laboratory and poured into prepared core barrels. Each core was 50 cm in length, and inspected for length and quality immediately after preparation. Four approved cores so generated were capped and stored in the laboratory until the testing assigned to that core was to be performed, allowing consolidation to occur within the core tubes. The densities of the Sedflume cores were determined by sub-sampling locations within each core and using wet/dry sample weights to calculate the bulk density in each sub-sample. Particle size analysis was also performed.

The cores were successively tested after being stored and allowed to consolidate for four different lengths of time: 1 day, 7 days, 17 days, and 28 days. In addition, each core was sub-sampled at vertical intervals to determine bulk properties. Measurements included bulk density and particle-size distribution. Additional information can be found in the report Sediment Consolidation Analysis, Passaic River, New Jersey (SEI, 2008).

2.6 2005 Gust Microcosm Testing (Near-surface Sediment Erodibility)

Additional sediment erosion experiments were performed on sediment cores collected from May 16, 2005 through May 20, 2005 by Chesapeake Biogeochemical Associates for USEPA, USACE, and NJDOT. The purpose of this investigation was to determine the erodibility of near-surface sediments using the Gust Microcosm apparatus for comparison with parameter estimates yielded by Sedflume testing. Gust Microcosm testing uses techniques outlined by research performed at the University of Maryland Center for Environmental Science, and measures erodibility of undisturbed sediment cores by applying a series of controlled shear stresses representative of the flows in the river. This device uses a rotating disc with central suction to apply a known shear stress to a field-collected sediment core sample. Data generated from the Gust Microcosm was analyzed using the erosion formulation of Sanford and Maa (2001) to determine the erodibility of the sediment. Compared to Sedflume, the Gust Microcosm system is able to measure the erodibility at the very near surface. Additional information can be found in the report "Passaic River Erosion Testing and Core Collection: Field Report and Data Summary" (Chesapeake Biogeochemical Associates, 2006).

2.7 2005-2007 USEPA High Resolution Sediment Coring (Historical Water Column Suspended Matter Contaminant Loads)

Malcolm Pirnie, Inc. collected high resolution sediment cores from 14 locations in the Lower Passaic River and Upper Passaic River in September and October 2005 on behalf of the USEPA and USACE. The objectives of the program were to obtain several cores with consistent geochronologies (*i.e.*, dateable cores) that could then be used to assess historical contaminant loads on water column suspended matter and to evaluate current (2005) suspended matter concentrations. A dateable high resolution sediment core can be used to characterize historical water column suspended matter, because an interpretable geochronology is a direct result of steady accumulation in a continuously-depositional area. As sediments deposit, they bring with them the particle-borne chemistry of the water column at the time of their deposition. Like a strip recorder, the consistently depositional location preserves the chronology of particle-borne water column chemistry. Unlike the systematic, unbiased sampling approach necessary to determine the lateral and vertical extent of contamination, this approach needs a small number of highly selective sampling locations, similar to the approach for long-term water column monitoring of the system. It is important to find suitable (continuously depositional) locations that represent boundary conditions of the system ("end members") and locations intended to capture potential changes along the length of the Lower Passaic River due to external inputs such as tributaries or resulting from significant variations in flow regime.

Coring locations were pre-selected and identified as potential continuously depositional sites through a review of available data and a field reconnaissance program (August 29, 2005 to September 8, 2005) to confirm that sediments at the target locations contained Be-7 at the surface (0 to 1 inch) and had a fine-grained sediment texture. Coring locations were selected in "backwaters" or other areas unlikely to have experienced anthropogenic disturbances (*e.g.*, dredging) or significant erosional events. Cores collected from these apparently continuously depositional locations were finely segmented into approximately 40 sediment intervals per core with the top 8 intervals being half the thickness of the deeper intervals. Samples for analysis of metals, including mercury, and TOC from every

sediment segment were shipped immediately for chemical analysis. Samples from alternating segments were also shipped for radiological analysis including Cs-137. The remaining samples were retained for possible future analyses by freezing in accordance with the Quality Assurance Project Plan (Malcolm Pirnie, Inc., 2005b) and accompanying addenda.

Radiological data indicated that 5 of the 14 high resolution sediment cores had acceptable Cs-137 profiles, were considered dateable, and were fairly well distributed along the main axis of the river. These five cores were located at RM1.4, RM2.2, RM7.8, RM11.0, and RM12.6. Prior to shipping the sediment samples for organic analysis, the sediment segments were thawed and manually combined – every two intervals, consecutively – to yield approximately 20 samples per core. Organic compound analyses performed on these combined samples included PCDD/F congeners, PCB congeners, PAH compounds, and pesticides. The USEPA 2005 high resolution sediment core dataset can be summarized as follows:

- Correlated radiological and chemical data provide geochemical tools for interpreting historical contaminant loading to the Lower Passaic River.
- Surface sediments represent contaminant concentrations from the 2003 to 2005 time period. The observations from the 5 core sites were further supported and enhanced by the 2007 to 2008 USEPA Supplemental Sediment Programs (Section 2.9).
- Ratios among contaminants within and among cores were used to examine the variations in contaminant loads over time and distance.
- The dated sediment cores chronicle the history of contaminant discharges from the 1940s to the present and from RM1.4 to RM12.6.

Additional high resolution sediment cores were collected in 2007 by Malcolm Pirnie, Inc. from nine locations in the Upper Passaic River between Dundee Dam and the Interstate Route 80 Bridge. Locations were selected based on bathymetric data, historical satellite photographs that showed shoreline development, literature references, and field reconnaissance conducted on December 14, 2006. These data resources were used to identify coring locations with potentially undisturbed silt deposits in continuously

depositional areas that could be used to determine the contaminant load on particle-borne water column solids transported from the Upper Passaic River to the Lower Passaic River.

At each coring location, a geological boring and co-located high resolution sediment core were collected. The geological boring was split longitudinally to examine stratigraphic sequences and identify locations with silt deposits. Four locations were classified as potentially depositional based on the stratigraphic sequence; the corresponding co-located high resolution sediment cores from these four locations were divided into 2-cm (0.8-inch) and 4-cm (1.6-inch) intervals, yielding approximately 20 samples per core. Samples were shipped immediately for analysis of the following parameters: PCDD/F congeners, PCB congeners, PAH compounds, pesticides, metals including mercury and titanium, TOC, particle size distribution, Cs-137, and Be-7 (core top sample only).

As the radiological data were received and interpreted, two cores were eliminated from consideration because the core top was not Be-7 bearing, indicating that the location did not contain recently-deposited sediments. The corresponding chemical analyses for these cores were halted since it was unlikely that the cores could be dated. Chemical analyses were completed on the two remaining cores that possessed a Be-7 bearing core top; however, further evaluation of the Cs-137 data indicated that the radiological profile was discontinuous (suggesting that the sediments had been disturbed and that the core was not representative of a continuously depositional location). The January 2007 Dundee Lake sediment core dataset can be summarized as follows:

- Surface sediment concentrations from one coring location that contained reportable Be-7 levels represented contaminant loading to the Lower Passaic River from the Upper Passaic River in 2006.
- The dataset provided evidence to roughly characterize the scale of historical contaminant loadings to the Lower Passaic River from the Upper Passaic River, based on the presence of Cs-137 in the deeper layers of one core. However, the Cs-137 levels were too low to establish a core chronology.

In addition to the cores obtained by Malcolm Pirnie, Inc., several high resolution sediment cores had been obtained by scientists from Rensselaer Polytechnic Institute (RPI) and Lamont-Doherty Earth Observatory (L-DEO) in September 2005 above the Dundee Dam. These cores were initially segmented and dried to permit long-term storage while awaiting subsequent analysis. Two of the cores were shown to contain Be-7 and were dateable using Cs-137. Segments from these cores were then subject to chemical analysis for the USEPA Lower Passaic River investigation.[5] These 2005 Dundee Lake dated sediment cores provide the following information, satisfying the major goals for the Upper Passaic River coring:

- Surface sediment concentrations from two coring locations that contained reportable Be-7 levels represent contaminant concentrations on suspended matter delivered to the Lower Passaic River from the Upper Passaic River in 2005.
- The dataset provides a dateable Cs-137 sediment core profile documenting historical contaminant loads to the Lower Passaic River from the Upper Passaic River. In particular, the profile provides a basis to estimate the historical loads of major contaminants to the Lower Passaic River going back to the 1960s.

2.8 2006 USEPA Low Resolution Sediment Coring (Nature and Depth of Contamination)

Low resolution sediment cores were collected by Malcolm Pirnie, Inc. on behalf of the USEPA and USACE from 10 locations in the Lower Passaic River (between RM2 and RM7) in January 2006 to re-examine sediment concentrations reported in the TSI 1995 RI dataset. In contrast to the 1995 TSI field program that systematically collected 6-foot cores, the 2006 low resolution cores were designed to penetrate to the sand or red-clay layer (underlying the silt deposits) to assess the nature and depth of contamination for the thickness of contaminated sediment deposited since the channel was dredged.

[5] A separate analysis was conducted to demonstrate the viability of the sample collection and processing procedures used by the RPI and L-DEO scientists. This demonstration was done on a series of separate sediment sample splits that were handled by the USEPA processing procedures (shipping frozen samples) as well as the drying procedures used by RPI and L-DEO. The samples were chemically analyzed following the standard Lower Passaic River procedures, thereby creating sample pairs differing only by the processing procedure. The analysis confirmed that the sample collection and processing procedures used by the RPI and L-DEO scientists were valid.

A low resolution sediment core is defined as a coarsely-segmented core that is analyzed to describe the general chemistry of the river sediments. Typical segmentation of these cores is six inches or greater. In some cases, the cores may provide data to approximate historical contaminant loads on the time scale of decades. The low resolution cores were split lengthwise to examine geologic sequences. Cores were then divided into approximately six slices based on sediment type with the bottom slice characterizing the underlying sand or red-clay sequence. Samples were processed and submitted for the following analyses: Cs-137, PAH compounds, PCB congeners, PCB Aroclors, PCDD/F congeners, pesticides, VOC, SVOC, chlorinated herbicides, TPH, TOC, pH, specific gravity, grain size, and metals including titanium and mercury. The 2006 low resolution sediment core dataset can be summarized as follows:

- Low resolution sediment cores fully characterized the nature and depth of contamination (in silt deposited since the channel was dredged) at the target locations in RM2 to RM7 because they were advanced to fully penetrate the contaminated sediments and characterized the underlying sand or red-clay layer.
- An extensive suite of chemical and physical parameters was analyzed to characterize the silt deposits and the underlying sand and red-clay layers.

2.9 2007 to 2008 USEPA Supplemental Sediment Programs (Characterization of Surface Sediments RM1 to RM14 and Fine-grained Sediment Deposits above RM8)

On behalf of the USEPA and USACE, Malcolm Pirnie, Inc. conducted two supplemental sediment sampling programs in the Lower Passaic River. The first program was designed to characterize recently-deposited surface sediment concentrations (0 to 1 inch) in the Lower Passaic River from RM1 to RM14. These surface sediment samples were collected using an Ekman dredge or by manually collecting the upper 1-inch of sediment and placing it into a sampling tray underwater in shallow areas inaccessible by boat. The second program involved the collection of low resolution cores above RM8 in fine-grained sediment areas to further evaluate the nature and extent of contamination in these deposits.

Surface sediment samples (0 to 1 inch) to characterize recently-deposited sediments were collected from 23 locations in the Lower Passaic River,[6] four locations in the Upper Passaic River, four locations on the Saddle River above the head-of-tide, and two locations on the Third River above the head-of-tide between December 2007 and January 2008. Depositional areas were specifically targeted during this program and were identified using data collected during a field reconnaissance, evaluating existing side scan sonar data, and evaluating 2007 sediment probing data. No samples were collected on Second River or near Ackerman Avenue Bridge (immediately downriver of the Dundee Dam) because fine-grained sediment deposits could not be located during the field reconnaissance. Sediment samples from each location were analyzed for metals including mercury, TOC, grain size distribution, and radiological parameters (including Be-7, the presence of which is interpreted as confirming that the material was deposited in the previous 6 months or less). Nearly all samples were found to contain Be-7. A subset of the Be-7 bearing samples were then further analyzed for PCDD/F congeners, PCB congeners, PAH compounds, and pesticides.

The low resolution cores were collected in January 2008 between RM8.5 and RM14.5 in fine-grained sediment deposits. Coring locations were identified using late 2007 sediment probing data collected during a field reconnaissance as well as existing side scan sonar data on sediment texture. Cores were advanced until refusal and then divided into two segments: 0 to 6 inches and 6 inches to the bottom of the silt layer or to the core bottom (when underlying coarser material was not recovered with the core). Samples were analyzed for metals including mercury, radiological parameters, grain size distribution, PCDD/F congeners, PCB Aroclors, PAH compounds, and pesticides. The two supplemental sediment sampling programs can be summarized as follows:

- Be-7-bearing sediment samples provide a current (2007) representation of recently-deposited surface sediments in the Lower Passaic River (RM1 to RM14).

[6] In the Lower Passaic River, five of the 23 locations re-occupied the successful 2005 high resolution sediment coring locations to build on the chronologies already established for these locations. Refer to Data Evaluation Report No. 3 for more information on high resolution sediment coring.

- Surface sediment samples collected from the Upper Passaic River and above the tributary head-of-tide provide a representation of the current (2007) suspended solids-borne contaminant loading from these external sources to the Lower Passaic River.

2.10 2008 CPG Low Resolution Sediment Coring (Lateral and Vertical Extent of Contamination RM0 to RM17.4)

In 2008, the CPG conducted a low resolution sediment coring program under USEPA oversight, which included the collection of sediment cores along the Lower Passaic River from RM0 to RM17.4 (Dundee Dam) with additional sampling locations positioned in the tributaries and above Dundee Dam. Surface sediment samples were defined as the top 6-inches of the sediment core. The remaining core length was continuously sectioned into 1-foot or 2-foot intervals to the core bottom. Cores were advanced to refusal or presence of the red sand/clay layer. (If necessary, multiple cores were collected to provide enough sediment mass for analysis.) A co-located sediment grab sample was also collected at each coring location for the analysis of Be-7 in the top 1-inch of sediments.

Sediment samples were analyzed for a suite of chemical parameters, including PCDD/F congeners, PCB Aroclors and congeners, PAH compounds, pesticides, SVOC, VOC, herbicides, metals including mercury, methylmercury, TPH, TOC, grain size, and other general chemistry parameters. A finalized report summarizing these data has not been published; however, the dataset is available. Assessment of the usability of the 2008 datasets indicates:

- Based on a comparison of split samples analyses conducted by USEPA and the CPG, the PCDD/F concentrations generated during the 2008 CPG coring program were found to be biased low and have been corrected following recommendations by the USEPA. Correction factors are based on an independent review of the data by Computer Sciences Corporation (CSC) Environmental Solutions, Inc. (CSC and Interface, Inc., 2010, 2011).

- Surface sediment samples (0 to 6 inches) provide a representation of surface sediment conditions across a variety of geomorphological units in the Lower Passaic River (RM0 to RM17.4).
- Surface sediment samples with detectable levels of Be-7 provide additional information on the current (2008) contaminant load on recently-deposited material. However, data usability is constrained by the fact that surface sediment depth interval covered 0 to 6 inches while the Be-7 measurement was completed on a separate 0 to 1-inch grab sample. In some areas of the river and on the tributaries, 0 to 6 inches of sediment does not represent recently-deposited material.
- Low resolution cores provide information on the contaminant inventory in the different geomorphological units of the river, particularly above RM8.
- Some dated down-core profiles provide an estimate of contaminant loading over time.

2.11 2009 - 2010 CPG Benthic and Sediment Program (Taxonomy, Toxicity, and Exposure Characterization)

In 2009 to 2010, the CPG, under USEPA oversight, conducted a sediment sampling program, which was part of a benthic community survey. At each sampling location in the river, multiple sediment grab samples were collected to represent a spatially composited 0 to 6 inches surface sediment sample. These samples were used to support macrobenthic taxonomy classification, laboratory toxicity testing, and sediment chemistry. Sediment sampling locations were positioned in the river to characterize different benthic habitats. A subset of locations was sampled to characterize human health exposure at shallow nearshore locations or places with human access to the river (such as boat clubs, docks, and fishing locations).

Sediment samples were analyzed for a suite of chemical parameters, including PCDD/F congeners, PCB Aroclors and congeners, PAH and alkylated PAH compounds, pesticides, SVOC, VOC, herbicides, metals including mercury, TPH, TOC, grain size, and other general chemistry parameters. A finalized report summarizing these data has

not been published; however, the dataset is available. Assessment of the usability of the 2009-2010 datasets indicates:

- Surface sediment samples (0 to 6 inches) provide a representation of surface sediment conditions across a variety of geomorphological units in the Lower Passaic River (RM0 to RM17.4). The sampling program was designed to satisfy biological data quality objectives; hence, the locations were positioned in the river to characterize different benthic habitats.
- Each sampling location represents a composite of multiple grab samples. These grabs were homogenized, and an aliquot of sediment was analyzed for chemical parameters while the remaining material was used to support toxicity testing.
- Surface sediment samples were not collected on the tributaries or in the Upper Passaic River.
- Due to the biological nature of the program, Be-7 measurements were not incorporated into the program; thus, there is no direct measure of how recently the sediments were deposited in the system.

2.12 2012 CPG Low Resolution Coring Supplemental Sampling Program

In 2012, the CPG, under USEPA oversight, conducted a low resolution coring program to support delineation of the nature and extent of chemical contamination, the parameterization and calibration of the sediment transport and chemical fate and transport models, and delineation of stable and potentially erosional sediments. One set of cores from 86 locations were sampled using low resolution sampling intervals. Samples from the low resolution cores were collected from the 0 to 0.5 foot surface interval (from the core and grab samples), from two 1-foot segments for a total core depth of 2.5 feet at 83 locations and from four 1-foot segments for a total core depth of 4.5 feet within the footprint of the 2005 Environmental Dredging Pilot Study at 3 locations. Under certain conditions, the segmentation scheme was altered to adjust the sampling intervals to account for a stratigraphic change in the sediment sequence (*e.g.*, change in sediment size, obvious depositional boundary or unconformity) that occurs within a segment.

The samples were analyzed for PCDD/Fs, PCB congeners and homologs, PAHs, SVOCs, organochlorine pesticides, butyltins, metals, mercury, TPH-Extractables, cyanide, TOC, grain size, percent moisture, and specific gravity. Sulfide, nutrients (ammonia-nitrogen, phosphorus, and Total Kjeldahl Nitrogen [TKN]) and Acid-Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM) analyses were performed for surficial samples (grabs) only. Field measurements included salinity measurements of pore water from grab samples and calculation of bulk density.

The surface sediment data were incorporated in the FFS report. The results showed that the 2012 surface sediment concentrations for the parameters examined in the data evaluation reports are comparable to the concentrations from other data collected previously. The median concentration of 2,3,7,8-TCDD is not statistically different than from any other sampling programs (see Data Evaluation Report No. 4).

2.13 2005 and 2007 TSI Newark Bay Study (Contaminant Nature, Extent, and Chronology)

From October through December 2005, TSI, under USEPA oversight, conducted a Phase I field investigation in Newark Bay as part of the RI/FS for the bay. This field investigation included an evaluation of the biologically active zone using sediment profile imagery, bathymetry, sediment coring, and sediment grab sampling. For the sediment component of the investigations, cores were collected using vibracore equipment while co-located grab samples were collected with a Ponar dredge that was lowered into the bay via a winch-operated cable. Cores were collected at 69 locations from a variety of identified geomorphic units. Cores were advanced to varying depths, depending on the geomorphic unit, in an effort to identify the 1940 sediment horizon and to determine contaminant concentrations and gradients. Co-located sediment grab samples were collected immediately adjacent to the coring locations to provide information on sediment characteristics and recent deposition. Cores were divided into segments (generally one 6-inch core top, then 1-foot segments to a depth of 3.5 feet, and 2-foot segments below 3.5 feet) and analyzed for PCDD/F congeners, PCB congeners,

PCB Aroclors, pesticides, TPH, SVOC, herbicides, organotins, metals, cyanide, mercury, titanium, VOC, TOC, grain size, and bulk density.

The pesticide results obtained by this program had a substantive limitation. Approximately 90 percent of the pesticides results were not detected (*i.e.*, flagged with a qualifier containing a "U") due to high method detection limits and matrix interference. The only pesticide regularly detected in Newark Bay as part of this program was Dichlorodiphenyldichloroethylene (DDE). Mean surface sediment concentrations for select contaminants are provided in the Data Evaluation Report No. 2.

In November 2007, TSI conducted Phase II sediment coring activities to continue investigations of the nature and extent of contamination in Newark Bay while also sampling locations proximal to potential sources of contamination on the bay's industrial waterfront. Sediment cores were collected from 50 locations with sampling depths ranging up to 30 feet below the sediment surface in an attempt to capture the circa-1940 depositional horizon. Some Phase I locations where cores were not advanced deep enough to encounter the 1940 horizon were re-sampled during Phase II. Surface sediment samples were collected along with the sediment cores to continue to characterize contaminant concentrations and to determine areas of recent deposition via Be-7 analysis.

The scope of the Phase II sampling programs is described in the Phase II Remedial Investigation Work Plan (RIWP; TSI, 2007). The data generated by the Phase II investigations are presented in the Phase I and Phase II Sediment Investigation Field and Data Report (TSI, 2008). The Phase I and II field investigation in Newark Bay can be summarized as follows:

- Surface sediment concentrations (0 to 6 inches) provide a representation of current (*circa* 2005 and 2007) surface sediment conditions in Newark Bay.
- Be-7 was detected in most sampling locations (0 to 1 inch) located in the navigational channel. Surface samples (0 to 6 inches) from these locations were examined to assess contamination levels in the recently-deposited (*circa* 2005 and 2007) material. It is important to note that the data usability is limited by the fact that surface

sediment depth interval covered 0 to 6 inches while the Be-7 measurement was completed on a separate 0 to 1 inch grab sample. In some areas of the river and on the tributaries, 0 to 6 inches of sediments does not represent recently-deposited material.

3 WATER INVESTIGATIONS

This section describes the water investigations that were conducted in the Lower Passaic River. The water data collected prior to 2005 are limited and do not cover a large temporal and spatial extent. Water investigations datasets are available on the project web site "ourPassaic.org."

3.1 1995 and 1999 Water Investigations in the Lower Passaic River (Modeling Parameters and Water Quality)

Multiple entities conducted water sampling in the Lower Passaic River in the 1990s. In 1995, TSI conducted various surface water characterization efforts (TSI, 2004) for the USEPA. As part of sediment mobility modeling, 1,317 total suspended solids (TSS) samples and measurements of physiochemical parameters, including temperature, pH, and conductivity profiles, were collected from 8 transects during three rounds of sampling. In addition, TSI conducted a surface water characterization investigation to evaluate water quality in relation to the rest of New York/New Jersey Harbor. For this investigation, physiochemical parameters including temperature, pH, and conductivity profiles were collected at each mudflat sampling station between RM1 and RM7.

Adding to the collection of Lower Passaic River water quality data during this period is National Oceanic and Atmospheric Administration's (NOAA) August 1999 water quality monitoring (temperature, dissolved oxygen, salinity, pH, and conductivity) conducted as part of a bivalve mussel deployment in the Lower Passaic River (NOAA, 1999) and two surface water samples collected on behalf of the Diamond Shamrock Chemicals Company during the 80 Lister Avenue Site Investigation for the New Jersey Department of Environmental Protection (NJDEP) [DSCC, 1985].

3.2 2005 Large Volume Water Column Sampling Study (Dissolved versus Suspended Matter Concentrations)

As part of the 2004 to 2006 USEPA hydrodynamic sampling program, Malcolm Pirnie, Inc. collected large volume water column samples from RM2.5 on October 6, 2005 and RM10.5 on October 5, 2005. Samples were collected one meter (3.3 feet) below the water surface to represent freshwater above the salt front at RM2.5 and freshwater at RM10.5 (uninfluenced by saline intrusion); however, only the samples collected at RM2.5 were analyzed. Samples were analyzed for PCB congeners, PCDD/F congeners, pesticides, TSS, dissolved organic carbon (DOC), and particulate organic carbon (POC).

The objective of the study was to evaluate various techniques for large volume water column sampling to separately characterize dissolved phase and suspended phase hydrophobic organic contaminants. The equipment compared in the study included an Infiltrex, Trace Organic Platform Sampler (TOPS), and collection of whole water samples in 20-liter containers for filtering at the laboratory. The Infiltrex is a high efficiency, high volume automatic water sampling system designed for the extraction of trace-level organic contaminants. The Infiltrex consisted of three distinct components: (1) a 1 micrometer (μm) [3.937×10^{-5} inches] glass wound cartridge filter used to remove the majority of particulates from the influent whole river water; (2) a 0.7 μm (2.756×10^{-5} inches) Whatman glass fiber filter used as a polishing step for particulate removal; and (3) a solid phase extraction system used to measure trace quantities of dissolved-phase organic contaminants. The TOPS is an automatic water sampling system that is similar in design and function to the Infiltrex (developed as part of CARP). For the Lower Passaic River sampling events, it consisted of two components: (1) a 0.5 μm glass wound cartridge filter used to remove the majority of particulates from the whole water; and (2) a 0.7 μm Whatman glass fiber filter used as a polishing filtration step. Both TOPS and Infiltrex can operate from any water sampling platform and removes solids and hydrophobic organic compounds/organometals from water samples (in the field) through the use of filters and XAD traps.

Each method was used to collect samples for laboratory analysis followed by comparison of the results. The intent of the study was to compare the efficacy of field processing of water column samples to laboratory processing. The large volume water column sampling study can be summarized as follows:

- Dissolved and suspended phase of the samples provided the partitioning coefficients of the organic contaminants.
- The lab-filtered results were comparable to the field-filtered results.
- The lessons learned from this effort were applied to the design and execution of the Combined Sewer Overflow/Stormwater Outfall (CSO/SWO) program (Section 3.5).

3.3 2005 Small Volume Water Column Sampling Study (Modeling Parameters)

As part of the 2004 to 2006 USEPA hydrodynamic sampling program, Malcolm Pirnie, Inc. collected small volume water column samples from four locations on the Lower Passaic River on November 8, 2005. Additional small volume water column samples were collected at Ackerman Avenue Bridge on the Lower Passaic River and from the head-of-tide on Second River, Third River, and Saddle River on November 10, 2005. These locations were selected to correspond to mooring locations and other water column samples being collected under the hydrodynamic program.

To sample the length of the Lower Passaic River simultaneously, four boats were stationed at RM1.0, RM2.5, RM4.5, and RM10.5. Each boat crew was assigned to collect water samples along a transect perpendicular to the river's axis at the designated location. Each transect included five surface locations positioned 1 meter (3.3 feet) below the water surface (designated as nodes: S1, S2, S3, S4, and S5) and three corresponding bottom locations positioned 1 meter (3.3 feet) above the river bottom (designated as nodes: S2D, S3D, and S4D). The surface water samples were designed to represent freshwater above the salt front, and the deep water samples were designed to represent brackish water in the salt front. Samples were collected during three "passes" generally conducted during the incoming tide.

Tributary sampling was conducted at the head-of-tide of Second River, Third River, and Saddle River, with an additional water column sample collected at Ackerman Avenue Bridge (RM17) to represent water quality and contaminant loads from Dundee Dam (located at RM17.4). For these four locations, samples were only collected at one node (15 centimeters [5.9 inches] below the water surface); consequently, they represent discrete grab samples. Unlike the simultaneous sampling that was conducted at each transect on the Lower Passaic River main stem on November 8, tributary samples were collected consecutively on November 10. Third River was sampled first, then Second River, Ackerman Bridge, and finally Saddle River. Moreover, only one sampling pass was performed at each location regardless of tide.

Depending on the analytes of interest, water column samples were collected as either discrete grab samples to represent a node or as a composite sample to represent all five nodes along the transect. All mercury/methylmercury samples were collected following a clean-hands method outlined in Standard Operating Procedure #20, "Ultra-clean Water Sampling Procedures for Mercury" (Malcolm Pirnie, Inc., 2005b and addenda). Other metals samples were filtered and preserved at a field facility before shipment, whereas the mercury/methylmercury samples were shipped as whole water samples and filtered by the laboratory following a clean-hands method. The samples were analyzed for the following analytes: DOC, mercury, methylmercury, metals (filtered and total), POC, ammonia, Biochemical Oxygen Demand (BOD), chlorinated herbicide, Chlorophyll A, Chemical Oxygen Demand (COD), cyanide, orthophosphate, TKN, total phosphorous, TSS, SVOCs, and VOCs. The small volume water column samples provided preliminary suspended solids metals concentrations in the tributaries. However, these data were subject to analytical issues and did not meet the data quality objectives. As a result, these results were not used for further analyses.

3.4 2005 Semi-Permeable Membrane Device (SPMD) Study (Dissolved Phase Contamination)

As part of the 2004 to 2006 USEPA hydrodynamic sampling program, Malcolm Pirnie, Inc. deployed SPMDs to estimate dissolved phase contamination based on lab-determined partitioning coefficients and sampling rates. The SPMD is a semi-quantitative technique; it does not provide direct measurements of concentration, but it can be used to compare the relative concentration among the stations (assuming turbulence and temperature are uniform). The SPMDs were deployed at RM0, RM2.5, RM4.5, RM10.5, Second River, Third River, Saddle River, and Dundee Dam for duration of 30 to 45 days. However, the SPMD at RM2.5 was lost during the deployment. The SPMDs were analyzed for the following parameters: PCDD/F congeners, PCB congeners, PAH compounds, and pesticides. The SPMD data were not used in any of the analyses due to some disadvantages using SPMDs such as bio-fouling, variations in temperature, and flow-turbulence regime that can affect uptake estimates and back-calculated water concentration.

3.5 2008 USEPA High Flow Storm Event Sampling (External Contaminant Load Inputs)

To characterize the suspended phase contaminant loading to the Lower Passaic River from CSO/SWO discharge points and major tributaries, Malcolm Pirnie, Inc. collected large volume water column suspended solids samples[7] and sediment trap samples during high flow storm events between January 2008 and March 2008 on behalf of the USEPA and USACE. High flow storm events were targeted because they deliver large quantities of suspended matter over a short period of time, thus providing a good opportunity for sampling to integrate a large portion of the solids load. In fact, for CSO discharge, releases to the Lower Passaic River are largely restricted to large rainfall events whereas SWO discharges may occur under any precipitation event.

[7] Dissolved-phase contaminant loading was not investigated because the contaminants being examined are hydrophobic and largely associated with suspended matter.

CSO sampling locations (mainly in Newark, New Jersey) were selected considering both sewer drainage areas and sampling accessibility. SWO sampling locations were focused upriver of the City of Newark in the separately-sewered areas of Nutley, Belleville, Rutherford, and Lyndhurst, New Jersey. Note that SWO outfall pipes are typically positioned below the high-tide mark on the river. It was determined after sampling that river-originating solids were able to flow back into the outfall pipes during high tide events and settle inside. Consequently, solids collected during the storm events represent a mixture of river-originated solids and SWO-originated solids that were flushed out of the system.

Whole-water samples were shipped to the laboratories for filtration. A 20-liter (5.3-gallon) whole-water sample was filtered using a nominal 0.5 micrometers (µm) [1.969 x 10^{-5} inches] glass-fiber cartridge filter and a 0.7 µm (2.756 x 10^{-5} inches) glass-fiber flat filter. The filters, representing the particulate phase, were analyzed for PCDD/F congeners, PCB congeners, pesticides, and PAH compounds. A separate 4-liter (1.1-gallon) whole-water sample was filtered using a Whatman QMA (quartz fiber) filter. The QMA filter, representing the particulate phase, was analyzed for metals and mercury. In addition, a time-integrated TSS sample was analyzed using the QMA filter. The TSS value reported using the QMA filter was then compared to a corresponding time-integrated, TSS sample following USEPA Method 160.1. A time-integrated sample was also analyzed for POC. Lastly, a series of time-integrated whole-water samples were collected for grain size distribution analysis. Solids in these whole-water samples were allowed to settle out of the water over a three day period. Overlying water was decanted, and the remaining settled particles were analyzed for grain size distribution.

In addition to whole water CSO/SWO samples, field filtration of whole water samples collected from tributaries also occurred during the high flow events. Samples were collected from Saddle River, Third River, Second River, and the Lower Passaic River near the Ackermann Avenue Bridge (RM17; representing the Dundee Dam boundary

condition[8]). Suspended matter was collected by pumping water through a glass-fiber cartridge filter with a nominal 1 μm pore size followed by a flat filter with a nominal 0.7 μm pore size. Suspended matter at each station was collected continuously over a period of 1 to 2 hours under high flow conditions. The filters were analyzed for PCDD/F congeners, PCB congeners, PAH compounds, pesticides, and POC.

Solids originating from the tributaries were also characterized with sediment traps. Each trap deployment represented a two week period (with at least one high flow event). Solids from the traps represented solids that were suspended in the water column of the tributary during the two week period. These trapped solids were analyzed for PCDD/F congeners, PCB congeners, PAH compounds, pesticides, metals including mercury, radiological parameters, TOC, and grain size distribution. The 2008 storm event sampling program can be summarized as follows:

- The dataset includes samples that characterize the instantaneous loads of suspended matter-borne contaminants delivered to the Lower Passaic River from the Upper Passaic River, CSO discharge points, and tributaries during individual high flow events.
- The dataset includes sediment trap samples that characterize the integrated of suspended matter-borne contaminants loads delivered to the Lower Passaic River from the Upper Passaic River and tributaries over two week periods, incorporating one or more individual high flow events.
- Suspended matter samples collected from SWO sites were not considered usable because the outfall pipes were located below the high-tide mark. Solids collected during the storm events represent a mixture of river-originated solids and SWO-originated solids that were flushed out of the outfall pipe. Due to the nature of the water collection systems for Second River and Third River (*i.e.*, they are urban streams primarily fed by storm water collection systems), samples collected from these tributaries are considered representative of a typical SWO site.

[8] The area near the Ackermann Avenue Bridge is considered at or above the head-of-tide because of proximity of the bridge to the Dundee Dam and the rapid downstream water flow generally associated with this location.

3.6 2011 CPG Small Volume Chemical Water Column Monitoring (CWCM)

The small volume CWCM program implemented by the CPG under USEPA oversight was intended to characterize changes in chemical concentrations associated with the movement of suspended sediments over a range of tides and flow regimes.

Broadly defined, the goals of the CWCM Data Collection Program were to:

1. Collect data to support the calibration, validation, and sensitivity analysis of the Chemical Fate and Transport (CFT) model developed by the CPG under USEPA oversight. The data provide information to develop the inputs to the model and to characterize the transport of contaminants in the LPRSA and NBSA, including the preliminary calibration of the flux of contaminants from the sediments to the water column through routine monitoring events. Water column contaminant concentration data collected in the LPRSA and NBSA with sufficient spatial coverage and frequency and over a range of flow conditions was used to characterize potential gradients, mixing and general inputs to the system.
2. Collect data to characterize the impacts of storm-related high flow conditions on contaminant sources and transport in which resuspension of contaminants from the sediment bed and subsequent deposition from the water column are expected to dominate over other transport processes. Water column contaminant concentration data collected during high flow conditions were used to assess the potential for increased contaminant loading to the water column from upstream sources and/or through resuspension of existing sediments.
3. Collect data to characterize the transport of contaminants under low flow conditions and maximum tidal excursion, which occurs during low flow conditions at spring tides. Water column contaminant concentration data collected during a combination of low flow and spring tide conditions were used to better assess the up-river transport potential and support the understanding of the fate and transport for the 17-mile LPRSA RI/FS Conceptual Site Model and Lower Passaic River/Newark Bay Model.

4. Estimate average water column concentrations of contaminants in the LPRSA over several seasons and flows for use in exposure point concentration estimation for the 17-mile LPRSA RI/FS Human Health Risk Assessment, Ecological Risk Assessment and Food Web Model (FWM).

These monitoring goals were designed to support the ongoing 17-mile LPRSA RI/FS site characterization and modeling efforts and included the following elements:

- **Routine Events** - Water samples were collected for chemical analysis from seventeen locations in the LPRSA (including the LPRSA tributaries), above Dundee Dam, Newark Bay, and Newark Bay at its confluences with the Hackensack River, Arthur Kill, and Kill van Kull during five routine events spread over winter, spring and summer. The samples included whole water (unfiltered) and filtered water samples, depending on the analyte. Samples were filtered for dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc), dissolved methyl mercury, hexavalent chromium, and dissolved solids. Organic carbon was analyzed as dissolved, particulate and total (*i.e.*, DOC, POC, and TOC). Samples for chlorophyll a were filtered at the laboratory. All other samples were whole water. The sampling events were conducted during typical medium flows (400 - 3,000 cfs at Dundee Dam) and likely bracketed several flow regimes over the tidal cycle and captured spring and neap tide conditions. Samples were collected from the deepest part of the river (thalweg) and at two depths (3 feet above the bottom and 3 feet below the surface) for the stations from RM 0 to RM17.4 of the Lower Passaic River and the NBSA, and at mid-depth for locations above Dundee Dam and the LPRSA tributaries. These depths were selected with the goal of sampling the relevant layer while avoiding artifacts associated with sampling in close proximity to the sediment bed, the pycnocline (layer with the greatest density gradient), and the water surface. The thalweg was targeted because it was assumed that the denser layer with net inflow was located in the deepest part of the cross section and the collected samples would best represent the dominant flux past that cross-section.
- **High Flow Events** - Water samples were collected for chemical analysis during high flow conditions (>3,000 cfs at Dundee Dam) at seventeen locations in the LPRSA

(including the LPRSA tributaries), above Dundee Dam, Newark Bay, and Newark Bay at its confluences with the Hackensack River, Arthur Kill, and Kill van Kull through two separate high flow events. Stations were generally co-located with stations occupied during the Routine Events and the samples were collected from the same depths and analyzed for the same parameters as described above. Fourteen of the seventeen stations were sampled four times each throughout the predicted storm hydrograph; the station above Dundee Dam was sampled six times throughout the predicted storm hydrograph. The Arthur Kill and Kill van Kull were sampled just before high and low slack tides.

- **Low Flow/Spring Tide Event -** Water samples were collected for chemical analysis during a single event under low flow and spring tide conditions at nine locations in the LPRSA and above Dundee Dam. Stations were generally co-located with Routine Event stations with each station sampled four times during the tidal cycle and the samples were analyzed for the same parameters as described above. Stations in the Lower Passaic River were sampled at two depths; stations above Dundee Dam and in the LPRSA tributaries were sampled from one depth.

4 BATHYMETRIC, GEOPHYSICAL, GEOTECHNICAL, AND HYDRODYNAMICS SURVEYS

4.1 Bathymetric, Geophysical, and Geotechnical Surveys of the Lower Passaic River (Evidence of Erosion and Deposition)

Multiple bathymetric surveys have been conducted on the Lower Passaic River by various organizations (see Table 2-1). The bathymetric survey data obtained for the Lower Passaic River are substantial, covering a period of 23 years (1989 to 2011) from 13 separate surveying events. These data were used to examine long-term and short-term movement of sediments in the Lower Passaic River, and to identify the boundaries of different geomorphological features of the river. Five of these bathymetric surveys were conducted between 1995 and 2001 in the region between RM0.9 and RM7. For these surveys, elevation data were collected along transects that were planned to be co-located. The degree of alignment achieved between these survey events was typically 18 feet or less. Eight bathymetric surveys are available to characterize RM0 to RM8 or RM0 to RM17.4 (see Table 2-1) and consist of the 1989, 2002, 2004, 2005, 2007, 2008, 2010 and 2011 surveys. In 2007, both single-beam and multi-beam surveys were conducted by CPG. The 2007, 2008, 2010 and 2011 surveys used a multi-beam technique, which provides a three-dimensional representation of the river bottom. The level of confidence in the bathymetric data is discussed further in Appendix B along with a detailed discussion on several analyses that used the data and the implications of differences in transect points.

A side scan sonar survey was conducted in 2005 between RM0 and RM14 to characterize the sediment surface in the Lower Passaic River. This survey involved the use of a geophysical acoustic surveying technique capable of discerning sediment classes by acoustic reflectivity. The interpretation of the acoustic reflectivity was then calibrated by the collection of discrete surface samples throughout the Lower Passaic River. Grain size distribution was also analyzed, providing a quantitative sedimentological description as well as a means to “calibrate” the qualitative field classifications.

4.2 Hydrodynamic Surveys

Several hydrodynamic studies were conducted from 1995 to 2010 to characterize how water flows in the Lower Passaic River, Newark Bay, and Kill Van Kull. All of the studies are summarized in Table 2-1.

Most surveys from 1995 to 2005 involved deployment of tide gauges and current meter moorings throughout the river for a period of time to measure tidal water elevations, current velocities, water temperature, and salinity. Boat-based surveys were also done to collect cross-river current velocity profiles, conductivity, temperature, and depth.

Surveys from 2008 to 2011 consisted of Acoustic Doppler Current Profilers (ADCPs) deployed in the river to record vertical profiles of current velocity and sediment flux (through acoustic backscattering), water temperature, and conductivity.

4.2.1 1995-1996 TSI Passaic River Study Area RI/FS (Modeling Parameters)

TSI collected data between 1995 and 1996 in the Lower Passaic River consisting of three bottom moorings that measured tidal currents, water elevations, temperature, and conductivity as well as a series of transect measurements of current velocities using ship-mounted ADCPs and vertical Temperature/Salinity (T/S) casts to obtain snapshots of hydrographic conditions. The 1995 to 1996 TSI data provided tidal stage measurements at three locations on the Lower Passaic River (RM1, RM3, and RM8). The data collection periods extend from mid-April 1995 to mid-June 1996. Water surface elevations were measured at five- and six-minute intervals and the data were used for model calibration for these periods.

4.2.2 2000-2004 Rutgers University Institute of Marine & Coastal Sciences (IMCS) Hydrographic Measurements (Modeling Parameters)

On behalf of NJDOT and USACE, from December 2000 through April 2002, IMCS of Rutgers University collected data which consist of bottom mounted ADCP, pressure, temperature, and conductivity sensors at five locations: Perth Amboy, the Arthur Kill, the Kill van Kull, and two in Newark Bay. However, the instruments were rotated between the locations at different periods so that there are many gaps in the data.

In 2004-2005 IMCS of Rutgers University deployed a set of six moorings, most of them equipped with two probes (an upper and lower probe) between RM1 and RM8. Data are available from these probes for several distinct periods: August to October 2004, November 2004 to January 2005, and July to September 2005. The data set includes high resolution profiles of salinity and TSS, fixed location measurements of salinity, TSS derived from backscatter, and velocity. Field data collected include bottom mounted ADCP and pressure sensors, and surface and bottom mounted T/S sensors in the Lower Passaic River. The data include low and high flow events providing an excellent range of river behavior for evaluation.

The study implemented by Robert Chant at Rutgers University in 2004 and 2005 provides a baseline of water column velocity, salinity, and TSS measurements in the Lower Passaic River focused on better understanding sediment transport in the system. The study is summarized in a 2010 paper (Chant *et al.*, 2010). Longitudinal profiles of salinity and TSS during low and high flow cases illustrate the dominance of estuarine and riverine processes depending on flow.

4.2.3 2004 to 2005 USEPA and NJDOT Hydrodynamic Studies (Modeling Parameters and Salt Front)

Two separate hydrodynamic studies were conducted on the Lower Passaic River to characterize the movement of the salt front in the river, as follows:

- A hydrodynamic study was conducted as part of NJDOT's Environmental Dredging Pilot Study and involved the placement of several salinity probes between RM2.7 and RM3.1. Six probes were placed near the water surface and four near the water column bottom. Data collection occurred over a period of about 10 days in December 2005.
- On behalf of USEPA and USACE, Malcolm Pirnie, Inc. deployed three moorings with probes located in the upper and lower water column. Two moorings (at RM8.6 and RM9.8) successfully measured salinity data between November 2004 and September 2005.

Note that during the evaluation of these hydrodynamic datasets, the quality of portions of the data was called into question. Data quality issues were attributed largely to probe calibration, which is believed to affect the probe response. Many of the probes seemed to lose their calibration during the course of the deployment periods, which was attributed to the large amount of debris carried by the Lower Passaic River. In addition, some probes showed erratic changes that were not replicated in nearby probes or yielded salinity conditions that were highly improbable. Refer to Appendix B, which describes the data problems and the processes used to separate valid data from inaccurate data.

4.2.4 2009 TSI ADCP Moorings Study (Modeling Parameters)

In 2009, TSI, under USEPA oversight, collected data (from RM2.1, RM3.2 and RM4.1) for use in the design of the Phase 1 Removal Action hydrodynamic model. The hydrodynamic assessment data collection consisted of three tasks (TSI, 2009):

1. *Water sampling and monitoring.*

   Current profiling, water samples, and water quality monitoring data were collected along three cross-river transects with three monitoring locations per transect (¼, ½, and ¾ river width) for seven consecutive days. Water samples were collected from mid-water column depth. At the half-river width location, water samples were also collected 3 feet below the water surface and 1.5 feet above the sediment surface.
2. *Water surface elevation monitoring.*

Tidal elevation data was collected using one primary and one backup tide gauge installed across the river from 80 Lister Avenue. The water surface elevation data was collected at 6-minute intervals in accordance with NOAA/National Ocean Service standards (NOAA, 2008). The tide gauge data was collected for 35 consecutive days to capture a full lunar tidal cycle.

3. *In-situ current and water quality monitoring.*

   One ADCP and one co-located water quality probe were deployed along three cross-river transects, at the approximate half-river width location. The water quality probe collected temperature, conductivity, salinity, and turbidity data. The ADCP collected current and acoustic backscatter data. Settling testing was performed approximately once every 6 hours at one location near the river bottom using Sequoia's laser in-situ scattering and tranmissometry instrument-settling test (LISST-ST). Current and water quality data were collected at 12-minute intervals, synchronized with the tide gauge for 35 consecutive days.

4.2.5 2009-2010 CPG Physical Water Column Monitoring (PWCM) Study (Modeling Parameters)

To characterize Lower Passaic River and Newark Bay estuarine dynamics and the movement of suspended sediments, the CPG, under USEPA oversight, deployed five moorings in the fall of 2009 (Lower Passaic River) and the spring and summer of 2010 (Newark Bay). The five stations were located at RM1.4, 4.2, 6.7, 10.2, and 13.5. The moorings were equipped with meters to record water level, temperature, conductivity, salinity, and optical and acoustic backscatter. A wave gauge was also installed in Newark Bay.

Ocean Surveys, Inc. (OSI) collected ADCP current velocity and turbidity data from the moorings during this study, capturing a broad range of flow conditions. Water column profiles of TSS were computed from the ADCP acoustic backscatter (ABS) data, which were used to develop a series of estimated TSS for comparison to model predictions. During mooring deployment, boat-based ADCP surveys were also conducted in the Lower Passaic River and Newark Bay to obtain velocity profiles.

Water column samples analyzed for suspended solids concentration (SSC), DOC, and POC were collected at the time of mooring deployment, at each mooring servicing event, and upon mooring retrieval. Water column samples for SSC analysis were also collected during the ADCP transect surveys in the Lower Passaic River and Newark Bay.

The scope of the PWCM program also included the collection of water samples for laboratory analysis for SSC, POC, and DOC from the Passaic River upstream of Dundee Dam, just downstream of Dundee Dam (Ackerman Avenue Bridge at RM17), and within the major tributaries to the Lower Passaic River under storm-enhanced flow conditions. Tributaries included in the program consisted of the Saddle River, Second River, and Third River. Samples were collected from shore-based stations in the major tributaries to the Lower Passaic River for suspended solids analysis under wet weather conditions. The program included acoustic backscattering measurements at 12-minute intervals, which provided a basis for evaluation of sediment transport behavior on intra-tidal time scales.

5 ACRONYMS

ABS	Acoustic backscatter
ADCPs	Acoustic Doppler Current Profilers
AVS/SEM	Acid-Volatile Sulfide/Simultaneously Extracted Metals
Be-7	Beryllium-7
BOD	Biochemical Oxygen Demand
CARP	Contaminant Assessment and Reduction Program
cfs	Cubic Feet per Second
CFT	Chemical Fate and Transport
cm	Centimeter
COD	Chemical Oxygen Demand
CPG	Cooperating Parties Group
Cs-137	Cesium-137
CSC	Computer Sciences Corporation
CSO	Combined Sewer Overflow
CWCM	Chemical Water Column Monitoring
DDE	Dichlorodiphenyldichloroethylene
DFIRM	Digital Flood Insurance Rate Map
DOC	Dissolved Organic Carbon
FEMA	Federal Emergency Management Agency
FFS	Focused Feasibility Study
FWM	Food Web Model
HOC	Hydrophobic Organic Constituents
HQI	HydroQual, Inc.
IMCS	Institute of Marine and Coastal Sciences
L-DEO	Lamont-Doherty Earth Observatory
LISST-ST	Laser in-situ scattering and tranmissometry instrument-settling test
LPRSA	Lower Passaic River Study Area
MB	Multi-Beam

MLW	Mean Low Water
NBSA	Newark Bay Study Area
NJDEP	New Jersey Department of Environmental Protection
NJDOT	New Jersey Department of Transportation
NJGS	New Jersey Geological and Water Survey
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Services
NS&T	National Status & Trends
NY/NJ HEP	New York and New Jersey Harbor Estuary Program
NYSDEC	New York State Department of Environmental Conservation
OSI	Ocean Surveys, Inc.
PAH	Polycyclic Aromatic Hydrocarbon
Pb-210	Lead-210
PCB	Polychlorinated Biphenyl
PCDD/F	Polychlorobenzodioxin/furan
POC	Particulate Organic Carbon
PRSA	Passaic River Study Area
PWCM	Physical Water Column Monitoring
QAPP	Quality Assurance Project Plan
RI	Remedial Investigation
RI/FFS	Remedial Investigation and Focused Feasibility Study
RI/FS	Remedial Investigation and Feasibility Study
RIWP	Remedial Investigation Work Plan
RM	River Mile
RPI	Rensselaer Polytechnic Institute
SB	Single-Beam
SEI	Sea Engineering, Inc.
SPMD	Semi-Permeable Membrane Device
SSC	Suspended solids concentration
SVOC	Semi-Volatile Organic Compounds
SWO	Stormwater Outfall

TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOPS	Trace Organic Platform Sampler
TPH	Total Petroleum Hydrocarbons
T/S	Temperature/Salinity
TSI	Tierra Solutions, Inc.
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
μm	Micrometers

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TABLES

Table 2-1: Historical and Current Datasets Incorporated into the Data Evaluation Reports and the RI/FFS Report

Year	Data Source Name	Approved QAPP or Work Plan	Data Validated
GIS Layers			
1995	Chromate Waste Sites, NJDEP	Not Applicable	Not Applicable
1999	NJDEP Wetlands, NJDEP	Not Applicable	Not Applicable
2001	Habitat, NJDEP Division of Fish and Wildlife	Not Applicable	Not Applicable
2002	Land Use, NJDEP	Not Applicable	Not Applicable
2003	Toxic Release Inventory Facilities, USEPA	Not Applicable	Not Applicable
2004	National Priority List Sites, USEPA	Not Applicable	Not Applicable
2005	Known Contaminated Site List, NJDEP	Not Applicable	Not Applicable
2006	Soils, NRCS and USDA	Not Applicable	Not Applicable
2005-2007	FEMA Flood Zones, FEMA DFIRM Database	Not Applicable	Not Applicable
2007	NWI Wetlands, National Wetland Inventory Dataset	Not Applicable	Not Applicable
2007	Bedrock Geology, NJGS and NJDEP	Not Applicable	Not Applicable
Tissue			
1993	NYSDEC 1993	Unknown	Unknown
1994	NYSDEC 1994	Unknown	Unknown
1995	1995 Biological Sampling Program	Unknown	Yes
1999	1999 Late Summer/Early Fall ESP Sampling Program	Yes	Yes
2000	2000 Spring ESP Sampling Program	Yes	Yes
2005	2005 Sediment Profile Imaging Survey of Sediment and Benthic Habitat Characteristics of the Lower Passaic River	Yes	Yes
2005	2005 Taxonomic Identification of Benthic Invertebrates	Yes	Yes
2009-2010	2009-2010 CPG Benthic and Surface Sediment Program	Yes	Yes
2009-2010	2009-2010 Fish Community and Tissue Collection Surveys	Yes	Yes
2010	2010 CPG Habitat Identification Survey	Yes	Yes
2010	2010 CPG Summer/Fall Avian Community Survey	Yes	Yes
Sediment			
1991	1991 Core Sediment Investigation	Unknown	Yes
1993	NOAA NS&T Hudson-Raritan Phase II- 1993	Unknown	Unknown
1993	1993 Core Sediment Investigation - 01 (March)	Unknown	No
1993	1993 Core Sediment Investigation - 02 (July)	Unknown	No
1994	1994 Surficial Sediment Investigation	Unknown	No
1995	1995 TSI Remedial Investigation Sampling Program	Yes	Yes
1999	1999 Sediment Sampling Program	Yes	No
1999	1999 Late Summer/Early Fall Environmental Sampling Program	Yes	Yes
1999/2000	1999/2000 Minish Park Monitoring Program	Yes	No
2000	2000 Spring Environmental Sampling Program	Yes	Yes
2005	2005 Newark Bay Phase I Remedial Investigation	Yes	Yes
2005	2005 Sedflume Testing	Yes	Yes
2005	2005 Gust Microcosm Testing	Yes	Yes

Table 2-1: Historical and Current Datasets Incorporated into the Data Evaluation Reports and the RI/FFS Report

Year	Data Source Name	Approved QAPP or Work Plan	Data Validated
2005	2005 USEPA High Resolution Sediment Coring	Yes	Yes
2005	Polytechnic Institute (RPI) and Lamont-Doherty Earth Observatory (L-DEO) Upper Passaic High Resolution Sediment Cores	Unknown	Unknown
2006	2006 USEPA Sampling Program (Malcolm Pirnie, Inc.) Low Resolution Cores	Yes	Yes
2007	2007 USEPA Upper Passaic High Resolution Sediment Coring	Yes	Yes
2007	2007 Newark Bay Phase II Remedial Investigation	Yes	Yes
2007-2008	2007-2008 USEPA Supplemental Sediment Programs	Yes	Yes
2008	2008 USEPA Suspended-Phase High Flow Storm Event Sampling	Yes	Yes
2008	2008 Sedflume Consolidation Testing	Yes	Yes
2008	2008 CPG Low Resolution Sediment Coring	Yes	Yes
2009-2010	2009-2010 CPG Benthic and Surface Sediment Program	Yes	Yes
2012	2012 CPG Low Resolution Coring Supplemental Sampling Program	Yes	Yes
Water Column			
2005	2005 Large Volume Water Column Sampling Study	Yes	Yes
2005	2005 Small Volume Water Column Sampling Study	Yes	Yes
2005	2005 Semi-Permeable Membrane Device Study	Yes	Yes
2005	2005 USEPA High-Flow Water Column Suspended Solids Sampling	Yes	Yes
2005	NJDOT Environmental Dredging Pilot Study	Yes	Yes
2009-2010	2009-2010 CPG Physical Water Column Monitoring	Yes	Yes
2010	CPG High-Flow Water Column Suspended Solids Sampling	Yes	Yes
2011-2012	CPG RI Water Column Monitoring/Small Volume Chemical Data Collection	Yes	Yes
Hydrodynamics			
1995-1996	TSI Passaic River Study Area RI/FS	Yes	Yes
Nov, 2004 to Sep, 2005	November 2004 to September 2005 Malcolm Pirnie, Inc. Survey	Yes	Not Applicable
Aug – Oct 2004	August to October 2004 Rutgers University Survey First Deployment	Yes	Yes
Nov, 2004 to Sep, 2005	November 2004 to January 2005 Rutgers Survey Second Deployment	Yes	Not Applicable
Jul – Sep 2005	July to September 2005 Rutgers Survey Third Deployment	No	Not Applicable
2005	NJDOT Environmental Dredging Pilot Study	Yes	Not Applicable

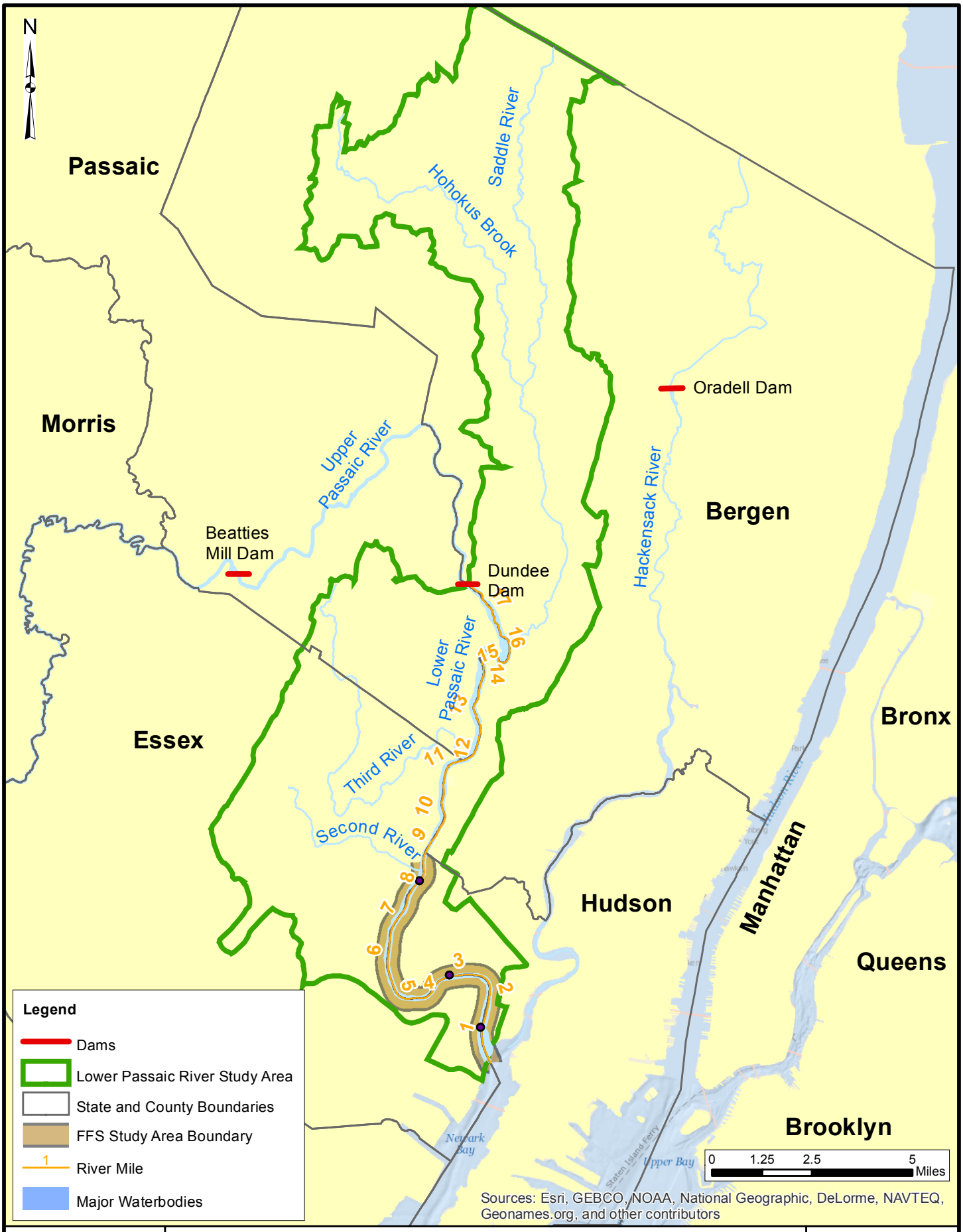
Table 2-1: Historical and Current Datasets Incorporated into the Data Evaluation Reports and the RI/FFS Report

Year	Data Source Name		Approved QAPP or Work Plan	Data Validated
2008-2009	Rutgers University and University of Delaware ADCPs Study		Unknown	Unknown
2009	TSI ADCP Mooring Study		Yes	Yes
2010	CPG Physical Water Column Monitoring Program		Yes	Yes
Bathymetry				
1989	November 1989 Topo-Metrics, Inc. for USACE	RM-0.5 to RM14.98	Not Applicable	Not Applicable
1995	March/April 1995 Ocean Surveys, Inc. for TSI	RM0.87 to RM6.97	Not Applicable	Not Applicable
1996	November 1996 Ocean Surveys, Inc. for TSI	RM0.87 to RM6.95	Not Applicable	Not Applicable
1997	April 1997 Ocean Surveys, Inc. for TSI	RM0.87 to RM6.95	Not Applicable	Not Applicable
1999	June 1999 Ocean Surveys, Inc. for TSI	RM0.89 to RM6.97	Not Applicable	Not Applicable
2001	August 2001 Ocean Surveys, Inc. for TSI	RM0.89 to RM6.96	Not Applicable	Not Applicable
2002	July 2002 TVGA Consultants for USACE	RM-0.44 to RM8.01	Not Applicable	Not Applicable
2004	November 2004 Rogers Surveying, Inc. for USACE	RM-0.54 to RM17.42	Not Applicable	Not Applicable
2005	Aqua Survey Inc. Geophysical and Side Scan Sonar Survey	RM0 to RM17	Yes	Not Applicable
2007	CPG - Multi-Beam (MB) and Single-Beam (SB) Bathymetry	RM-0.50 to RM14.45 (MB) RM0.5 to RM8.21 and RM14.38 to RM16.54 (SB)	Not Applicable	Not Applicable
2008	CPG - Multi-Beam and Single-Beam Bathymetry	RM-0.5 to RM14.26	Not Applicable	Not Applicable
2010	CPG - Multi- Beam Bathymetry	RM-0.5 to RM14.27	Not Applicable	Not Applicable
2011	CPG - Bathymetric Survey of Lower 14 Miles of the Passaic River After Hurricane Irene	RM-0.5 to RM14.27	Not Applicable	Not Applicable

a: The original vertical datum for surveys was MLW as defined by the USACE. The transect density for the surveys was approximately 52 transects per mile.

b: The validation status of the historical sediment and tissue datasets was reported in the "Passaic River Study Area RI/FS Database PRSA version 4."

FIGURES



FFS Study Area Location Map

Lower Eight Miles of the Lower Passaic River

Figure 1-1

2014

Path: P:\0285924\Mapping\CSM_MassBalance\sitelocation_CSM_no_logos.mxd