New York City
Department of Environmental Protection

Brookfield Avenue Landfill
Operable Unit 2
Final Feasibility Study Report

December 2006



Final Report

CDM

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January 3, 2007

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Subject: Brookfield Avenue Landfill Operable Unit 2 (OU2)
Final Feasibility Study Report

Dear Mr. Wuthenow:

CDM is pleased to provide the enclosed Final Feasibility Study (FS) Report for OU2 of the Brookfield Avenue Landfill. The Final FS Report has been modified based on comments received on the Draft FS Report of December 2005 from the New York State Department of Environmental Conservation (NYSDEC); the Citizens Advisory Committee (CAC) and their consultant Ransom Environmental, Inc.; and the New York State Department of Health (NYSDOH).

We look forward to working with the NYCDEP, NYSDEC, and CAC as we progress toward the Record of Decision (ROD) for OU2. Please do not hesitate to call with any questions.

Very truly yours,

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Acronyms

% D	percent difference
% RSD	percent relative standard deviation
$[A^{+m}]$	concentration of positively charged ion in solution
$[B^{-n}]$	concentration of negatively charged ion in solution
ACG	Annual guideline concentration
ACOE	Army Corps of Engineers
ADD_{pot}	potential average daily dose
APC	area of probable concern
APDD	average potential daily dose
ARAR	applicable or relevant and appropriate requirement
ARCS	Assessment and Remediation of Contaminated Sediments Program
αS	Activity of the chemical in the sediment (or suspended particles)
ASGECI	Amy S. Greene Environmental Consultants, Inc.
ASI	Aqua Survey, Inc.
ASP	Analytical Services Protocol
αW	Activity of the chemical in the water (aqueous phase)
AWQC	ambient water quality criterion
BAF	bioaccumulation factor
BCF	bioconcentration factor
BMPs	Best Management Practices
BTEX	benzene, toluene, ethylbenzene, and xylenes
BUD	beneficial use determination
BW	body weight of predator
C	substrate concentration
C	average COPC concentration in food type
C&D	construction and demolition
CAC	Citizens Advisory Committee
CARP	Contaminant Assessment and Reduction Program
CCV	continuing calibration verification
CDF	confined disposal facility
CDM	Camp Dresser & McKee
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Cfs	cubic feet per second
CLP	Contract Laboratory Program
CMP	Coastal Management Program
cm/sec	centimeter per second
CNS	central nervous system
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern

CRQL	Contract Required Quantitation Limit
Cs	mass of solute in the solid phase per unit mass of solid phase
CT	central tendency
Cw	concentration of solute in solution
CWA	Clean Water Act
cy	cubic yard
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DFWMR	Division of Fish, Wildlife and Marine Resources
DO	dissolved oxygen
DQO	data quality objective
ECD	electron capture detector
ECL	Environmental Conservation Law
ED	effects dose
EDV	Environmental Data Validation, Inc.
EIS	environmental impact statement
EO	Executive Order
EPA	Environmental Protection Agency
EPC	exposure point concentration
EQBA	Environmental Quality Bond Act
EqP	equilibrium partitioning
ERA	Ecological Risk Assessment
ERED	Environmental Residue-Effects Database
ERL	Effects Range Low
ERM	Effects Range Medium
f_{oc}	fraction of natural organic carbon in sediment
f_{oc}*	critical level of organic carbon
FDA	Food and Drug Administration
fps	feet per second
FR	dietary fraction of intake of food type
FS	Feasibility Study
FWIA	Fish and Wildlife Impact Analysis
g/cm^3	gram per cubic centimeter
GC	gas chromatograph
GOC	grams organic carbon
GRA	general response action
H	Henry's Law constant
HEAST	Health Effects Assessment Summary Tables
HEP	Harbor Estuary Program
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
IDL	instrument detection limit
IR	ingestion rate of predator

IRIS	Integrated Risk Information System
IS	Internal Standards
k	rate constant for chemical disappearance
K_d	soil/water distribution coefficient
K_H	air-water equilibrium coefficient
K_{oc}	organic carbon partitioning coefficient
K_{om}	organic matter partitioning coefficient
K_{ow}	octanol-water partitioning coefficient
K_{sp}	solubility product constant
lbs	pounds
LCS	Laboratory Control Samples
LD1	lethal dose to 1 percent of exposed organisms
LD50	lethal dose, 50th percentile
LGP	low ground pressure
LOAEL	Low Observed Adverse Effect Level
LOED	lowest observed effects dose
LTMP	Long Term Monitoring Plan
M	relative number of anions that form the solid phase
MCLs	maximum contaminant levels
MDL	method detection limit
mg/kg	milligram per kilogram
mg/L	milligrams per liter
mm	millimeter
mm Hg	millimeters of mercury
MS	mass spectrometry
MSA	Method of Standard Additions
msl	mean sea level
N	relative number of cations that form the solid phase
N/A	not applicable
NAPL	non-aqueous phase liquid
NCEA	National Center for Environmental Assessment
NHPA	National Historic Preservation Act
NIR	normalized ingestion rate of food type
NIR_{dw}	normalized ingestion rate, expressed as dry weight
NIR_{ww}	normalized ingestion rate, expressed as wet weight
NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NOED	no observed effects dose
NSI	National Sediment Inventory
NY	New York
NYCDEP	New York City Department of Environmental Protection
NYCDPR	New York City Department of Parks and Recreation

NYCDOS	New York City Department of Sanitation
NYCDOH	New York City Department of Health
NYCRR	New York Codes Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSPDES	New York State Pollutant Discharge Elimination System
NYS	New York State
OC	organic carbon
OCETA	Ontario Centre for Environmental Technology Advancement
O&M	operation and maintenance
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU1	Operable Unit 1
OU2	Operable Unit 2
PAH	Polycyclic aromatic hydrocarbon
PARCCS	precision, accuracy, representativeness, completeness, comparability, and sensitivity
PCB	polychlorinated biphenyl
PEL	probably effects level
PID	photo ionization detector
ppm	parts per million
ppt	parts per thousand
PRG	Preliminary Remediation Goal
QA/QC	quality assurance/quality control
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RBC	risk based criteria
RCRA	Resource Conservation and Recovery Act
REMAP	Regional Environmental Monitoring and Assessment Program
RfC	reference concentration
RfD	reference dose
RG	remedial goal
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RPDs	relative percent difference values
RRF	relative response factor
SA	surface area
SAC	Science Advisory Committee
SAP	Sampling and Analysis Plan
SCGs	Standards, Criteria, and Guidance values
SEC	sediment effects concentration
SF	slope factor
SFF	site foraging factor
SOP	Standard Operating Procedure

SOW	Statement of Work
SQC	sediment quality criterion
SQRT	Screening Quick Reference Table
SRM	standard reference material
SVOA	semi-volatile organic analyte
SVOC	semi-volatile organic compound
T	Time
TAGM	Technical and Administrative Guidance Memorandum
TAL	Target Analyte List
TBC	to be considered
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TEL	Threshold effects level
TIC	Tentatively Identified Compound
TOC	total organic carbon
TOGS	Technical and Operational Guidance Series
TRV	toxicity reference value
TCLP	Toxicity Characteristic Leachate Procedure
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UCL	upper confidence limit
ug/L	microgram per liter
USACE	United States Army Corps of Engineers
U.S.C.	United States Code
USFWS	United States Fish & Wildlife Servce
US	United States
VOA	volatile organic analyte
VOC	volatile organic compound
wt	weight
yd	yard
yr	year

Section 1
Introduction

1.1 Purpose

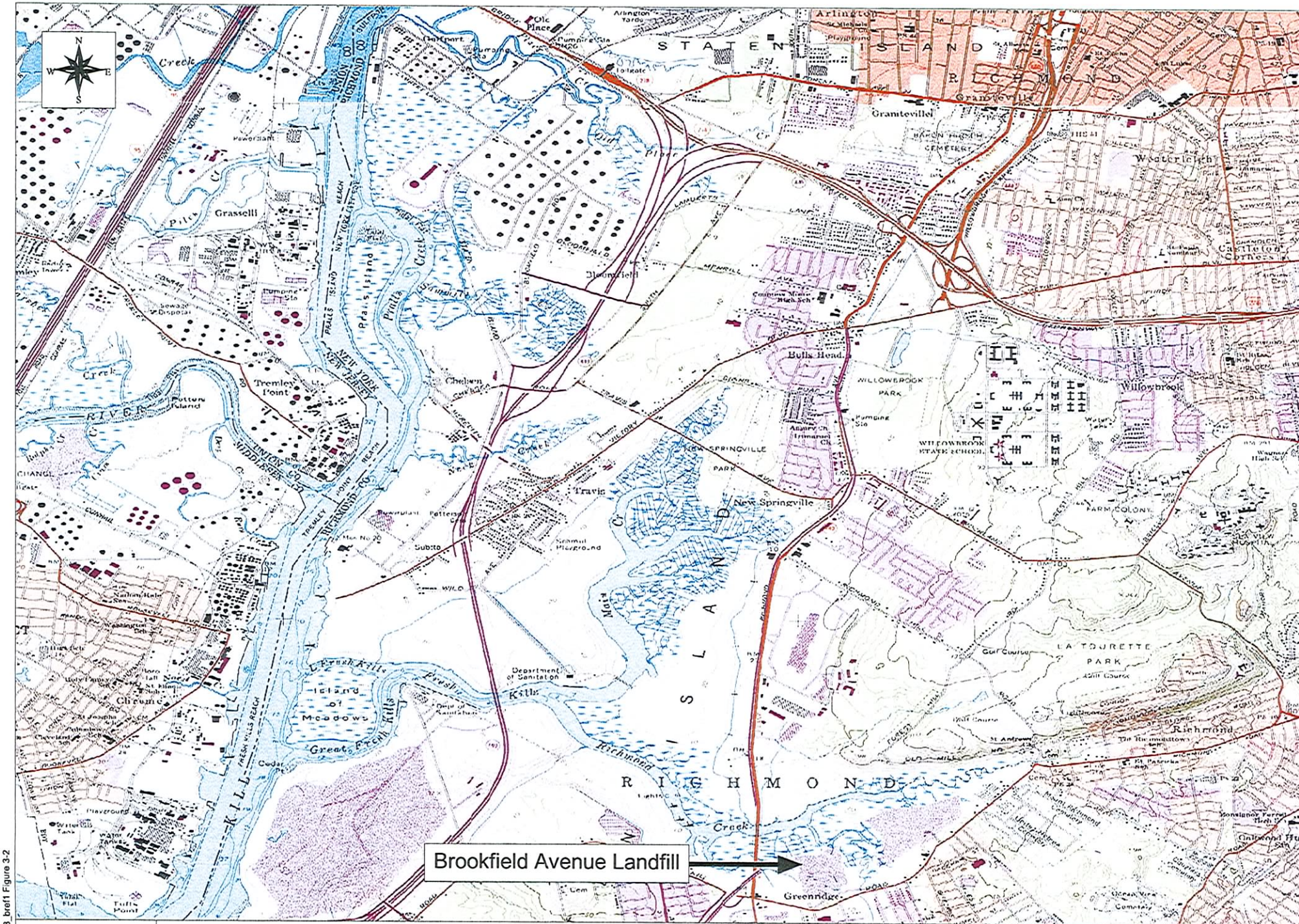
This Feasibility Study (FS) Report for the Brookfield Avenue Landfill Operable Unit 2 (OU2) site has been prepared on behalf of the New York City Department of Environmental Protection (NYCDEP) by Camp Dresser & McKee (CDM). The purpose of this report is to evaluate potential remedial options for the site and recommend a remedy. The Brookfield Avenue Landfill, located in Staten Island, New York, is presently classified by the New York State Department of Environmental Conservation (NYSDEC) as a Class 2 Inactive Hazardous Waste Site. An Order of Consent from the NYSDEC dated April 7, 1992, required the City of New York to develop and implement a remedial program for the Brookfield Avenue Landfill. On March 23, 1993, CDM was retained by the NYCDEP to assist the Department in developing a Remedial Investigation/Feasibility Study (RI/FS) and remedial design for the site.

Following the completion of the Brookfield Avenue Landfill Remedial Investigation (RI) (NYCDEP, 1998a) and Feasibility Study (FS) (NYCDEP, 2001), the NYSDEC directed that the site be separated into two operable units. The landfill portion was designated as Operable Unit 1 (OU1). The Richmond Creek area, adjacent to the landfill, was designated as OU2. A Record of Decision (ROD) (NYSDEC 2002a) was issued for OU1 in March 2002 specifying landfill capping with active gas collection, leachate collection and barrier wall as the remedy for the Brookfield Avenue Landfill, and serves as the basis for the ongoing Remedial Design. This solution, that is anticipated to start construction in 2007, will effectively control the migration of contaminants from the landfill to Richmond Creek. Although the original RI included investigation of Richmond Creek, the NYSDEC required that a supplemental RI/FS be conducted for OU2 to characterize further the impacts of releases, establish exposure pathways, evaluate risk to public health and the environment, and evaluate methods for mitigating contaminated media in OU2.

This feasibility study report summarizes the results of the remedial investigations conducted at the site to date, presents an overview of the planned remedy for OU1, identifies the remedial action objectives (RAOs) for OU2, identifies and screens applicable remedial technologies, and evaluates potential remediation alternatives for OU2 of the Brookfield Avenue Landfill site. This FS was conducted in accordance with the NYSDEC-approved RI/FS Work Plan (CDM, 2003a) as well as relevant NYSDEC technical guidance memoranda.

1.2 Site Description

The Brookfield Avenue Landfill is located at 40°33'44" latitude and 74°09'38" longitude in Richmond County, Borough of Staten Island, City of New York, in the State of New York. The site is approximately 272 acres in size and is bounded on the


Brookfield Avenue Landfill
STATEN ISLAND
RICHMOND
Arlington
Granteville
Westerleigh
Castleton Corners
Grasselli
Bloomfield
Bulls Head
Willowbrook
Travis
New Springville
Tremley Point
Chelsea
Howland Hook
Port Richmond
Elm Park
Graniteville
Meadows
Island of
Great Fresh Kills
Fresh Kills
Richmond Creek
Greenridge
LA TOURETTE PARK
Richmond
Department of Sanitation
Subito
Travis
Chelsea
Chrome
Tufts Point
Old Place
Arlington Yards
Pumping Sta.
Sewage Disposal
Playground
Cemetery
Golf Course
Willowbrook Park
Willowbrook State School
Farm Colony
Victory Memorial Park
Mariners Harbor
Port Ivory
Howland Hook
Elm Park
Graniteville
Westerleigh
Castleton Corners
Bulls Head
Willowbrook
New Springville
Travis
Chelsea
Tremley Point
Grasselli
Bloomfield
Arlington
Port Richmond
Meadows
Island of
Great Fresh Kills
Fresh Kills
Richmond Creek
Greenridge
Chrome
Tufts Point
Subito
Department of Sanitation
LA TOURETTE PARK
Richmond

north by Richmond Creek, on the east by the Colonial Square Condominium properties, on the south by Arthur Kill Road, and on the west by Richmond Avenue. Figure 1-1 presents a location map showing the site in its regional context. Dense residential areas are present to the south and southwest of the landfill with commercial use across Arthur Kill Road. To the north of the landfill, across Richmond Creek is the former Richmond Truck Fill (a former "construction and demolition" (C&D) landfill) now part of La Tourette Park. To the northeast is the heavily forested slope of La Tourette Park. To the east is the less dense residential neighborhood of the restored "Historic Richmond Town". Less than half a mile to the west of the site, beyond Richmond Avenue, is Fresh Kills Landfill, a 2,200-acre land parcel composed of four landfill mounds containing primarily household waste, identified as Sections 1 and 9, Sections 2 and 8, Sections 3 and 4, and Sections 6 and 7. Figure 1-2 presents a schematic of the Fresh Kills landfill site and the various mounds (NYCDOS, 2000). Brookfield Avenue Landfill is located to the west of Fresh Kills landfill, on the east of Richmond Avenue.

Before 1966, prior to use as a landfill, the Brookfield Avenue Landfill site was a coastal marshlands area with little topographic relief. Site topography was altered by the filling, resulting in a site with both flat areas and areas with slopes exceeding eight percent. Figure 1-3 presents an enlargement of the site location map showing site topography from a 1966 survey with a 1981 photorevision date. As shown, the two landfill cells are located south of Richmond Creek. The two mounds of the landfill are straddling a marshy area and twisting stream of the original Sweet Brook. The interceptor sewer and the fill currently present between the two landfill mounds are not present in this 1981 photo revision.

Today, the landfill ranges in height from 15 to 40 feet above surrounding grades, with the general landfill area being fairly level. Stands of ponded water are located on both the east and west sides of the main landfill access road, and a tidally-influenced pond is located at the southeast corner of the landfill. Stormwater runoff from the landfill generally drains into the marsh, however, some runoff is directed to an onsite drainage channel, which flows east and west, emptying into local streams that feed into Richmond Creek.

The site is currently inactive, with a well-established vegetative cover. The landfill portion of the site (OU1) encompasses approximately 132 acres. The main gate to the site is on Arthur Kill Road. An old office building and trailer are located near the landfill entrance. A partially paved road, now overgrown with weeds, accesses the top of the East Cell. Figure 1-4 shows the site, its existing roads and the location of the interceptor and storm sewers which cross the site.

A paved road bisects the westerly fill area, and lies above the 48-inch diameter wastewater interceptor that leads to the Eltingville Pump Station. The pump station lies between the east and west landfill cells. A three pipe, 16-foot by 6.5-foot storm

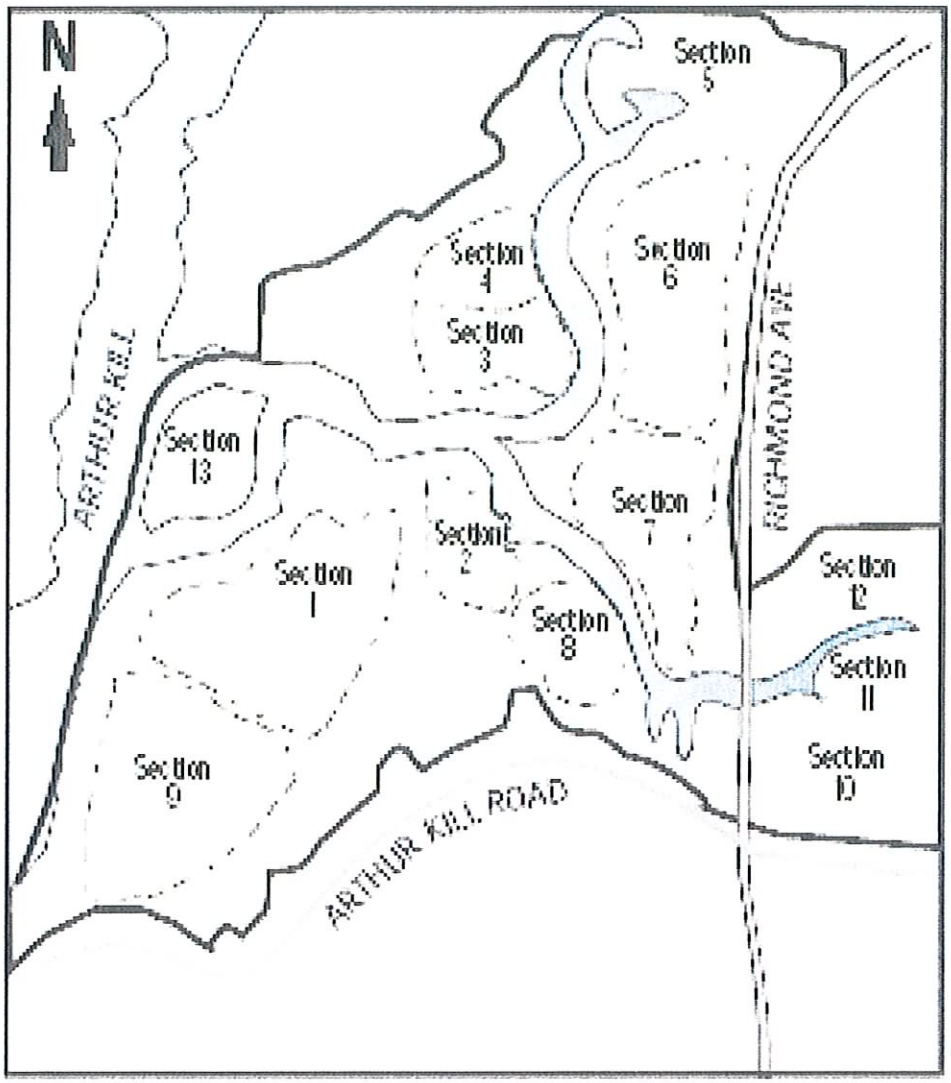
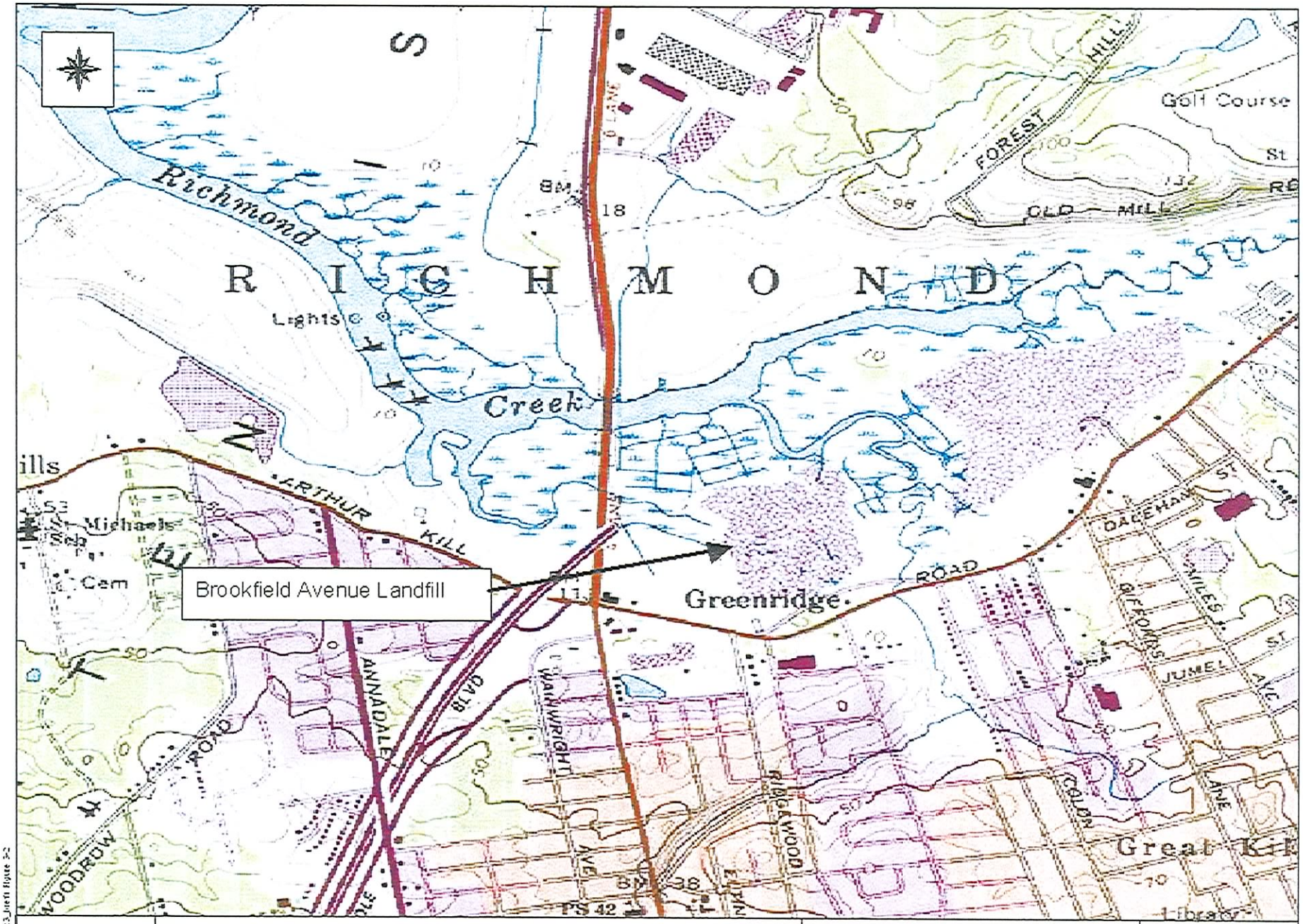


Figure 1-2 Fresh Kills Landfill: 1948 Original Landfill Boundary (2,800 acres)

(from The DOS Report, New York City Department of Sanitation Report for February 2000)



CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

DEP

Historic Topographic Map

Figure 1-3

Fresh Kills Landfill

Richmond Creek

East Cell

West Cell

Colonial Square

Eltingville
Pump Station

Holterman's Bakery

United Hebrew Cemetary

Forest Hill Rd
Richmond Ave
Arthur Kill Rd
Newvale Ave
Tanglewood Dr
Corbin Ave
Troy St
Greaves Ave
Cromer St
Mills Ave
Elmhurst St
Teakwood Ct
Nutwood Ct
Country Woods Ln
Ironwood St
Cottonwood Ct
Emery Ct
Token St
Ladd Ave
Berry Ave
Crestfield Ave
Drumgoole Rd W
Drumgoole Rd E
Gurley Ave
Getz Ave
Ridgewood Ave
Brandis Ave
Macon Ave
Armstrong Ave
Abington Ave
Brookfield Ave
Colon Ave
Duane Ave
Elverton Ave

LEGEND

- Storm Sewer
- Sanitary Sewer
- Approximate extent of OU1 boundary
- Approximate extent of OU2 boundary
- Surface water feature

N
W
E
S

200 0 200 400 Feet

c:\ou2gis\fs_sec1_fig1-4.apr Figure 1-4

CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION DEP

Site Plan

Figure 1-4

sewer culvert bisects the east and west cells conveying drainage from the Sweet Brook drainage basin from the south to Richmond Creek. A 36-inch diameter force main exits south from the Eltingville Pump Station proceeding across Arthur Kill Road. Another 48-inch diameter interceptor sewer enters the Eltingville Pump Station from the north. This sewer was installed in 1982 and carries flow south across the former Richmond Truck Fill, through an overflow chamber on the north side of the creek, and then passes under Richmond Creek. The site is completely enclosed by fencing with the exception of the boundary along Richmond Creek, which is unfenced.

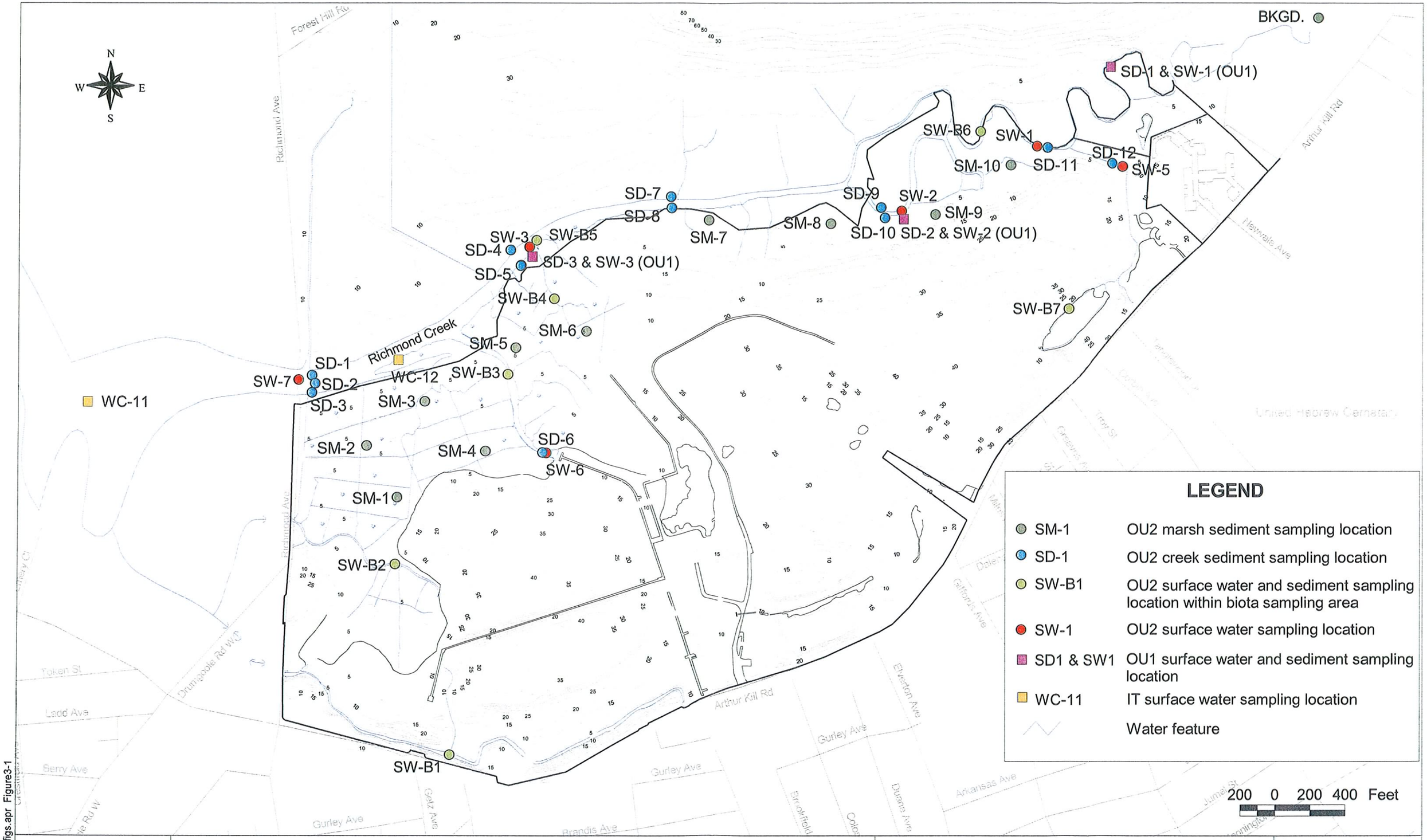
The site is guarded 24 hours per day, seven days a week. For public safety purposes, signs have been placed just inside the perimeter fence identifying the area as an inactive hazardous waste site.

The eastern portion of the landfill (approximately 38 acres) was covered with a clay cap in 1983. Localized erosion of the clay cap is evident. It should be noted that a new cap will be installed on both the eastern and western cells of landfill during the engineering phase of the OU1 remediation, as approved in the OU1 ROD. The cap will be installed in accordance with NYSDEC regulations and will include an impermeable liner (CDM, 2002). The latter was not installed on the 1983 cap. Along the southern perimeter of the landfill, a 525-foot long passive methane collection trench was installed to halt the migration of methane gas toward the residences near the landfill.

OU2 is generally located to the north of OU1 as shown on Figure 1-4. The area includes Richmond Creek, between the eastern limit of the landfill site and Richmond Avenue, several small tributaries that empty into the creek from the south, and the tidal wetland/marshlands between the creek and the landfill. Tidal and freshwater wetland areas located at the southern end of the site, between the landfill and Arthur Kill Road, were addressed as part of the OU1 remedial activities and have generally not been further investigated as part of the OU2 RI; however, as directed by the NYSDEC, biota was collected from both the eastern and western drainage ditches between the landfill and Arthur Kill Road.

1.3 Summary of the Results of the Remedial Investigations

Several phases of field investigations have been conducted on the OU2 portion of the site since the remedial investigations began in December 1993. In addition to the source characterization and hydrogeologic evaluations conducted during the OU1 RI, surface water and sediment sampling were conducted in 1994 and 1997 and sediment toxicity testing was performed in 1994 and 1997. The OU2 RI was designed to supplement the original RI investigations to collect the data necessary to meet the objectives of the OU2 RI. OU2 RI tasks included: (1) collection and analysis of surface water from Richmond Creek; (2) collection and analysis of shallow and deep sediment from both Richmond Creek and the marsh between the creek and the landfill; and (3)



c:\ou2gis\ri_sec3_figs.apr Figure3-1

CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

Surface Water, Sediment, and Biota Sampling Locations

Figure 1-5

collection of biota from the creek and marsh and analysis of tissue. The OU1 and OU2 surface water, sediment, and biota sampling locations are shown in Figure 1-5. A complete description of the RI findings for OU2 is contained in the two remedial investigation reports prepared for the site, *Brookfield Avenue Landfill Remediation Project Final Remedial Investigation Report* (NYCDEP, 1998a) and the *Brookfield Avenue Landfill Operable Unit 2 Final Remedial Investigation Report* (NYCDEP, 2005). The major findings of the investigations are summarized below.

1.3.1 Surface Water, Wetlands and Drainage

1.3.1.1 Surface Water

Richmond Creek within OU2 has received a regulatory classification of Class SC (Class C saline water) under the New York State Surface Water Standards. As per 6 NYCRR Part 701.12, surface waters classified as SC are suitable for fish propagation and survival. SC classified waters should also be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes. Primary contact recreation includes, but is not limited to, swimming, diving, water skiing, skin diving and surfing. They are not suitable for shellfishing for market purposes. Currently, access to Richmond Creek from the landfill is restricted by fencing and 24-hour security, thereby limiting it use to some extent.

Richmond Creek is a freshwater stream-fed tidal creek. Richmond Creek is the longest stream of Staten Island's surface drainage system, extending approximately 2.5 miles from the central part of the Island to the Fresh Kill. The tidal portion of Richmond Creek is fed by the freshwater portion of the creek from the east, upstream of the dam at St. Andrew's Church, and by the Sweet Brook tributary from the south. The freshwater portion of Richmond Creek is a Class B fresh surface water. The best usage of Class B waters is primary and secondary contact recreation. The Class B designation requires that these waters shall be suitable for fish propagation and survival.

Freshwater can extend downstream of the St. Andrew's Church dam, depending on tidal conditions and precipitation/stormwater runoff. During heavy precipitation events, Richmond Creek is dominated by freshwater streamflow and stormwater drainage into the main trunk from overland flow from many non-point sources, as well as point sources such as stormwater culverts and outfalls. During periods of low precipitation, and minimal freshwater streamflow and overland flow, Richmond Creek is dominated by tidal flushing which moves saltwater from the Arthur Kill to Fresh Kills to Richmond Creek during high tide, and in the opposite direction during low tide. At high tide, the zone of changing salinity will be less pronounced due to the decreased dilution of fresh water. At low tide, fresh water will have a greater diluting effect on the salt water.

Two unnamed streams are located on site, each within one of the two field-observed wetlands located south of the landfill. According to the NYSDEC Region 2 Office, the freshwater portions of both streams are considered Class B (personal communications

between NYSDEC Region 2 and CDM, 2005). Tidally influenced segments of each stream are designated Class SC. The unnamed stream which feeds into Richmond Creek from the east is designated a Class B stream from the Richmond Hill Road culvert to its source. A second, unnamed, Class B stream empties into Richmond Creek at the northwest corner of the site along Richmond Avenue. Its source, a freshwater pond located in the La Tourette Park Golf Course, lies directly north of the eastern end of the site.

Conductivity measurements taken within the creek during the OU1 investigations show an increasing salinity gradient from east to west. A conductivity of 0.707 millivolts per centimeter (mv/cm) was recorded at the eastern end of the creek compared to a conductivity of 17.57 mv/cm at the westernmost sample location taken just east of Richmond Avenue. Data collected during the OU1 investigation show a trend of increasing temperature and decreased dissolved oxygen and pH in Richmond Creek, progressing from the east to the west. The average water temperature at the east end of the creek was approximately six degrees (Celsius) lower than the average water temperature at the western edge of the site (when sampled in summer months). These findings are expected given the tidal influence from the west and freshwater input from the east.

Dissolved oxygen (DO) levels were measured ranging from 8 to 9 mg/l at the eastern end of the creek and between 6 to 7.5 mg/l at the western end of Richmond Creek with an average of 6.43 mg/l for Richmond Creek, indicating that aquatic life in the creek was not stressed (DO>5 mg/l). DO levels provide an indication of a water body's ability to sustain aquatic life. Aquatic life generally can be stressed when DO is below 5 mg/l and severely stressed when DO is below 3 mg/l. DO levels obtained from the Richmond Creek were slightly lower than DO levels obtained from the NYCDEP monitoring stations along Arthur Kill (range from 6.6 to 7.42 mg/l, an average of 7.1 mg/l) in the NYCDEP Harbor Survey (NYCDEP 2005). The average pH measured at five locations near the eastern end of Richmond Creek (8.64) was almost one standard unit greater than the average of five western sample locations (7.68). The dissolved oxygen gradient is as expected, given a freshwater source from the east (comprised of both stream base flow and stormwater).

Levels of nutrients, such as nitrate and ammonia-nitrogen, measured during the Brookfield Avenue Landfill Operable Unit 1 Remedial Investigation (OU1 RI), were compared to levels obtained by the NYCDEP during the annual New York Harbor Water Quality Survey (Yao, 2005). Excessive levels of nutrients in estuaries can lead to heightened algae growth which can lower DO levels and impair water clarity. Results obtained from the RI report and Harbor Survey show that the mean value of nitrate in Arthur Kill was higher than that in Richmond Creek (0.53 vs. 0.24 mg/l). However, the mean value of ammonia-nitrogen in Arthur Kill was lower than that in Richmond Creek (0.5 vs. 2.21 mg/l). Landfill leachate from the Brookfield Avenue Landfill, the Fresh Kills Landfill, and stormwater runoff that enters Richmond Creek may contribute to the elevated levels of ammonia-nitrogen detected in Richmond

Creek. Brookfield Avenue Landfill will be eliminated as a potential source of leachate following implementation of the OU1 remedy.

The mean value of total suspended solids (TSS) measured in Richmond Creek was also compared to that in Arthur Kill. Results show that the mean TSS value in Richmond Creek was higher than that in Arthur Kill (52 vs. 12.3 mg/l). Runoff from the Fresh Kills and Brookfield Avenue landfills including silt, decaying plant and animal matter, industrial wastes, sewage, and landfill leachate, may contribute to the relatively high level of TSS in Richmond Creek. Implementation of the OU1 remedy will significantly reduce the TSS contribution of the Brookfield Avenue Landfill to Richmond Creek.

1.3.1.2 Wetlands

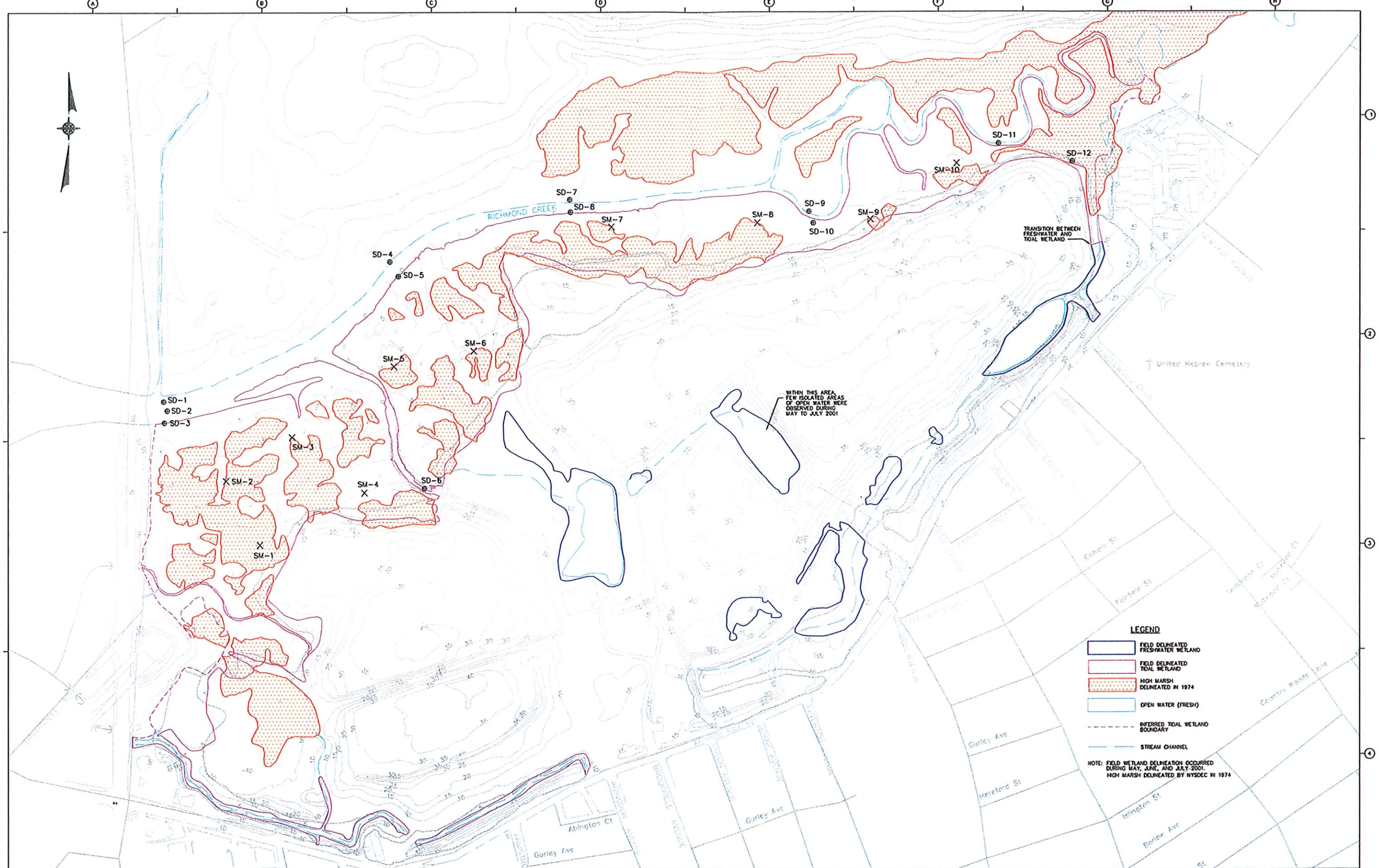
Freshwater and tidal wetlands were field delineated by a CDM wetlands specialist in July 2001 as part of one of the OU1 pre-design tasks. Figure 1-6 depicts the extent of the freshwater (shown in blue) and tidal (shown in magenta) wetlands from this 2001 field delineation. Tidal wetlands within the limits of the site cover 73 acres. The entire Fresh Kills estuary represents the largest tidal wetland ecosystem in the Manhattan fells ecological region, covering approximately 1,000 acres.

The latest tidal and freshwater maps available from the state represent the result of NYSDEC's 1987 (freshwater) and 1974 (tidal) inventory mapping (NYSDEC, 1974). This inventory mapping indicates three classifications of tidal wetlands present within OU2 including high marsh, intertidal marsh, and littoral zone. High marsh or salt meadow is the uppermost tidal wetland zone, designated HM on the inventory map. The boundaries of the high marsh delineated by NYSDEC in 1974 are shown in stipple with red outline on Figure 1-6. High marsh is usually dominated by salt meadow grass *Spartina patens*; and spike grass, *Distichlis spicata*. Intertidal marsh is the vegetated tidal wetland zone, designated IM on an inventory map, lying generally between average high and low tidal elevation. The predominant vegetation in this zone is low marsh cordgrass, *Spartina alterniflora*. Littoral zone is the tidal wetlands zone, designated LZ on an inventory map, that includes all lands under tidal waters which are less than six feet deep at mean low water.

Wetlands such as these at the Brookfield Avenue Landfill OU2 site perform many beneficial functions, including marine food production, valuable habitat for aquatic and terrestrial plants and animals, floodwater control and storage, reduction of wave energy during storms, sediment trapping, and improvement of water quality through nutrient and pollutant removal. The beneficial functions of wetlands, including many specific functions observed and documented within the tidal wetlands in OU2 and Richmond Creek are discussed below.

The Habitat Value of OU2 Tidal Wetlands

The Step I Fish and Wildlife Impact Analysis conducted during the OU1 RI noted a wide variety of waterfowl, wading bird and seabird species nest in OU2 and/or the



REV. NO.	DATE	DRWN	CHKD	REMARKS

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DRAWN BY:
SHEET CHK'D BY:
CROSS CHK'D BY:
APPROVED BY:
DATE:

CDM Camp Dresser & McKee

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL
OPERABLE UNIT 2

BROOKFIELD AVENUE LANDFILL
WETLAND DELINEATION

PROJECT NO. 5215-12929
FILE NAME: WETMAP02 FS.dwg

SHEET NO.
Figure 1-6

adjoining tidal marshes including, but not limited to: Canada goose, mallard, black duck, blue-winged teal, wood duck, Virginia rail, common moorhen, spotted sandpiper, cattle egret, snowy egret, yellow-crowned night heron, green-backed heron, glossy ibis, herring gull, black -backed gull, fish crow, marsh wren, and swamp sparrow. During the winter, the nearby William T. Davis Wildlife Refuge commonly has a substantial population of raptors, including the red-tailed hawk, northern harrier, and long-eared owl. The tidal marshes of Richmond Creek are important to a broad assemblage of birds and other wildlife due mainly to the availability of cover for nesting and the abundance of prey. The extensive network of tidal creeks and freshwater inflows provide potential spawning and nursery habitats for anadromous and resident freshwater fishes and invertebrates.

The Role of OU2 Tidal Wetlands in the Estuarine Food Web

Many of the juvenile fish and larval invertebrates that reside within tidal wetlands serve as a primary food source for local crustacean and bird populations. Wetlands are also the primary source of much of the organic matter and nutrients forming the basis of the coastal and estuarine food web. As wetland vegetation decays, a steady supply of detritus is released into surrounding waters, promoting the secondary production of finfish, shellfish, crustaceans, and birds. The presence within OU2 of species within all four of these groups was noted during field reconnaissance and sampling tasks.

Floodwater Control, Storage, and Sediment Trapping

Encompassing 73 acres, the tidal wetlands of OU2 provide a significant amount of flood control and storage. During heavy rain events, storm flows from the freshwater portion of Richmond Creek and Sweet Brook undergo attenuation as they reach the tidal wetlands within OU2. Reduction of flow velocities by the wetland vegetation present in OU2 also contributes to flood control. Decreased flow velocities allow water to be transferred into soils and underground watercourses (Desbonnet et al., 1994). During storms, the salt marsh wetlands in OU2 reduce wave energy. The presence of wetland grasses such as smooth cordgrass (*Spartina alterniflora*) reduces the energy of waves moving shoreward. The ability of salt marsh wetland vegetation to reduce wave energy helps prevent shoreline erosion. Reduction of wave and current energies in salt marsh wetlands causes them to trap sediment.

The Role of OU2 Tidal Wetlands in Improving Water Quality

Pollutants are removed in natural wetlands via various physical, chemical, and/or biological processes. Some of the specific contaminant attenuation processes likely to be occurring in the wetlands of OU2 include biodegradation, biotransformation, bioturbation, diffusion, dilution, adsorption, volatilization, chemical reaction or destruction, resuspension, downstream transport, and burial by clean material. In some cases, these processes transfer some or all of the mass of contaminants (or derivative end-products) to and from the sediment and overlying water. The net result of such processes is a reduction in the concentration of the contaminants within

the sediment and surface water, and the overall water quality improvement in the estuary.

For biological processes, microorganisms in marsh deposits can provide organic contaminant uptake and storage by utilizing the carbon in the organic matter as a source of energy and then converting it to carbon dioxide or methane gases. Wetland plants and vegetation, such as woody and herbaceous plants, uptake excess nutrients (nitrate, ammonium, and phosphate) as well as organic compounds and metals. This uptake helps check the proliferation of algal blooms which cause a depletion of oxygen levels and can result in fish kills. The woody plants located on the edge of the high marsh in OU2 offer long-term storage of contaminants, and herbaceous plants located throughout the tidal marsh may have high contaminant uptake rates per unit area. This uptake and storage on organic matter and sediment can result in increased concentrations of some compounds and metals in the sediment. However, the general trend and impact of these processes is that the sequestering of these compounds makes them less bioavailable.

Peat formed by slow anaerobic decomposition of organic matter in wetland soil of OU2 store pollutants long-term. Peat (Meadow Mat) was noted to be present throughout much of the tidal marsh during the OU1 and OU2 field investigation. Certain bacteria typically present in marsh sediments can permanently remove inorganic nitrogen, such as nitrate, by metabolically transforming nitrate into nitrogen gas (denitrification). Ammonium, a major environmental product of landfills, is removed through sequential nitrification and denitrification processes by microbial transformation of ammonium to nitrate in aerobic soil and surface water and then denitrification in deeper anaerobic soil. Hernandez et. al (circa 1997) estimate that the bacteria present in one square yard of the Richmond Creek marsh sediments convert between 1 and 10 milligrams of ammonia into nitrate each hour and 10 to 100 milligrams of nitrate into nitrogen gas. Other bacteria present in sediments found in OU2 convert sulfate into hydrogen sulfide, which combines irreversibly with metals such as cadmium and copper, thereby reducing the bioavailability of these potentially toxic metals. The OU2 salt marsh vegetation stabilizes the sediments, allowing formation of the anoxic environment required for deposition of these heavy metal-sulfide complexes.

Chemical processes also play a role in pollutant removal in wetlands. Sorption causes long-term immobilization of contaminants via transfer of ions from solution phase to solid phase. This two-reaction process consists of adsorption and precipitation. Adsorption is the attachment of ions to soil particles (clay and organic matter) by either cation exchange or chemisorption. Phosphate and calcium in the wetland soil can precipitate with metals to form mineral compounds. Volatilization is diffusion of a dissolved compound from the water into the atmosphere. The OU2 RI Report highlights each of these as important fate and transport processes occurring in the tidal wetlands of OU2.

Fiddler crab burrows are noted as being present in almost every square yard of the high marsh within portions of OU2. The mere presence of these crabs indicates that the water is clean enough for sensitive organisms which otherwise do not thrive in areas where high concentrations of pollutants occur. The crab burrows, like the roots of the salt meadow grass and other marsh grasses in which they live, allow oxygen to reach the deeper sediments, which in turn improves the biogeochemical filtering capacity of the marsh (Hernandez, circa 1997).

NYSDEC Tidal Wetland Regulations

Based on the above noted beneficial functions, the wetlands of Richmond Creek and marsh are undoubtedly a significant resource of high value. The overall importance of tidal wetlands in New York State are made apparent in NYSDEC's tidal wetland regulations:

> "Intertidal marsh and coastal fresh marsh tidal wetlands are the most biologically productive of all tidal wetlands areas. …Because of these high values and their sensitive location at the land and water interface, intertidal and coastal fresh marshes must be the most stringently protected and preserved tidal wetlands zones. Even small portions of these zones are critically important resources. Consequently, only very limited types of land use and development are compatible with the values of these areas" (6 NYCRR Part 661.2(d)).

Therefore, destruction of this resource would only be allowed if it could be proven that the current resource is significantly impaired and would be better off being destroyed and reconstructed. This is not the situation in OU2, therefore protection of the wetlands and vegetated habitat is of paramount importance. Further, experience has shown that it is often difficult to fully replicate the functionality of established wetlands (National Academy of Sciences, 2001). Based on a review of numerous attempts at wetland restoration and creation projects, the National Academy of Sciences suggests that although wetland structure may be replaced, it is often difficult to replace the many of the more important functions of a wetland such as those related to water-quality improvements. For example, denitrification, a process that benefits water quality, only occurs under the presence of a nitrate supply, a labile source of carbon, anaerobic conditions, and microbial activity. A site that has been reconstructed by replacement of a vegetation assemblage might not provide the same water quality function of denitrification if these four requirements are not met. Therefore, in many instances, reconstructed wetlands are often inferior to those that they replace with regard to some of the most important functions such as pollutant removal.

NYSDEC indicates in their Salt Marsh Restoration Guidelines that where restoring historical acreage is not feasible (e.g., the Fresh Kills estuary), habitat restoration is less likely to succeed. In this case the habitat should be given higher priority for protection than for restoration. Therefore, NYSDEC discourages or refrains from

authorizing damage to protected habitats and wetlands by active remediation if the wetlands are functioning and not significantly impaired, as these are.

1.3.1.3 Drainage

From Richmond Creek, surface water flows to the Fresh Kill and from there into the Arthur Kill. Intermixing of drainage water from both Fresh Kill and Richmond Creek occurs in this tributary system due to tidal effects. Two major stormwater systems are routed into the creek: the Richmond Creek system (east of Mill Pond) from the east and the Sweet Brook system from the south. Richmond Creek brings flow estimated at between 0.64 to 1.8 cubic feet per second (cfs) as the base stream flow from groundwater (NYCDEP, 1997) . The storm flow is considerably more significant as estimated by NYCDEP in their Environmental Impact Statements (EISs) for the Richmond Creek Drainage plan and the Wolfe's Pond and Sweet Brook Drainage Plans which are part of the Staten Island Bluebelt program (see below). The Richmond Creek EIS estimates that flows beneath the Arthur Kill Road bridge (just east of the dam at St. Andrew's Church) for a 1-year storm under 1997 ("existing") conditions are 175 cubic feet per second (cfs) and flows under full "build-out" (i.e., with all the upstream lots developed) and with Best Management Plans (BMPs) in place will be 212 cfs (NYCDEP 1997). The Sweet Brook EIS estimated that the Sweet Brook system brings storm water runoff estimated at 441 cfs for the 1-year storm under 1999 (existing) conditions, at 485 cfs under full "build-out" (all lots developed), and 479 cfs with BMPs in place (NYCDEP 1999). Construction of the last of the Richmond Creek BMPs was completed in 2005. The Sweet Brook BMPs are about 50% complete as of Fall 2005. No new modeling or flow measurements are available since the EISs were completed (CDM, 2005).

The Staten Island Bluebelt program, which is a combination of NYCDEP-initiated natural and structural storm control measures, has mitigated the excessive flooding and water pollution problems in South Richmond, Staten Island. At the same time, the South Shore's natural drainage system of streams, ponds, marshes, and wetlands has been preserved. Brookfield Avenue Landfill is located in this same area, and Richmond Creek performs the function of floodwater conveyance and storage for this comprehensive drainage management plan (Vokrol et al, 2001).

The area's waterways, such as Richmond Creek, along with adjacent wetlands, provide natural drainage corridors for stormwater conveyance. A variety of stormwater BMPs have been applied in the Bluebelt program to effectively manage stormwater runoff, with the goal of reducing the impact of the stormwater runoff discharge on the local streams. BMPs include settling ponds, sand filters, and constructed wetlands, all of which provide a first level of water quality and quantity control. Additionally, in some cases, existing wetlands were restored or enhanced as part of this plan creating enhanced natural areas. Implementing these BMPs serves to attenuate peak stormwater flows while also reducing pollutant loadings to the local streams. Stormwater quality is naturally enhanced or improved before ultimately discharging into the local waterways.

With this program in place, the local community benefits from and enjoys the continued availability of open space and natural habitat. The wetlands and surrounding woodlands provide important habitat for a wide variety of urban wildlife and several migratory bird species. Residents have observed cleaner water and less runoff as a result of the project (NRDC, 1999). Some feel that the project has resulted in property value increases and other economic benefits to the community (NRDC, 1999).

Several of the Bluebelt program's BMPs for Richmond Creek are located just upstream of the Brookfield Avenue Landfill where CDM's upstream surface water and sediment samples were collected. The BMPs at this location include pond and wetland marsh enhancement, weir improvements, and sand filter purification. The EIS for the Richmond Creek drainage plan project indicated that the BMPs would serve to reduce peak flow velocities and volumes for storm events more frequent than the 5-year event. The water flow models performed for the EIS estimated that upon completion of the storm sewers and BMPs, the same volume of water would reach Richmond Creek as under prior conditions, but the amount would be staggered over time and released at point discharges instead of coming as overland flow. These point discharges were controlled using stilling ponds and detention basins which were designed to reduce the flow velocities for the frequent (less than 5-year) storms to below 3.5 to 5 feet per second (fps) so that bank erosion would not occur. Richmond Creek and the associated wetlands have served as an important part of the natural drainage corridors within the Richmond Creek Bluebelt Program for storm water conveyance and provide storage for this additional storm water flow.

If maintained properly, the BMPs installed in the freshwater portion of Richmond Creek will provide water quality improvement within OU2 indefinitely. The existing upstream wetlands which were restored or enhanced as part of the Bluebelt Program will also help achieve long-term improvement to water quality in OU2.

1.3.2 Endangered, Threatened, or Special Concern Species

A United States Department of the Interior Fish and Wildlife Service (USFWS) publication, *Significant Habitats and Habitat Complex of the New York Bight Watershed, Arthur Kill Complex* indicates a total of 19 endangered, threatened, rare, or special concern species of plants and animals were observed within a two mile radial area of the Brookfield site (USFWS, 1997). The list includes the peregrine falcon, a Federally-listed endangered species, the northern diamondback terrapin, and cerulean warbler, both Federal species of concern.

According to the NYSDEC Wildlife Resource Center, there has only been one documented sighting of endangered, threatened, special concern or protected wildlife species, or rare plant, animal or natural community concerns at the Brookfield Avenue Landfill OU2 site (NYSDEC, 2005). In 2002, the common barn owl (a protected species) was observed to be nesting under the Richmond Avenue Bridge.

Although none have been observed, additional common barn owl nesting locations may exist in the area. The barn owl habitat includes open areas such as grassy fields, wet meadows and wetland edges, all which are present in the vicinity of the Brookfield Avenue Landfill.

The New York State Department of State Division of Coastal Resources has designated Richmond Creek and the surrounding tidal wetlands as a Significant Coastal Fish and Wildlife Habitat (NYSDOS, 2004). The area was first listed as a Significant Habitat in September of 1992 and was assigned the highest Significance Value of the five Significant Habitats located on the north and west side of Staten Island, as determined by the Coastal Management Program (CMP). The Arthur Kill complex supports seasonal or year-round populations of 178 species of special emphasis, incorporating 37 species of fish and 128 species of birds. Of primary significance in this area is the presence of major nesting colonies and foraging areas of herons, egrets, and ibises in a complex of closely associated natural habitats occurring within a major metropolitan area. Three island colonies, or heronries, were established in the 1970s; in 1995 these heronries collectively contained nearly 1,400 nesting pairs of colonial wading birds of special regional emphasis or management concern, including, in declining order of abundance, black-crowned night-heron (*Nycticorax nycticorax*), glossy ibis (*Plegadis falcinellus*), snowy egret (*Egretta thula*), great egret (*Casmerodius albus*), cattle egret (*Bubulcus ibis*), yellow-crowned night-heron (*Nyctanassa violacea*), green-backed heron (*Butorides striatus*), and little blue heron (*Egretta caerulea*) nesting pairs. This is the largest heronry in New York State and accounts for about 25% of all the waders that breed in coastal New Jersey, New York, and Connecticut. The largest number of nesting great egret, cattle egret, snowy egret, and yellow-crowned night herons in New York State occur at these colonies (USFWS, 1997).

The Arthur Kill complex was awarded a high score in the species vulnerability category due to its use as a wintering area by the northern harrier (threatened) and long-eared owl, and as a nesting area by the barn owl (a special concern species). Conservation of the wetlands at the Brookfield Avenue Landfill OU2 site can protect the habitats for these species of concern.

1.3.3 Hydrogeology

The landfill site is underlain by approximately 150 feet of unconsolidated sediments which overlay bedrock consisting of weathered serpentine. The uppermost unit consists of recent marsh deposits including silts, clays, and "meadow mat". This unit is approximately 10 to 15 feet thick within the study area. A series of glacial sediments, consisting of glacial till, and glacial outwash type sands lay directly below the marsh deposits in the wetlands, and are in direct contact with the fill material beneath the landfill. The glacial sediments comprise the Upper Glacial aquifer, which ranges in approximate thickness from 60 to 70 feet within the study area.

The shallow sediments were further characterized during a geotechnical investigation conducted in the fall of 2002 as part of the remedial design for OU1. The investigation confirmed the presence of fine-grained marsh deposits at the northern toe of the landfill, and helped to define a zone of predominantly sandy deposits in the area of the sewer pump station. The fine-grained marsh deposits are thin to non-existent in the sandy zone.

A lower aquifer, known as the Cretaceous aquifer, consists of marine sands, silts and clays, and is also present within the study area. Both of these aquifers contain a number of sub-aquifers. A continuous, leaky, confining unit made up of overlapping glacio-lacustrine clay, glacial till, and Cretaceous clay separate the Upper Glacial and Cretaceous aquifers.

Regional groundwater flow in the recent sediments and the Upper Glacial aquifer is to the north. Regional flow in the Cretaceous aquifer is to the south. Groundwater is present within zero to a few feet of the ground surface throughout most of the study area. Mounding of the water table within the landfill reaches heads as great as 12 feet above mean sea level (msl) resulting in a radial flow pattern in the landfill portion of the Site. Shallow groundwater discharges to the surface waters and wetlands to the north, east, and west of the landfill. In the southerly direction, this radial flow is countered by the regional flow, which is to the north. This results in groundwater deflection back toward surface waters to the east and west. This turning point or deflection point occurs at the south boundary of the site. While data suggests that leachate has impacted groundwater in localized areas just south of the site boundary, the hydrologic head and chemical data indicate that the regional northward flow limits the extent of impact to potentially only several hundred feet south of the site.

The OU1 RI and previous studies have concluded that Richmond Creek and its associated wetlands areas are the local discharge point for the Upper Glacial aquifer, and the Cretaceous aquifer. The Cretaceous aquifer leaks upward to the Upper Glacial aquifer and eventually into Richmond Creek. Over the rest of the site, the Upper Glacial aquifer leaks downward into the Cretaceous aquifer. This results in a complex local flow pattern in the Cretaceous aquifer.

The Upper Glacial aquifer near Richmond Creek is moderately influenced by tidal fluctuations in the creek; however, the influences are not strong enough to reverse flow directions over large areas. Tidal influences in the Cretaceous aquifer are slight and insignificant.

The Brookfield Avenue Landfill generates approximately 95,000 gallons of leachate per day. Approximately 92,000 gallons per day (96.5%) of the leachate currently discharges to the local surface water bodies such as Richmond Creek and associated wetlands (CDM, 1998). The components of the OU1 remedy including the landfill cap, leachate collection system, and barrier wall will effectively (1) reduce the amount

of leachate generated by preventing direct infiltration of rainfall through the landfill and (2) capture and control any remaining leachate that is generated.

1.3.4 Contaminant Nature and Extent

As part of the remedial investigation, screening criteria were developed for chemicals in the various sample media, surface water, sediment and biota. Individual chemicals were identified as significant based on the degree to which their analytical results exceeded their established, respective screening criteria. Wherever possible, chemical-specific established regulatory criteria, known as Standards, Criteria and Guidance Values (SCGs) were used to screen the analytical data. These SCGs are used for comparison with the analytical data to determine the nature and extent of contamination.

Surface Water

In 1994 and again in 1997, as part of the OU1 RI, surface water samples were collected from three surface water sampling stations in Richmond Creek (SW1, SW2, SW3) and two stations (SW4 and SW5) in the drainage channels on the south side of the landfill (see Figure 1-5). In addition, as part of the Fresh Kills Landfill Long Term Monitoring program, IT Corporation (IT) sampled three locations in Richmond Creek (WC 30, WC12 and WC11) (IT, 1994). The OU1 samples were analyzed for volatile organic contaminants (VOCs), semi-volatile organic contaminants (SVOCs) , metals, pesticides and polychlorinated biphenyls (PCBs). One VOC, tetrachloroethene, and seven pesticides, 4,4'-DDE, 4,4'-DDD, Gamma-BHC, heptachlor, aldrin, dieldrin, and endrin were detected at concentrations exceeding the NYS Surface Water Standards. For metals, total metal analyses were performed. Cyanide, copper, mercury, nickel, lead, and zinc were all detected in exceedance of standards. Copper and lead were the most frequently detected above standards. Ammonia also exceeded the EPA-established continuous concentration criteria at four of eight surface water sample locations in Richmond Creek.

During the OU2 RI sampling conducted in 2003, chlorobenzene, copper, mercury, nickel, and lead were all detected in surface water above standards at one or more sampling locations. Figures 1-7 and 1-8 present a summary of this data. Copper was the most commonly detected metal, appearing above the SCG at 12 of 14 sample locations. These five analytes were also detected in landfill leachate and shallow groundwater sampled during the OU1 RI, but at much higher concentrations. This indicates that the Brookfield Avenue Landfill is a potential source of contamination to surface water in OU2. Per the OU1 ROD, this source will be removed via the remedy consisting of a landfill cap, leachate collection system, and barrier wall.

It is important to note that these contaminants have also been identified from other sources such as leachate from the adjacent Fresh Kills Landfill. Over time, the Fresh Kills Landfill has undoubtedly been a significantly larger source of leachate to the Richmond Creek/Fresh Kills estuary, based on its order-of-magnitude difference in size. Prior to the installation of leachate controls in the mid to late 1990s, IT

Corporation (1993) estimated a combined leachate discharge rate from all sections of the Fresh Kills Landfill to the Fresh Kills estuary of 1.45 million gallons per day (mgd). In comparison, the amount of leachate discharging from the Brookfield Avenue Landfill to Richmond Creek has been estimated at 0.092 mgd, or nearly 16 times smaller (CDM, 1998). Further evidence of the potentially greater impact to water quality degradation from Fresh Kills Landfill, compared to the Brookfield Avenue Landfill, is demonstrated in Table 1-1. The table presents the estimated amount (in pounds per year) of select contaminants that were detected in leachate from both landfills, based on the estimated annual leachate generation rates. The five contaminants shown in the table were selected based on the availability of data and are not necessarily indicative of all contaminants found in leachate from both landfills. It should be noted that the leachate controls that were completed at the Fresh Kills Landfill by 1998 have significantly reduced the amount of leachate discharging to the estuary. Furthermore, the impending remedy for OU1 will prevent leachate from discharging from the Brookfield Avenue Landfill.

The OU2 surface water data indicates that Richmond Creek water quality has improved for most of the chemicals detected in the OU1 and OU2 datasets. The mean copper concentration was almost one-half of the mean concentration detected in 1994 and 1997. In addition, several VOCs and pesticides were detected in 1997, but were not detected (with similar detection limits) in 2003. Appendix A.1 presents a summary of the inorganic chemicals detected in surface water at sampling stations in the main branch of Richmond Creek during the OU1 RI, OU2 RI and during the IT Fresh Kills Long Term Monitoring Program over time. As can be seen, the concentration of some metal constituents has also decreased over time.

Also noted in Appendix A (Appendix A.2) is that concentrations of copper, lead, mercury, nickel, and zinc measured at low tide in surface water from IT sampling station 12, located within OU2 limits, generally are higher than concentrations at stations 9, 10, and 11 located in Richmond Creek west of OU2. However, an identical pattern was identified in Main Creek, which like Richmond Creek is a tidal tributary to the Fresh Kills estuary. Main Creek is far distant from Brookfield Avenue Landfill and OU2; therefore the Brookfield Avenue Landfill is not considered a likely source of the contaminants observed in Main Creek. The higher contaminant concentrations in the upper reaches of these two tidal tributaries has been explained by contaminant loadings from leachate from Fresh Kills landfill under the influence of tidal action (IT, 1994). Specifically, the hydraulics of leachate discharge encourages maximum leachate discharge to surface water at low tide. At high tide, these contaminants are pushed to the upper reaches of both Richmond and Main Creeks creating an increasing concentration gradient toward the headwaters of each creek. Although this pattern suggests an upstream source, it is likely to be more a result of tidal action and groundwater/leachate discharge hydrodynamics. It should also be noted that the nickel concentrations at the most eastern (upstream) end of Richmond Creek ranged from about 4 to 20 times higher than at all other downstream Richmond Creek

N
W E
S

Location SW-3			
Parameter	Date	Tide	Conc.
Copper	10/14/03	H	8.5 J
Copper	10/22/03	L	5.6 JN

Location SW-2			
Parameter	Date	Tide	Conc.
Copper	10/14/03	H	15.1 J
Nickel	10/14/03	H	8.3 J
Copper	10/22/03	L	5.8 JN

BKGD.

Background
No Exceedances

SW-1
SW-5
SW-2
SW-3
SW-7
SW-6

Richmond Creek

Location SW-5			
Parameter	Date	Tide	Conc.
Copper	10/14/03	H	11.2 J
Copper	10/22/03	L	8.1 JN
Mercury	10/22/03	L	0.36 J

Location SW-7			
Parameter	Date	Tide	Conc.
Copper	10/14/03	H	16.6 J
*Copper	10/14/03	H	4.4 J
*Nickel	10/14/03	H	12.1 J
Copper	10/21/03	L	6.4 JN
Mercury	10/21/03	L	0.2 J

* duplicate sample

Location SW-1			
Parameter	Date	Tide	Conc.
Copper	10/14/03	H	13.1 J
Copper	10/22/03	L	8.1 JN

Location SW-6			
Parameter	Date	Tide	Conc.
Copper	10/14/03	H	14.1 J
Copper	10/21/03	L	8.6 JN
*Copper	10/21/03	L	12.6 JN

* duplicate sample

Notes:
1. All concentrations ug/l (ppb)
2. All samples collected between October 14-22, 2003

300 0 300 600 Feet

c:\ou2gis\ri_sec4_figs_B.apr SW

CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

DEP

SCG Exceedances in Surface Water

Figure 1-7

N
W E
S

Location SW-B5		
Parameter	Date	Conc.
Copper	10/16/03	12.5 J
Lead	10/16/03	12.9

Location SW-B6		
Parameter	Date	Conc.
Copper	10/16/03	13.9 J
Lead	10/16/03	12.8

Location SW-B4		
Parameter	Date	Conc.
Copper	10/16/03	3.7 J
Chlorobenzene	10/16/03	5.2

Location SW-B7
No Exceedances

Location SW-B3		
Parameter	Date	Conc.
Copper	10/16/03	9.2 J

Location SW-B2		
Parameter	Date	Conc.
Copper	10/16/03	11.9 J
Lead	10/16/03	13.0

Location SW-B1		
Parameter	Date	Conc.
Copper	10/16/03	5.5 J

SW-B6
SW-B5
SW-B4
SW-B7
SW-B3
SW-B2
SW-B1
Richmond Creek

Notes:
1. All concentrations ug/l (ppb)
2. All samples collected between October 16-17, 2003
3. Sample locations are approximate

300 0 300 600 Feet

c:\ou2gis\fs_fig1-8.apr SW-biota locations

CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION DEP

SCG Exceedances in Surface Water at Biota Sampling Locations

Figure 1-8

Table 1-1

Comparison of Estimates of Historical Mass Loading of Select Constituents in Leachate to the Fresh Kills Estuary System from the Fresh Kills and Brookfield Avenue Landfills

Contaminant	Estimated Historical Mass Loading From Fresh Kills Landfill (lbs/year)[1]	Estimated Historical Mass Loading From Brookfield Avenue Landfill (lbs/year)[2]	Approximate Ratio (Fresh Kills to Brookfield) of Historical Annual Contaminant Contribution from Leachate
Chromium	164.0	8.9	18 to 1
Copper	104.2	21.1	5 to 1
Lead	36.0	20.1	2 to 1
Zinc	265.0	48.2	5 to 1
Ammonia	1,291,138	17,616	73 to 1

[1] Leachate analytical and quantity data taken from the *Fresh Kills Leachate Mitigation Project, Final Hydrogeological Report, Vol. I*, Nov. 26, 1993, IT Corporation. Leachate quantity data was based on pre-1993 anaytical results from representative monitoring wells in the shallow, intermediate, and deep zones of landfill sections 1/9, 6/7, 2/8, and 3/4. The total amount of leachate, prior to the installation of leachate controls in the mid to late 1990s, from all Fresh Kills Landfill Sections to the Fresh Kills Estuary was 1.45 million gallons per day.

[2] See table 1-3 for an explanation of how these values were derived.

locations, indicating that the freshwater portion of the creek, as opposed to OU1, may be a source of this metal.

The IT data presented in Appendix A.2 in general also shows that concentrations of these metals in all stations were lower in the year 2000 data than those in the year 1991-1998 data. This indicates that water quality in Richmond Creek has improved following installation of leachate collection system in 1999 at the Fresh Kills Landfill.

The improvement of Richmond Creek water quality may be an indication that leachate collected at Fresh Kills Landfill and the wetlands at OU2 are effective in removing organic compounds and metals. Further improvements would be expected once the Brookfield Avenue Landfill is capped and the remaining leachate is collected.

Sediment
During the initial (OU1) investigation phases, sediment samples showed exceedances of SCGs for tetrachloroethene, several semi-volatile organics, pesticides and PCBs and the metals arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc. For the OU2 RI, sediment samples were taken in the main branch of Richmond Creek, the Sweet Brook and other tributaries east and west of the landfill, and open channel areas of the marsh. In addition, two reference samples were also obtained from two nearby reference sites: Old Place Creek, a tributary to the Arthur Kill, located about 4 miles north of OU2, and Kings Creek, a tributary to the Rahway River located west of OU2. In the OU2 dataset, the most frequently detected metals exceeding criteria were arsenic, copper, iron, lead, mercury, and nickel. Pesticides, PCBs, and some polycyclic aromatic hydrocarbons (PAHs) were also present in sediment at concentrations exceeding SCGs. However, many of these same constituents were found at similar concentrations at the two reference sites sampled during the OU2 RI . Appendix B reproduces Figures 4-3 through 4-10 from the Final RI report which summarize the extent of chemical concentrations in creek and marsh sediment above SCGs for the different sampling depths investigated during the OU2 RI.

Sediment quality improved at depth. The majority of the contamination was found in the first two feet of each boring. However, in a few locations, samples at depths of up to 78 inches contained some elements or compounds at concentrations above SCGs. Within Richmond Creek, no significant differences in the types and concentrations of detected analytes were observed between the southern shore samples (closest to the landfill) and the northern shore samples (farthest from the landfill). However, the larger depths of contamination above SCGs were associated with larger amounts of unconsolidated cohesive sediments measured in the sampling core which differed depending upon whether the sample was located within a deposition or eroding area of the creek.

In general, contaminant concentrations in marsh samples were higher than in Richmond Creek samples. As discussed in OU2 RI, marsh sediment at depths up to 30

inches from sampling locations close to the landfill's west cell (SM 1 and SM 4) contained significantly lower concentrations of metals compared to sediment from sampling locations further north of the west cell (SM 2 and SM3). It is believed that this is due to the depositional environment of the site.

In Appendix A.3, sediment quality in Richmond Creek reported in the OU2 RI was compared to sediment quality reported in two regional investigations and studies in the NY/NJ harbor area. The regional investigations include USEPA Regional Environmental Monitoring and Assessment Program (REMAP) and Contaminant Assessment and Reduction Program (CARP), both of which include sampling sites in Upper and Lower New York Bay, Jamaica Bay, Newark Bay and Raritan Bay. Mean concentrations of cadmium, chromium, and PCBs in sediment samples from OU2 were similar to those found in the two reference sites and the same or lower than those found in the regional studies (REMAP and /or CARP). Conversely, mean sediment concentrations of arsenic, copper, nickel and mercury reported in the OU2 RI were higher than the means from the regional studies (except for mercury in Newark Bay which had similar concentrations to OU2). Again, the nickel concentrations in OU2 sediment were likely due to influences upstream from OU1. However, in general, the sediment quality in Richmond Creek is impacted to the same degree as the NY/NJ Harbor.

Appendix A.4 compares the sediment data from the 2000 Annual Report of Fresh Kills Long Term Monitoring Program (IT 2000) that were taken in Richmond Creek and the Arthur Kill. This data reveals that levels of arsenic, cadmium, copper, chromium, lead, mercury, nickel, zinc, and PCBs detected at station 12 in Richmond Creek (within OU2 limits) were lower than those at stations 9, 10 and 11, further down Richmond Creek, particularly in the 2000 dataset (after Fresh Kills leachate collection systems were in place). However, the quality of sediment in Richmond Creek is better than that in Arthur Kill (which is its receiving body). Significantly, the IT data also shows that at station 12 within OU2 limits, concentrations of arsenic, copper, lead, nickel, zinc, cadmium, chromium, and PCBs were lower in the 2000 data when compared to the 1991 – 1998 data by up to 74 percent. This is an indication that the sediment quality of the Richmond Creek within OU2 is improving.

In summary, these comparisons indicate that the sediment quality of Richmond Creek is consistent with the sediment quality throughout the New York/New Jersey Harbor area. Sampling from locations in the OU2 creek and marsh did not identify any areas of sediment with significantly elevated levels of one or more contaminants that would be indicative of a hot spot or source area. Because the contaminant concentrations in OU2 are relatively similar to those found throughout the region, it strongly suggests that the many other sources of contamination which impact regional sediment quality such as stormwater outfalls, wastewater treatment plant discharges, and other area landfills, are likely to contribute to contamination in Richmond Creek. Through implementation of the OU1 remedy, however, improvements to sediment quality over time are expected due to the reduction in leachate resulting from construction of

the cap and installation of the leachate collection and barrier wall at the Brookfield Avenue Landfill.

Biota

Biota samples were obtained from seven locations in and around OU2 during October 2003 and analyzed for pesticides/PCBs, mercury, cadmium, and copper. Samples were also obtained from two nearby reference sites: Old Place Creek, a tributary to the Arthur Kill, located about 4 miles north of OU2, and Kings Creek, a tributary to the Rahway River located west of OU2. The targeted and collected biota were generally grouped based on size, trophic level, and foraging range as follows:

- Small, sedentary bivalves – ribbed mussel
- Forage fish – mummichog
- Medium and large, migratory fish – striped bass, white perch, American Shad, gizzard shad
- Large reptile – snapping turtle

4,4'-DDD, 4,4'-DDE, Aroclor-1254, copper, and mercury were detected in all biological tissue samples from all OU2 sampling locations including the reference locations. Alpha-chlordane, gamma-chlordane, and cadmium were detected in a portion of samples from all biota groups.

Mean contaminant concentrations in tissues of the ribbed mussel were generally found to be higher in OU2 locations than concentrations detected in the same species collected from the reference site. Mean contaminant concentrations in tissues of the mummichog collected at OU2 locations were found to be within the same range as the concentrations detected in those collected from the reference site. Contaminants detected in tissue of the sedentary ribbed mussel and the mummichog, which possesses a limited home range, are likely to have been consumed at the particular location where they were collected.

Mean contaminant concentrations in the medium and large migratory fish were generally lower at the three OU2 locations, compared to the reference site. Mercury was detected in surface water and sediment at one reference site at concentrations above each of the OU2 sampling locations where detections occurred. Mean mercury concentrations in fish tissue at this reference site were also above those in tissue from the OU2 sampling locations. The medium and large migratory fish may not have spent a significant portion of their life at the location where collected. Contaminants found in their tissue may have resulted from exposure to poor water quality or consumption of other contaminated species at various locations within and/or outside of OU2 and the reference site. Consumption of fish collected from OU2 are evaluated in the human health risk assessment. Potential risks to human health from this exposure pathway are discussed in Section 1.3.6.

1.3.5 Waste Characterization

As part of OU2, ten composite sediment samples for waste characterization were collected. Waste characterization analyses included hazardous waste characteristics testing (Toxicity Characteristic Leachate Procedure (TCLP), corrosivity, ignitability, reactivity) plus physical characterization, including grain size distribution (sieve and hydrometer) and water content. Composite samples were collected from two or three sediment locations and combined into one sample. For each set of composite samples, the material at the same depths was analyzed.

Based on the waste characterization laboratory analytical results, none of these samples exhibit Resource Conservation and Recovery Act (RCRA) characteristics for hazardous waste. No TCLP organics were detected in any of the composite samples collected.

In addition to the TCLP, cyanide and sulfide reactivity tests were all non-detect, no sample showed ignitibility, and pH varied from a low of 6.6 to a high of 7.8. Based on these waste characterization laboratory analytical results, the sediment analyzed is not considered to be hazardous waste.

1.3.6 Human Health Risks

In the Human Health Risk Assessment (HHRA), contaminants in various media in OU2 were quantitatively evaluated for potential health threats to the following receptors:

- Current and future recreational users of Richmond Creek
- Current and future recreational users of marsh adjacent to Richmond Creek and Brookfield Landfill

The estimates of cancer risk and noncancer health hazards and the greatest chemical contributors to these estimates were identified as summarized on Table 1-2. Risks associated with recreational use of Richmond Creek were estimated for adults and children (0 to 6 years), based on assumed incidental ingestion and dermal contact with sediment (from the creek alone) and surface water and ingestion of contaminated finfish and shellfish from the creek. Total reasonable maximum exposure (RME) excess lifetime cancer risks for adult recreational users were 1×10^{-3}, which exceeds the EPA acceptable carcinogenic risk range of 10^{-4} to 10^{-6}. Total RME excess lifetime cancer risks for child recreational users were 3×10^{-4}, which also exceeds the EPA acceptable carcinogenic risk range. This risk is almost entirely due to ingestion of finfish and shellfish taken from Richmond Creek, and mostly due to Aroclor-1254.

Cancer risks for the adult recreational user from exposure to sediment alone were 9×10^{-6}, and cancer risks for the child recreational user were 2×10^{-5} which are within the EPA acceptable risk range of 10^{-4} to 10^{-6}. Cancer risks from surface water to both adult

and child recreational users (6×10^{-7}) were below the acceptable carcinogenic risk range.

The total RME non-cancer hazard index (HI) for Richmond Creek for recreational adults was 86 and the total RME non-cancer HI for children was 87. Both HIs exceeded the EPA's threshold of 1 for non-cancer health hazard, indicating that noncancer health effects may occur from RME exposures to contaminated sediment, surface water and finfish/shellfish from Richmond Creek. As with the cancer risks, these noncancer hazards are almost entirely due to ingestion of finfish and shellfish taken from the creek. When the hazard index is segregated by effects and by mechanism of action to derive separate hazard indices for each group. The hazard index exceeds one for effects to the liver, kidney, central nervous system and skin. Noncancer effects to the kidney were mostly due to cadmium in shellfish. Noncancer effects to the liver were mostly due to heptachlor epoxide concentrations in shellfish. Noncancer effects to the central nervous system were mostly due to mercury in both finfish and shellfish. Noncancer effects to the skin were mostly due to Aroclor-1254 concentrations in both finfish and shellfish. The non-cancer risk due to exposure to Creek sediments alone was 0.1 for adults and 1.0 for the child recreational user. Therefore, the potential for noncancer health effects for adults and children exposed only to contaminated creek sediment is considered unlikely to occur.

The risk estimates due to consumption of finfish and shellfish from Richmond Creek are extremely conservative. The assessment assumes that 100 percent of the recreational-caught fish ingested by an adult and child are obtained from Richmond Creek. This is highly unlikely because even avid sports anglers who only consume fish that they have caught would likely obtain fish from many locations in the New York City area, rather than only from Richmond Creek.

Risks associated with recreational use of the marsh adjacent to Richmond Creek and the Brookfield Landfill were estimated for adults and children (0 to 6 years), based on incidental ingestion and dermal contact with sediment. Total RME excess lifetime cancer risks for adult recreational users were 3×10^{-5} and for children were 6×10^{-5}. Therefore the marsh sediments alone present risks that are within EPA's acceptable carcinogenic risk range. Cancer risks for these receptors were primarily associated with exposure to arsenic in the sediments. It was noted that, due to the greater concentrations above SCGs found within marsh sediments, the cancer risks for both adult and child receptors were about five times greater for exposure to sediments in the marsh versus exposure to Richmond Creek sediments.

The total noncancer HI for recreational adults exposed to sediment within the marsh (0.2) was below the threshold of 1, indicating that noncancer health effects are not expected to occur in adults from exposure to marsh sediments. However, the total noncancer HI for the recreational child exposed only to marsh sediments is 2.0, slightly above the threshold of 1. This HI value is for skin and is mostly due to arsenic within the marsh sediment.

Table 1-2
Human Health Risk Assessment Summary
Brookfield Avenue Landfill
Operable Unit 2

Pathway	RME Carcinogenic Risk	RME Non-Cancer Hazard Index
Ingestion of Fish		
Adult	**7×10^{-4} (7 in 10,000)**	**40**
Child (0 to 6yr)	**1×10^{-4} (1 in 10,000)**	**40**
Ingestion of Shellfish		
Adult	**7.4×10^{-4} (7.4 in 10,000)**	**45**
Child (0 to 6yr)	**1.5×10^{-4} (1.5 in 10,000)**	**50**
Recreational Exposure to Creek Sediment		
Adult	9×10^{-6} (9 in 1,000,000)	0.09
Child (0 to 6yr)	2×10^{-5} (2 in 100,000)	1.0
Recreational Exposure to Surface Water		
Adult	6×10^{-7} (6 in 10,000,000)	0.007
Child (0 to 6yr)	7×10^{-7} (7 in 10,000,000)	0.05
Total Exposure (Recreational +Fish/Shellfish Consumption)		
Adult	**1×10^{-3} (1 in 1,000)**	**86**
Child (0 to 6yr)	**3×10^{-4} (3 in 10,000)**	**87**
Recreational Exposure to Marsh Sediment		
Adult	3×10^{-5} (3 in 100,000)	0.2
Child (0 to 6yr)	6×10^{-5} (6 in 100,000)	**2.0**

RME = Reasonable Maximum Exposure
Bold = Exceeds EPA-acceptable risk range (10^{-4} to 10^{-6} carcinogenic risk or HI = 1)

In summary, the HHRA indicates the potential for both carcinogenic and adverse noncarcinogenic health effects to adult and child recreational users of Richmond Creek, in excess of EPA's acceptable carcinogenic risk range of 10^{-4} to 10^{-6} and HI of 1. These risks are primarily due to consumption of contaminated finfish and shellfish with Aroclor-1254 as the risk driver. Unacceptable human health risks to adults and children due to exposure to surface water were not identified. Unacceptable risks to adults and children due to exposure to creek sediment were also not identified. A hazard index of 2 (considered significant but relatively low) was calculated for children directly exposed to the highest concentrations in marsh sediment.

The calculated risks for fish consumption are likely to be significantly overestimated due to the extremely conservative assumptions applied to this exposure pathway. It was conservatively assumed that 100 percent of the recreational-caught fish ingested by the recreational user are obtained from Richmond Creek, and an adult and a child would consume fish daily for 30 and 6 years, respectively. This is highly unlikely because even avid sports anglers who only consume fish that they have caught would likely obtain fish from many locations in the New York City area, rather than only from Richmond Creek. Regardless, Aroclor-1254, the major risk driver in the fish consumption exposure pathway had a concentration at 95% upper confidence level of 4.27 ppm and an arithmetic mean of 2.5 ppm which are higher than the Food and Drug Administration (FDA) PCB residue tolerance of 2 ppm in fish. Precautionary action should be taken for consumption of fish caught from Richmond Creek.

Extensive fish advisories (issued by the New York State Department of Health) already apply to the Arthur Kill and its tributaries, including Richmond Creek. These advisories are based primarily on contamination with PCBs and dioxin (in finfish and crabs) and cadmium (in crabs) and are unrelated to the Brookfield Avenue Landfill. The presence of fish advisories in Arthur Kill, its tributaries, and other parts of the New York/New Jersey Harbor suggest the fact that the risks identified in OU2, which are almost exclusively related to ingestion of finfish and shellfish, are not unique to this part of Richmond Creek, but would be expected to be similar elsewhere.

1.3.7 Ecological Impacts

1.3.7.1 Step 1 Impact Analysis

A Fish and Wildlife Impact Analysis for Inactive Hazardous Waste Sites (Step 1) was conducted during the OU1 investigation to identify fish and wildlife resources and their habitats surrounding the Brookfield Avenue Landfill site and to observe whether they potentially have been or presently are being affected by contaminants detected in the OU2 study area.

The baseline ecological risk assessment performed for the OU1 RI calculated hazard quotients (HQs) for contaminants found in sediment and surface water at the site. Surface water risks were considered low (HQ < 10) for all detected chemicals except for mercury (HQ = 170) and barium (HQ = 22). However, the HQ of barium from background sampling was 42, indicating that barium was not a site related

contaminant. HQs of all detected chemicals from the Richmond Creek sediment were below 10, except for copper (HQ = 12) and mercury (HQ = 13). Marsh sediment-based risks were low (HQ < 10) for all of the detected chemicals.

Sediment toxicity was addressed during two separate sediment toxicity studies; the first was performed in May of 1994, and the second, which included a whole tissue bioaccumulation study, was conducted beginning January, 1998 (NYCDEP, 1998a). In the first toxicity test, samples were tested for acute toxicity in the fish, *Menidia beryllina*, the sandworm, *Neries virens*, and the grass shrimp, *Palaemonetus pugio* in 96-hour and 10-day flow through exposures. The results of the first set of toxicity testing indicated there was no measurable acute toxicity to the three test organisms. A second round of acute (10-day) toxicity testing was performed on more sensitive species, the amphipod, *Ampelisca abdita*. Amphipod survival after completion of the 10 day tests was between 52% and 59%, however, amphipod densities and abundance have been linked to levels of degradation in the sediments of New York Harbor (Cristini, 1990). The same study reported that the entire Arthur Kill was almost devoid of amphipods. Furthermore, amphipods were rarely found during benthic surveys of the Fresh Kills Study area (IT 1995, 2000).

The 2000 IT report concludes that benthic surveys have consistently found similar species composition, species richness and species diversity for the benthic communities of Main, Richmond and Marshes Creeks indicating that sediment quality is similar in the creeks that drain the landfill area and at another location on an Arthur Kill tidal creek that is not in the vicinity of the Fresh Kills Landfill.

Twenty-eight day chronic sediment toxicity and sediment bioaccumulation tests were performed using the polychaete worm, *Nereis virens,* and the mollusc, *Macoma nasuta*. Polychaete worm and mollusc survival after completion of the 28 day tests were greater than 90%, indicating no toxicity. Results of the tissue analysis on the molluscs and polychate worms after the chronic tests found bioaccumulation of arsenic, cadmium, chromium, mercury and nickel in the molluscs and copper in the worm, indicating that these compounds may bioaccumulate in the polychaete work and mollusks. Pyrene was the only organic which showed increased bioaccumulation compared to the control.

1.3.7.2 Fish and Wildlife Impact Analysis (FWIA)

A Step II FWIA was conducted during the OU2 investigation to determine the impact of site-related contaminants on fish and wildlife resources. The primary receptor groups evaluated in this assessment, the main levels of assessment, and a summary of risks to each group are presented below:

Carnivorous Mammals – Risks to carnivorous mammals were estimated to be insignificant from exposure to all contaminants of potential ecological concern (COPECs) identified for food chain modeling (copper, cadmium, mercury, total chlordane, total DDT, heptachlor epoxide, gamma-BHC, and total PCBs). These

insignificant risks are based on the assumptions that raccoons consume only shellfish (not finfish) taken from onsite locations.

Piscivorous Birds – Potential risks to piscivorous (e.g., osprey and great blue heron) were estimated to be significant only from exposure to total DDT (HQ>10) via food chain models. These risks are due to consumption of contaminated finfish serving as prey.

Benthic Macroinvertebrates – Creek sediment-based risks were considered high (HQ > 10) from exposure to chlordane, endosulfan, mercury, copper, and cadmium. Creek sediment-based risks from exposure to the remaining contaminants of potential ecological concern (COPECs) were low (HQ<10). Marsh sediment-based risks were considered high due to exposure to most of COPECs with mercury, copper and arsenic having the highest HQ (above 50). **Bivalves** Residue-based risks from exposure to all COPECs were considered low risk with HQs below 10.

Fish –Residue-based risks from exposure to all COPECs, except copper, to fish were also considered low risk with HQs below 10. The calculated HQ for copper was 61, considered to be high risk.

Aquatic Biota (fish, water column benthic invertebrates, aquatic plants and larval amphibians) : Risks were estimated to be high from exposure to mercury (HQ=514) in surface water. The remaining COPECs had HQs below 10.

In summary, mercury in creek sediment, marsh sediment, and in surface water, and copper in creek sediment of the Richmond Creek may pose potential risks to aquatic biota. In addition, potential for adverse effects to piscivorous birds consuming fish from the Richmond Creek may also exist due to exposure to total DDT. Considering the similar and often higher levels of COPECs detected in Arthur Kill and other parts of the New York/New Jersey Harbor, similar risks to aquatic biota are expected elsewhere in the waterways of New York/New Jersey.

1.4 Contaminant Fate and Transport

There are three contaminant transport pathways from the landfill (OU1) to surface water and/or sediment (OU2). These are:

- Pathway No. 1—transport of contaminants from waste and soils of OU1 into stormwater runoff and surface waters
- Pathway No. 2—transport of contaminants in shallow groundwater into surface waters
- Pathway No. 3—transport of contaminants in surface waters, including contaminants adsorbed to sediments suspended in surface water.

A number of fate and transport processes act on contaminants as they migrate along these pathways.

Pathway No. 1—Transport of Contaminants from Waste and Soils into Stormwater Runoff and Surface Waters

During rain events, runoff is generated from the site. In isolated portions of the landfill, heavy rain events have resulted in the formation of gullies, especially in the east cells. Some gullies were observed during the OU1 field investigation to be deep enough to expose waste. Runoff coming in contact with potentially exposed waste in these gullies can result in the transport of contaminants found in waste into runoff. Additionally, surficial soil sampling conducted during the OU1 field investigation indicated areas where low levels of contaminants (e.g. PAHs and metals) were present in soils. However, because most of the site is well vegetated and there are only a few isolated areas where gullies are present, this pathway is not expected to be significant.

Dissolved and particulate associated concentrations above SCGs (organic and inorganic) were and still are transmitted intermittently during rain events to the tidal marsh and directly to Richmond Creek. The freshwater wetland and tidal marsh area promote settling of particulate associated contamination. The laminar flow of surface water in wetlands helps to settle particulate matters. In addition, mats of floating plants serve as sediment traps and limit resuspension of settled particulars.

The fate of metals in aquatic systems depends on partitioning between soluble and particulate solid phases. These processes are governed by pH, oxidation-reduction potential (Eh), ionic strength of the water, concentration of the complexing ions, and the metals concentration and species. Sediments in wetlands such as those in OU2 play a significant role in the fate of metals. For example, wetlands can filter and accumulate heavy metals. Most metals, such as copper and mercury, which were detected in Richmond Creek, form insoluble sulfides that adsorb onto clay, organics, and precipitate in the sediments.

Built on the floodplain of Richmond Creek, Brookfield Landfill is dissected by tidally and stormwater influenced drainage channels which receive runoff from residential areas found south and east of the site. Non-point source contaminants carried in stormwater from offsite can concentrate in sediment deposition areas where the stormwater drops the suspended sediment load. The drainage channels also act as conduits for transporting contaminants originating from the landfill as a result of stormwater runoff and soil erosion.

The transport of contaminants from waste and soils into stormwater runoff and surface water pathways will be eliminated by installation of the part 360 cap specified in the OU1 ROD.

Pathway No. 2—Transport of Contaminants in Shallow Groundwater into Surface Waters

Shallow Groundwater Flow

Infiltration of rainwater through the unsaturated zone to the shallow water table is fairly rapid in areas where meadow mat and recent silt and clay are absent. Groundwater flow within the fill material is dominated by hydraulic mounding within the landfill mass and the resulting hydraulic gradient. Overall, groundwater/leachate flow radiates from the topographically high fill areas of the east and west cells outward, toward surface water features, including drainage channels, ponds and wetlands.

Underlying shallow lenses of low permeability meadow mat and recent silt and clay retard the vertical flow of water where they are present, such as wetlands at the OU2. These lenses promote horizontal flow and result in the formation of both temporal and permanent bodies of standing water in topographically low areas and seepage flows to drainage channels. In areas where the low permeability sediments are absent, groundwater/leachate from the fill may continue downward into the Upper Glacial aquifer flow system if permeable glacial sands underlie the fill areas.

Tidal fluctuations in groundwater levels will increase dispersion of contaminants. As documented in the OU1 RI, tidal fluctuations have the most impact on groundwater levels closest to the creek, and very minimal impact on groundwater levels within the landfill. However, wetlands at OU2 can slow the tidal floodwater momentum and reduce tidal fluctuations in groundwater levels. Typical fluctuations within the landfill due to tide are on the order of 0.1 to 0.2 feet.

Chlorinated VOCs generally have a low solubility but are relatively mobile in groundwater. Volatilization is the predominant fate for these compounds. Chlorinated VOCs usually undergo biotransformation in the environment but rarely decompose entirely during biodegradation processes. As a result, these compounds likely travel through the shallow groundwater and discharge to Richmond Creek. 1,1,1-Trichloroethane and chlorobenzene were detected at concentrations less than 10 µg/l in the surface water during the OU2 investigation. Similar concentrations of these and other chlorinated VOCs were found in the Upper Glacial aquifer during OU1 and very low concentrations were found in the deep (54-78 inch) sediments from the creek in OU2. Dispersion within the groundwater and surface water and sorption onto organics and fines within the deep sediments especially in wetlands are the primary mechanism for concentration reduction.

The petroleum related VOCs, (benzene, toluene, ethylbenzene, xylene (BTEX)) follow the same pathways as the chlorinated VOCs, volatilization also is the dominant fate of these compounds. These compounds are also prone to biodegradation, especially in wetlands such as those in OU2 which are rich in microbes. Retardation will limit the transport of these compounds in the shallow aquifer offsite. Even though several areas of these compounds were located within the soils and leachate wells during the

OU1 studies, the Upper Glacial groundwater data showed very low concentrations. BTEX compounds were detected in a few surface water samples at concentrations less than 5 µg/l during the OU2 investigation and were also found at low concentrations in some shallow and deep creek and marsh sediment samples. The low levels of BTEX detected in surface water and sediment samples may be evidence of the functionality of the existing wetlands, such as biological and chemical removal processes taking place at wetlands in OU2.

Other VOCs that have been detected within the landfill at significant concentrations include 2-butanone and chloroform. Both of these compounds are highly soluble and considered highly mobile in the groundwater system; however, both are also highly susceptible to biodegradation. Neither compound was detected in surface water during the OU2 investigation; however, 2-butanone was found in shallow sediment samples, particularly in the marsh.

Although a number of SVOCs, pesticides and PCBs (Aroclors) have been detected in groundwater, these detections have been limited to the shallow aquifer at the perimeter of the landfill. This observation is consistent with their characteristics of being slightly mobile to immobile in the groundwater system. This is due primarily to adsorption to the aquifer sediments as those in wetlands. They exhibit very low biodegradation potential and will not undergo significant dispersion due to their tendency to sorb to the aquifer materials, especially those in wetlands. As a result these compounds will be very persistent in aquifer sediments but not highly mobile in the onsite groundwater. Low concentrations of SVOCs, pesticides and PCBs were found in both shallow and deeper sediment samples throughout the marsh and creek.

As discussed in Section 5.2.1.2 of the RI, the mobility of metals and other inorganic species will be dependent on a number of processes, including mineral dissolution, precipitation, bioaccumulation, complex formation and redox reactions. Leachate is high in dissolved metals. During the formation of leachate, organic matter decomposing under aerobic conditions produces carbon dioxide which combines with the leaching water to form carbonic acid. This, in turn, reacts upon metals in the refuse significantly increasing concentrations of the reacted metals within the leachate. Wetlands such as those in OU2 enhance these chemical, physical, and biological processes and immobilize metal contaminants via adsorption and precipitation to transfer ions from solution phase to solid phase. Furthermore, sediments in wetlands will also filter and accumulate metals. Marsh vegetation in wetlands also stabilizes the sediments, allowing formation of the anoxic environment required for deposition of heavy metals-sulfide complexes.

Iron and manganese concentrations vary widely within leachate samples but appear to be well in excess of natural background conditions expected for groundwater and surface water. These two elements are generally rich in wetland sediments. Due to the reducing nature of the landfill environment, the more soluble reduced forms of these metals are present within the leachate and groundwaters immediately

downgradient of the landfill. However, as leachate impacted groundwater returns to ambient oxygen levels (increased redox potential) these metals will precipitate out of the groundwater in the form of oxide and hydroxide minerals. This reduction in iron and manganese concentrations will occur when leachate discharges to Richmond Creek or to the ground surface through seeps. This oxidation of iron and manganese is most evident around leachate seeps, where dark brown to red precipitates cover the landfill surface.

As with iron and manganese, but at a significantly lesser degree, heavy metals can be found at elevated concentrations in leachate since they are in a more soluble reduced form. Additionally, due to the large amount of organics and inorganic solutes in leachate, heavy metals may be more concentrated due to complex reactions. Despite the increased concentrations of heavy metals within the leachate, most heavy metal species are relatively immobile at or near the landfill. This is supported by the fact that though high concentrations of lead, chromium, cadmium, copper and other heavy metals were documented within the leachate, significantly lower concentrations of these metals were identified within Richmond Creek surface water.

The relative immobility of heavy metals within the landfill leachate/groundwater system can be attributed to the following factors:

- Very low solubilities of heavy metal species;
- Transition of low redox to high redox at landfill edge precipitate metal oxides, and oxyhydroxides out of groundwater; and
- Mobility of most heavy metals decrease further at typical groundwater pH's of 6-7.

Implementation of the OU1 remedy, which includes a cap to prevent infiltration, a slurry wall to prevent groundwater and leachate migration, and a leachate collection system, will effectively eliminate this pathway.

Pathway No. 3—Transport of Contaminants in Surface Waters, Including Contaminants Adsorbed to Suspended Sediments

The surface water features which affect the distribution of contaminants originating from the landfill include: stormwater runoff, drainage channels, ponds where runoff and leachate collect, and the receiving waters of the Richmond Creek estuary. All of these surface water features play a role in the distribution of concentrations above SCGs. In addition, several physical characteristics affect the transport of contaminants in surface water, including circulation patterns, flushing time, settling and resuspension, tides, salinity, and grain size. These characteristics are discussed in Section 1.5 below, Site Conceptual Model. As indicated above, implementation of the OU1 remedy, specifically the cap, will remove any source of contamination to OU2. The processes described in the Site Conceptual Model have influenced the

distribution of concentrations above SCGs and will influence the response of the system after removal of the OU1 sources.

1.5 Site Conceptual Model

The evaluation of the existing data, presented in the previous pages, provides a starting site conceptual model for the OU2 remediation. However, since the OU2 investigation focuses on Richmond Creek it is also important to understand the dynamic nature of the creek. The following sections discuss the nature of the Richmond Creek Estuary, and complete the site conceptual model.

1.5.1 Richmond Creek Estuary

The Brookfield Avenue Landfill is located along the south shore of Richmond Creek, immediately downgradient of the freshwater segment of Richmond Creek. Richmond Creek is tidal adjacent to and upstream of the landfill property up to the dam at St. Andrew's Church. Downstream of Brookfield Avenue Landfill, Richmond Creek joins with Main Creek (from the north) and enters Fresh Kills Creek. Fresh Kills Creek empties into the Arthur Kill.

The tidal portion of the Fresh Kills/Richmond Creek/Main Creek system is classified as an estuary. The term estuary is used to describe "a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with freshwater derived from land drainage" (Pritchard 1967). Pritchard defines four types of estuaries based upon physical characteristics and geologic setting: drowned river valley (coastal plain estuaries), fjord, bar-built, and tectonic. Coastal plain estuaries were formed by the flooding of river valleys following a rise in sea level over geological time. Coastal plain estuaries are shallow and sedimentation rates are low, so that the ancient river valley still determines the estuarine topography. Bar-built estuaries are drowned river valleys with a high sedimentation rate. They are typically very shallow, and often branch out towards the mouth into a system of shallow waterways. The sediment accumulates near the mouth of the estuary and forms a bar, where the water depth decreases even further. Bar-built estuaries are common in the subtropics and tropics but can occur wherever the coastal zone is characterized by deposition of sediment. The entire Fresh Kills/Richmond Creek/Main Creek estuary system most closely resembles a coastal plain estuary. However, due to the large sediment source of the Fresh Kills and Brookfield Landfills and the barriers to flow presented by Richmond Avenue, which crosses the creek just west of the OU2 site, the Richmond Creek portion of the estuary system possesses some characteristics of a bar-built estuary. While Richmond Avenue has been constricting flow from OU2 for a long period of time, it is shown on the 1895 USGS topographic map as a series of bridges crossing the marsh and creek of the area.

Estuaries may be further defined based on salinity of the system (Chapman 2001). Classification is based upon the relationship between fresh and saltwater. There are

effectively three types of estuaries based on salinity regime: salt-wedge, partially mixed systems, and vertically homogeneous (Chapman 2001).

Salt-wedge estuaries are characterized by a freshwater/saltwater interface located near the mouth of the estuary. The saltwater is in the form of a wedge, with low salinity water located on top of and upgradient of the saltwater. Salt-wedge estuaries are characterized by a large river flow compared to the tidal flow. The wedge forms when the freshwater flows seaward and encounters the denser seawater. Salt-wedge estuaries tend to be narrow, which has the effect of decreasing the tidal prism (or total volume of water introduced by the tide) for a given tidal range compared to a wide estuary.

Partially mixed estuaries have a greater tidal influence (compared to river influence) than highly stratified estuaries. The tidal influence causes the water within the estuary to oscillate, which has the effect of introducing a large amount of energy into the system. The energy is dissipated within the estuary by working against frictional forces on the bottom. The resulting turbulence works against the density gradients, producing partial mixing.

Vertically homogenous estuaries are characterized by very strong tidal influences compared to river flow and a high width to depth ratio. Like the partially mixed estuary, the tidal energy is dissipated by friction with the bottom. However, in the vertically homogenous estuary, a greater proportion of the bottom is in contact with the water (due to the high width to depth ratio), resulting in greater turbulence and more thorough mixing. With its limited drainage area and high width to depth ratio, the Fresh Kills/Richmond Creek/Main Creek estuary system is most accurately defined as a vertically homogenous estuary. Tidal influences throughout the system are much stronger, compared to river flow. An exception to this is during infrequent heavy storm events, when stormwater runoff significantly increases freshwater input, reducing the relative impact of the tides.

1.5.2 Estuarine Marsh

The southern portion of the OU2 study area is classified as a tidal or estuarine marsh. Marshes are defined as sediment sinks having shallow depth, thick sediment layer, vegetation, and limited water circulation. Conditions are often reducing or anoxic. Marshes are affected by tides to a lesser extent than the adjacent water body. Salinity may also vary significantly within a marsh, based on variable and limited circulation.

1.5.3 Richmond Creek Hydrodynamics

The hydrodynamic conditions of the creek have been the focus of a number of studies in the past, including the *Richmond Creek Drainage Plan* (NYCDEP, 1997) and the *Final Surface Water and Sediment Investigation Report -Fresh Kills Leachate Mitigation System Project* (IT Corporation, 1993). Because of the existing information, no additional field studies were performed as part of the OU2 RI, or the OU1 RI, other than the completion of a bathymetric survey of Richmond Creek, within OU2. The

bathymetric survey was completed primarily to provide information for the FS portion, although it does provide insight into the tidal nature and flushing.

1.5.3.1 Tides and Salinity

Tidal range in the Arthur Kill is 4.2-6.4 feet and tidal currents are less than two knots. Salinity values range from 17 to 27 parts per thousand (ppt) at the southern end of the Arthur Kill and exhibit a very gradual decline northward with a rising trend nearing Newark Bay. Salinity differences between surface and bottom layers are slight due to tidally induced vertical mixing.

Tidal fluctuations in Richmond Creek were monitored for two periods during the OU1 field investigation study: July 1994 and April 1-5, 1996. The April 1996 data were collected during a new moon when the greatest or spring tides occur. On April 2, 1996, 0.83 inches of rainfall were recorded onsite. The July 1994 data was collected during the second quarter when the lowest or neap tides occur. During spring tide, the tide range was 5.0 feet. During neap tide, the tidal range was 4.8 feet. The average tidal period was 12.2 hours.

The water depths observed during OU2 field investigation at low and high tides were 2.5 feet and 4.5 feet respectively, upstream at sampling location SW-1; and were 1.5 feet and 6.0 feet downstream at sampling location SW-7, which is close to Richmond Avenue. These observations are consistent with mean high water (5.5 feet) and mean low water (0.25 foot) data obtained from National Oceanic and Atmospheric Administration (NOAA) for Port Reading, Arthur Kill, which is about two miles downstream from the Richmond Creek OU2 study area (NOAA, 2005).

During OU2 RI, a bathymetric survey was conducted in Richmond Creek. The data was contoured to produce a bathymetric contour map (Figure 3-4 of the OU2 RI). (CDM, 2005). The bottom elevation of the Richmond Creek varies from 1 foot MSL upstream in the meander area to less than -1 foot MSL downstream near Richmond Avenue. Combining the bathymetric information with the NOAA tidal data results in estimated water depths near the Richmond Avenue Bridge of less than 6.5 feet at high tide and about 1.5 feet at low tide (USFSW, 2005).

1.5.3.2 Freshwater Flows

Freshwater inputs cause a net flow out of this segment of Richmond Creek in a westward direction. These flows include base stream flow from the freshwater segment of Richmond Creek, stormwater runoff flows, and groundwater seepage directly into the creek.

The groundwater baseflow from the freshwater portion of Richmond Creek is approximately 1 cfs (NYCDEP, 2005; Soren, 1988). This estimate is based on Soren's observations from 1962-1968. Since the period between 1962 and 1966 was considered a drought, this is probably a low estimate. As previously discussed, the baseflow from groundwater to Richmond Creek was estimated at between 0.64 to 1.8 cfs from

the Richmond Creek EIS (NYCDEP, 1997). During storm events, flows over the weir at St. Andrews Church are significantly higher. The flow from a 3-month storm is estimated to be 77 cfs and for a 1 year storm is estimated at 212 cfs (NYCDEP, 1997).

Groundwater seepage directly into the creek from the OU1 landfill was estimated at 0.12 cfs using the site groundwater model developed during the OU1 RI.

1.5.3.3 Outfall Estimated Storm Flows

Storm flow associated with the Sweet Brook drainage basin, which lies to the south and west of the Brookfield Avenue landfill, is significantly greater than flow from the Richmond Creek drainage basin. The Sweet Brook drainage basin is almost entirely residential, therefore, the amount of impervious surface is high, as compared to the Richmond Creek drainage basin, which is approximately half residential and half parkland. Runoff from the Sweet Brook drainage basin is channeled into a large storm sewer which runs along Abingdon Avenue. The storm sewer passes under Arthur Kill Road, and empties into Richmond Creek via the large triple box culvert north of the Eltingville Pump Station. Storm flow from the Sweet Brook basin is estimated to be 479 cfs for a one year storm event (NYCDEP, 1999). The scouring of the creek bottom in this branch of Richmond Creek and extending downstream to under the bridge at Richmond Avenue indicates that the Sweet Brook drainage provides the largest source of surface water to this portion of Richmond Creek.

1.5.3.4 Flushing

The flushing time, or mean detention time, is the mean time that a particle of a pollutant tracer remains in the Richmond Creek segment. The flushing time was estimated from the fraction of freshwater method (USEPA, 1982). This method assumes that as freshwater inflow enters the creek segment an equal amount of estuary water is discharged and that this freshwater flow is the primary flushing vehicle. Some of the assumptions used in this method are:

- uniform salinity throughout the segment;
- during each tidal cycle a volume of water equal to the river discharge during one tidal cycle is moved through each segment, displacing the same amount of water;
- the water in the segment is completely mixed instantaneously following displacement; and localized stagnant areas are not considered to exist.

Flushing time was estimated for the span of Richmond Creek east of Richmond Avenue and west of the weir. This portion of the creek was divided into four segments based on salinity measurements taken at OU1 surface water sampling stations SW-1, SW-2, SW-3 and SW-5. Salinity for these locations ranged from 5.8 ppt to 16.1 ppt. Freshwater discharge was estimated at 3,600 cubic feet per hour (1 cfs), assuming dry weather flow. Volume calculations of each segment were computed

based on mid-tide area and depth estimates. Flushing time was calculated for each segment then totaled for the entire span. Based on this approach, flushing time for the Richmond Creek segment was estimated to be between three and four days, assuming dry weather conditions. Depending on the intensity and duration of a particular storm event, this value may be reduced by up to a factor of ten, during wet weather flows.

1.5.4 Sediment Stability

Investigators have found that the vast majority of the contaminant distribution within estuaries can be explained by evaluating suspended particulate matter and sediment erosion and deposition patterns. The deposition/erosion of sediments is controlled by the following:

- Energy of the environment
- Salinity
- Turbidity of the river flow
- Impacts to the system (storms/drought conditions, dredging, releases)

The following sections describe these processes in greater detail.

1.5.4.1 Energy Environments

High-energy environments within an estuary result in suspension of sediment while sediments are deposited within low-energy areas. The tidal cycles have an important influence on sediment transport and deposition. During ebb tides, sediment is suspended and carried seaward while during flood tides sediments are suspended and carried landward. Marine sediments can be carried into the estuary and mixed with land-derived sediments during the flood tide.

Other high-energy environments include areas where the estuary narrows, such as where constrictions such as bridge abutments force the tides through a smaller cross sectional area.

High winds can increase the energy of otherwise stagnant bodies of water, resulting in re-suspension of sediment especially in shallow estuaries.

Low energy environments include marshes, holding ponds, lagoons, and embayments. Deposition of sediment can occur following the flood and ebb tides during periods of slack water.

During periods of low tide, the water within marshes can be isolated from the rest of the estuary, resulting in a very low energy environment. Tidal flats and salt marsh areas above the high tide line can be inundated during storms and during spring tides; however, under normal conditions, these areas are stagnant and poorly drained,

which often results in hypersaline conditions and even the precipitation of salts and metal sulfate minerals due to evaporation (Borrego, 2002).

1.5.4.2 Settling Energy and Salinity Effects

Salinity can have a major impact on the suspended sediment load within estuaries, as well as on the deposition of contaminated sediment. Suspended particles with a specific gravity greater than water (>1 gram per cubic centimeter [g/cm^3]) would be expected to settle out. The repulsive forces between negatively charged particles lessen settling. Adsorption of positively charged ions from high-salinity seawater can neutralize the surface charge on the particles, alternately increasing settling.

1.5.4.3 Turbidity

Normally, the sediment load from the upstream river (or creek) and stormwater inflows are the primary source of sediment into an estuary. However, for the Brookfield Avenue Landfill OU2 site, additional sources of sediment loads are the currently uncapped Brookfield Avenue and Fresh Kills landfills. The Brookfield Avenue Landfill currently has a well vegetated cap but it was a source of sediment runoff during its active period. The Fresh Kills landfill cells closest to OU2 (cells 2/8, 6/7, and 3 /4) are fully capped and closed. However, further to the west, Fresh Kills cells 1/9 are still undergoing closure. Suspended solids eroding from these cells into Fresh Kills creek can be brought into the OU2 portion of Richmond Creek on the flood tide or during storm events.

In addition, the Arthur Kill undergoes continuous maintenance dredging to keep the channel open to depths of –35 feet msl for harbor transportation. Suspended solids released during this maintenance dredging could also be transported to the OU2 portions of Richmond Creek during flood tides or storm events.

Even when Brookfield Avenue and Fresh Kills landfills are capped, the maintenance dredging of the Arthur Kill will be continued providing a continual source of suspended sediment that may be transported upstream to Richmond Creek at flood tide.

1.6 Summary of the OU1 Remedy

As a result of the OU1 RI/FS, NYSDEC selected feasibility study Alternative 2B consisting of capping with active gas collection, leachate collection and a groundwater barrier wall. The remedy provides source control that will meet SCGs, be protective of public health and the environment, and serve to reduce future impacts to Richmond Creek and the marsh (OU2).

In the past decade, four other New York City Landfills were also investigated and closure plans were prepared. Three of the landfills, Edgemere, Pennsylvania Avenue, and Fountain Avenue are located along the shoreline of Jamaica Bay. The fourth, the Pelham Bay Landfill, is located in the Bronx, at Pelham Bay Park. The remedial measures selected for these landfills were generally limited to capping and gas

collection. At the Fountain Avenue Landfill, a leachate collection trench was deepened. At the Pelham Bay Landfill, a barrier wall was constructed to prevent offsite groundwater from migrating onsite. Although all four landfills are adjacent to the waterways of New York City, sediment management (i.e. dredging or capping) was not performed, except in a small area adjacent to the Pennsylvania Avenue Landfill where PCBs were found to be discharging from the landfill.

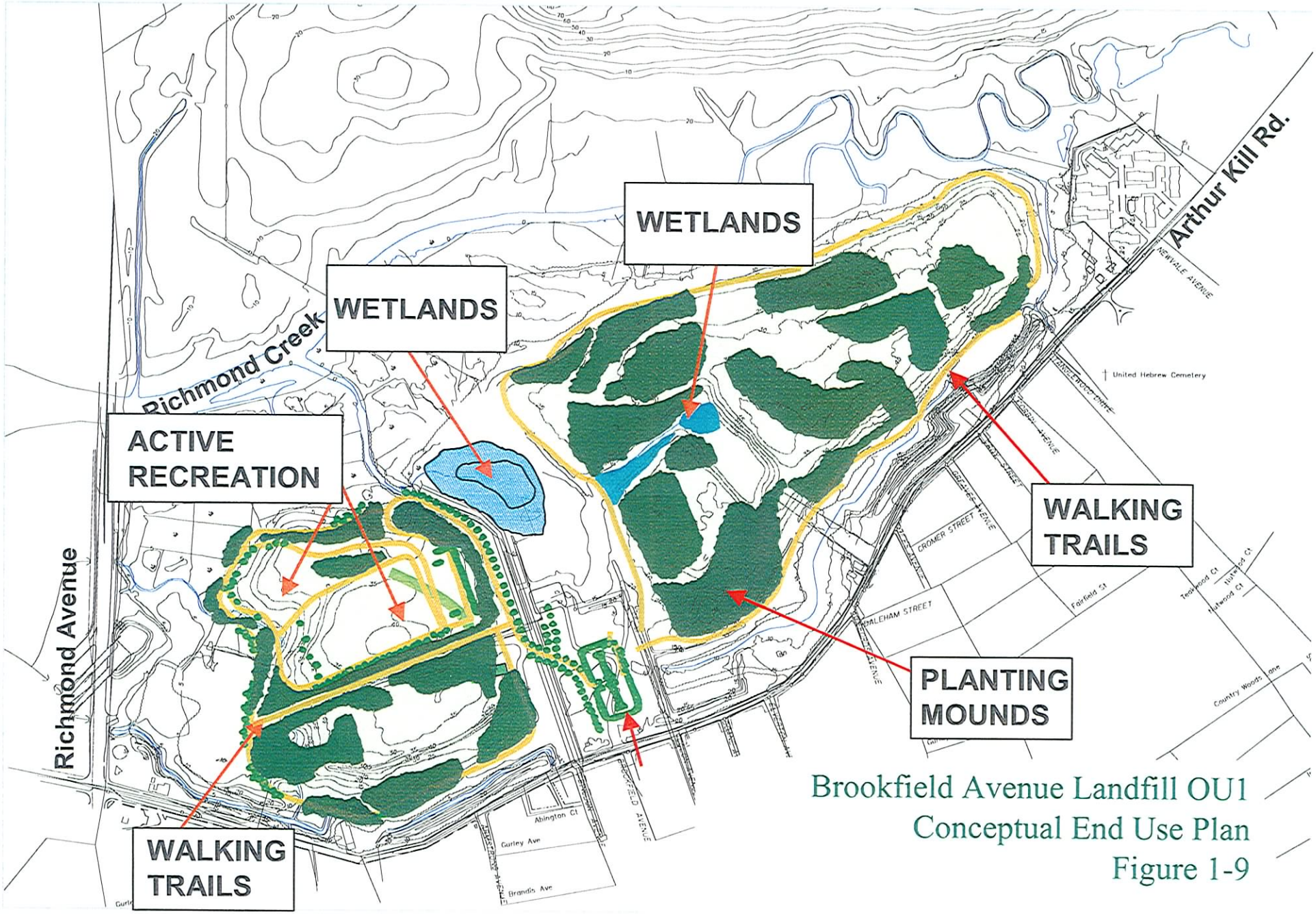
The End Use Plan for the OU1 site is presented below. Following this, the engineered aspects of the End Use are described, including the potential impacts of the engineered remedy on OU2.

1.6.1 End Use Plan

The End Use Plan for the Brookfield Avenue Landfill provides a unique opportunity to establish native plant communities, and to provide both active and passive recreational uses following the site capping and closure construction. It provides opportunities for community education, protection and replication of natural resource areas and when completed will be a community asset. An illustration of the End Use Plan is provided in Figure 1-9.

A subsurface barrier wall will be constructed around the entire landfill area containing waste. All of the landfill areas within the barrier wall will require the removal of existing vegetation, regrading, and installation of a cap. Above the cap a protective cover layer and fill to accommodate revegetation will be placed. In general, the depth of cover above the cap for plant communities will transition from a minimum of 1.5-feet to a maximum of 4-feet. The portions of the site outside of the barrier wall, where no waste was detected, will be treated by selectively removing exotic plant species and adding new plant materials to strengthen existing plant communities. New plant materials will also be added in disturbed areas resulting from construction of the barrier wall and regrading required for landfill drainage. These areas include wetlands, woodlands and stream corridors between Arthur Kill Road and the southern edge of the landfilled areas, and the tidal salt marsh between Richmond Creek and the northern edge of the landfill. A large list of native plant communities are proposed for revegetating capped landfill areas including: Atlantic white cedar, red maple and sweetgum, pitch pine oak and oak holly, coastal shrubs and grasslands, freshwater wetlands and ponds. In addition, a large portion of the north side of the East Cell will be revegetated with new woodland planting extending the existing woodland and reclaiming natural resource areas lost during landfill operations.

The End Use Plan for the Brookfield Avenue Landfill provides for a formal park entrance in the central area of the site at the intersection of Arthur Kill Road and Brookfield Avenue. Paved parking for approximately 30 vehicles will be located off the main entrance road and south of the Eltingville Pumping Station. This will serve visitors utilizing the extensive pedestrian trail system on both the East and West cells. Several wetland areas/stormwater detention basins and wet meadow interpretive



Brookfield Avenue Landfill OU1
Conceptual End Use Plan
Figure 1-9

areas could offer public educational opportunities. The main entrance road will also provide access to the Eltingville Pumping Station and the proposed landfill gas flare compound and leachate treatment facilities. Further north of the maintenance compound will be a wetlands area and detention basin that will emulate the existing wetlands. Stormwater from other areas of the site will be directed to the wetlands/detention basins. Ultimately, stormwater will flow from the detention basins/wetlands toward Richmond Creek. Waste in the central area will be capped in place. Clean fill will be placed to define the new wetland/detention basins and establish new wetlands.

The two distinct mounds of the West Cell provide a unique opportunity to separate active and passive recreation areas while providing common parking and access to both. Under this plan, the active recreation areas will be focused on the north mound of the West Cell. The existing topography also offers the best location for development of future athletic fields, which require large areas with minimum change in elevation. The active recreation area will accommodate up to three full size soccer fields.

The passive open area will be focused on the south mound of the West Cell. This area would not require a future automatic irrigation system. Turf areas will be planted with low maintenance grasses capable of withstanding low impact recreation activity. Trails will provide access to the passive areas but will not be paved.

Consistent with the End Use Plan, the wetland and woodland buffer area between Arthur Kill Road and the landfill would be upgraded by means of selective removal of exotic and invasive plant materials and replanting to enhance the indigenous plant communities. Stream banks in this area may require some reshaping to allow these plant communities to become fully established.

The primary goal of reuse on the East Cell will be to reclaim the natural vegetative character of the site that will be removed during the capping phase of the project. The end use plan will retain the three ponds as wetland/detention areas, providing a separate pond liner system while allowing the landfill drainage layer to pass beneath the wetland areas. The two ponds located on the perimeter of the east cell will be retained in the same location and at roughly the same elevation. Due to minimum capping requirements the pond located on the interior of the east cell will be raised to a slightly higher elevation to accommodate the landfill capping system. A surface swale designed with a natural appearance will direct stormwater from the interior wetland to the lower wetland on the west perimeter. Drainage will then pass beneath the perimeter service road into the stormwater detention basin/wetland in the Central area.

Following construction of the cap, the eastern landfill mound would be revegetated with plant materials indicated in the native plant communities list, above. Large open areas of warm season grasses and shrub land would be planted to contrast and

complement the areas that are reforested. Along the northern side of this area, planting on the cap would attempt to match and expand the existing woodland area. The higher elevations and long views and vistas on the eastern mound would be enhanced to provide observation points and opportunities for historical markers/interpretive signs linked by over 4.5 miles of hiking/interpretive trails and unpaved service roads, leading across the site and back to the central part of the site.

Facilities (such as canoe launches or boat ramps) that would encourage active use of Richmond Creek are not part of the End Use Plan. Additionally, signs noting the regional fish advisories will be posted to discourage consumption of fish caught in Richmond Creek.

1.6.2 Barrier Wall and Capping of Brookfield Avenue Landfill

The engineered components of the OU1 remedy are shown on Figure 1-10 and are discussed below:

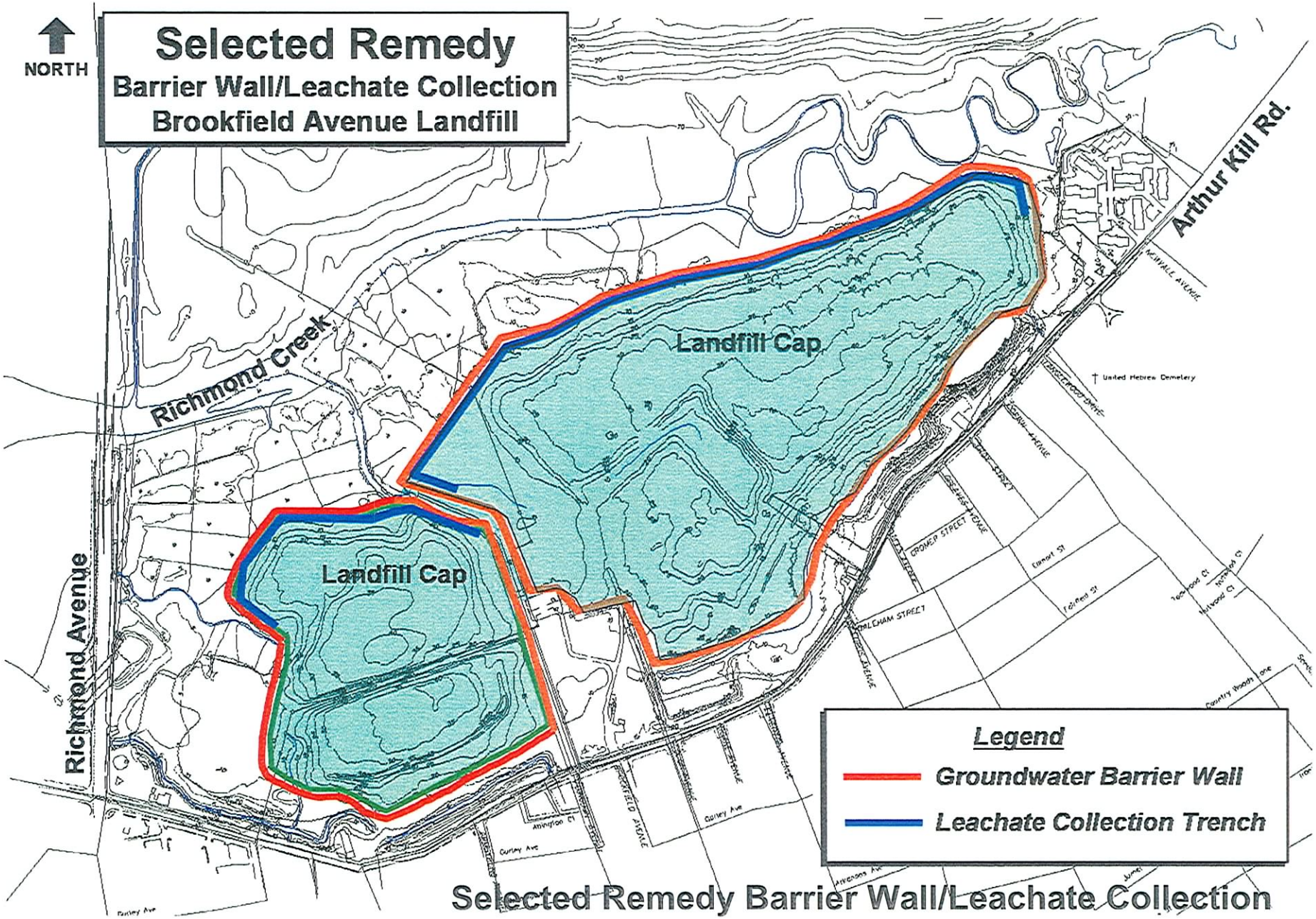
- Construction of a 127 acre Part 360 landfill cap, featuring a gas venting layer, synthetic membrane barrier layer, 12"-24" or greater soil barrier protection layer and vegetated topsoil layer. There will be two final cover system profiles, the basic design for the majority of the waste cells and a composite liner system profile where 1% minimum slopes will be used for the wetland detention areas.

- Construction and operation of an active gas collection system, conceptually consisting of a series of perforated pipes set in gravel wells beneath the landfill cap. Landfill gas will be extracted from these wells via blowers to an enclosed flare for combustion.

- Installation of a soil-bentonite barrier wall, minimum 3-foot thickness, and maximum depth of 40 feet below ground surface, around both the east and west cells of the landfill. The design will isolate the box culvert foundation in the center of the OU1 site and allow north-south ground water movement within the box culvert corridor.

- Construction of a surface water collection system where stormwater will be allowed to naturally flow along the landfill cap in areas where vegetation and slope gradient provide protection against erosion. Otherwise, the stormwater will be collected on the landfill cap using a series of cap swales, down chutes and rain gutters, which will direct the stormwater runoff directly into the adjacent wetland area or into one of, or a combination of five wetland detention areas, for ultimate discharge into Richmond Creek.

- Construction of a leachate collection trench along Richmond Creek and pretreatment system. Leachate control will consist of passive collection within the landfill cells in a stone-filled trench located inside the barrier wall along



Selected Remedy Barrier Wall/Leachate Collection
Figure 1-10

the northern side of the landfill. The leachate will flow to collection sumps where it will be pumped through a force main to an oil/water separator and then flow by gravity into Eltingville Pumping Station where it will be pumped to the Oakwood Beach Water Pollution Control Plant for treatment.

1.6.3 Expected Benefits of OU1 Remedy on OU2

The above-described OU1 remedy is a necessary source control measure that is critical to the effectiveness of any OU2 remedial goal. It will physically address and minimize landfill contaminant migration to OU2 via groundwater and surface water transport and overland flow of contaminated particulates. EPA's *Contaminated Sediment Management Strategy* states that generally, significant continuing upland sources should be controlled to the greatest extent possible before a sediment remediation strategy can be implemented. As a result of the OU1 remedy:

- Brookfield Avenue Landfill capping will prevent further contaminant migration to the marsh and Richmond Creek through runoff. Contaminated soil and waste material in and on the Brookfield Avenue Landfill will no longer be transported into Richmond Creek and marsh via overland flow. As a result of the OU1 remedy, the soils and waste materials will be included under the extensive landfill cap and rain water will flow over the landfill cap (in areas where vegetation and slope gradient provide protection against erosion) or collected and directed directly into the Richmond Creek wetlands or into wetland detention areas, for ultimate discharge into Richmond Creek.

- Active leachate collection and below-grade barrier wall installation will achieve source control. Approximately 92,000 gallons per day of leachate that currently enters Richmond Creek and marsh will be collected and processed through the sanitary waste network.

- OU1 wetland restoration will provide a high-quality habitat for fish and wildlife. The wetland and woodland buffer area between Arthur Kill Road and the landfill will be upgraded by means of selective removal of exotic plant materials and replanting to enhance the indigenous plant communities. Stream banks in this area will be restored to allow these plant communities to become fully established. This will serve to improve surface water quality before it enters Richmond Creek.

- Landfill gas (included methane, carbon dioxide, ammonia, and other organic gases) created during waste degradation will be collected and removed from the waste beneath the cap. This will divert gas from dissolving into the groundwater and surface water surrounding the landfill, improving the biochemistry of the creek and marsh and further improving water quality.

As required under NYSDEC regulations, long-term maintenance and monitoring of the engineered systems and landfill will be conducted to ensure the remedial

measures are performing as intended. Long-term monitoring will be conducted in groundwater surrounding the landfill and in select surface water locations in close proximity to the landfill. Leachate that is collected and sent to the offsite wastewater treatment plan will also be tested.

An estimate of the potential reduction in contaminant loading to Richmond Creek from OU1 as a result of the planned OU1 source control measures is depicted in Table 1-3. The mass loading was calculated for each contaminant that was detected in shallow groundwater above relevant SCGs during the OU1 investigation. The mass loading was calculated using a shallow groundwater discharge rate of 92,000 gallons per day (CDM, 1998). The OU1 source control measures are estimated to potentially reduce the organic contaminant loading into Richmond Creek by over 300 pounds per year (lbs/yr); copper by over 21 lbs/yr; ammonia by 18 lbs/year; arsenic by over 2 lbs/yr; and mercury by approximately 0.21 lbs/yr.

Table 1-3
Mass Loading of Contaminants to Richmond Creek from Shallow Groundwater Flow System
Under Current Conditions
(No OU1 Remedial Controls)

Description	Units	Sample Size, n	Number of Detections	Minimum Concentration[1]	Max. Detected Concentration	Arithmetic Mean	Mass Loading lbs/year
2-BUTANONE	µg/l	114	10	0.4	80,000	727	204
4-METHYL-2-PENTANONE	µg/l	114	7	0.7	1800	20.4	5.72
ACETONE	µg/l	114	16	1.8	9,300	89.1	25.0
BENZENE	µg/l	114	35	0.4	33	4.6	1.28
CHLOROBENZENE	µg/l	114	42	0.4	3,200	36.6	10.2
CHLOROFORM	µg/l	114	11	0.4	31	4.4	1.22
ETHYLBENZENE	µg/l	114	7	1.0	550	10.4	2.91
METHYLENE CHLORIDE	µg/l	114	16	1	90	5.4	1.51
TOLUENE	µg/l	114	19	0.5	8,400	114.8	32.2
TRICHLOROETHYLENE	µg/l	114	1	0.4	25	3.9	1.09
XYLENE, o-	µg/l	39	8	2.1	53	4.7	1.31
XYLENES (TOTAL)	µg/l	109	14	2.8	310	12.1	3.40
1,2-DICHLOROBENZENE	µg/l	90	3	2	140	6.5	1.82
1,4-DICHLOROBENZENE	µg/l	90	23	2	13	5.1	1.43
2,4-DIMETHYLPHENOL	µg/l	90	2	10	26	5.6	1.55
2-METHYLNAPHTHALENE	µg/l	90	16	1	17	4.9	1.38
2-METHYLPHENOL	µg/l	90	2	10	54	6.0	1.68
4-CHLORO-3-METHYLPHENO	µg/l	90	18	1	15	5.9	1.64
4-METHYLPHENOL	µg/l	58	12	2	98	7.7	2.17
ACENAPHTHENE	µg/l	90	15	1	24	5.1	1.44
BENZO(A)ANTHRACENE	µg/l	90	1	1	6	5.0	1.40
BENZO(A)PYRENE	µg/l	90	1	1	10	5.1	1.41
BENZO(B)FLUORANTHENE	µg/l	90	1	1	10	5.1	1.41
CARBAZOLE	µg/l	86	6	1	9	4.9	1.37
CHRYSENE	µg/l	90	1	2	6	5.0	1.40
DI-N-BUTYLPHTHALATE	µg/l	90	12	1	57	5.2	1.46
NAPHTHALENE	µg/l	90	25	1	130	9.3	2.59
PHENOL	µg/l	90	1	10	58	5.7	1.61
4,4'-DDD	µg/l	90	1	0.1	0.110	0.051	0.01
4,4'-DDE	µg/l	90	9	0.0042	0.062	0.047	0.01
ALDRIN	µg/l	90	1	0.023	0.031	0.025	0.01
AROCLOR 1232	µg/l	90	1	1	4.500	0.549	0.15
AROCLOR 1254	µg/l	90	1	1	1.900	0.520	0.15
BHC, ALPHA-	µg/l	90	2	0.0044	0.031	0.025	0.01
BHC, BETA-	µg/l	90	1	0.014	0.031	0.025	0.01
CHLORDANE, ALPHA-	µg/l	90	2	0.019	0.120	0.026	0.03
DIELDRIN	µg/l	90	2	0.01	0.060	0.050	0.01
ENDRIN	µg/l	90	1	0.017	0.060	0.050	0.02
ARSENIC, TOTAL	µg/l	96	18	2.5	230	8.29	2.32
BARIUM, TOTAL	µg/l	96	95	8.1	3,170	368.25	103.1
CADMIUM, TOTAL	µg/l	96	3	3	19.6	2.29	0.64
CHROMIUM, TOTAL	µg/l	96	44	3	1,140	31.80	8.9
COPPER, TOTAL	µg/l	96	65	2.4	2,960	75.27	21.1
CYANIDE, TOTAL	µg/l	112	10	1	27.5	3.80	1.07
IRON, TOTAL	µg/l	96	91	46.2	720,000	33,299	9,326
LEAD, TOTAL	µg/l	96	63	1	2,860	71.60	20.1
MANGANESE, TOTAL	µg/l	96	96	16.1	14,200	1,324	370.7
MERCURY, TOTAL	µg/l	96	16	0.1	39	0.76	0.21
SELENIUM, TOTAL	µg/l	96	23	1	38.8	3.20	0.90
SODIUM, TOTAL	µg/l	96	96	3050	4,840,000	752,101	210,631
THALLIUM, TOTAL	µg/l	96	2	2	20.5	2.23	0.62
ZINC, TOTAL	µg/l	96	69	7	4,940.00	171.96	48.2
AMMONIA	mg/l	45	37	0.025	460	62.90	17,616
BROMIDE	mg/l	90	62	0.005	22.8	2.27	635
CHLORIDE	mg/l	90	88	0.00	9,770	1,532	428,941
NITRATE	mg/l	90	41	0.02	3.62	0.36	102
SULFATE	mg/l	90	73	0.00	1,540	112.18	31,417

[1] Minimum concentration shown is either the lowest detection limit or the lowest detection of the sample set, whichever is lower.

- The table combines all leachate seep results, leachate well results, and results from all wells screened in the shallow flow system.
- The results are as reported in the OU1 RI Report (CDM, 1998).
- Organics: only parameters with detections above the standard or guidance value were included.
- Inorganics: only parameters with detections above the standard or guidance value were included.
- Estimated amount of shallow groundwater (i.e. leachate) discharging to surface water: 0.092 mgd
- Mass Loading = 0.092 mgd X constituent concentration in mg/l X 8.34 X 365 = constituent loading in lbs/year

Section 2
Remedial Action Objectives and General Response Actions

To select the most appropriate remedy for a site, remedial action objectives (RAOs) and contaminant-specific remediation goals (RGs) must be clearly defined. RAOs provide a general description of what the cleanup is expected to accomplish and help focus the development of remedial alternatives. RAOs address the significant exposure pathways identified in the human health and ecological risk assessments and often include the RGs for the site, which are developed on a medium-specific or operable unit-specific basis. RGs specify (1) the contaminants of interest, (2) exposure pathways and receptors, and (3) acceptable contaminant levels.

2.1 Identification of Standards, Criteria and Guidelines (SCGs)

As a first step in developing RAOs and appropriate remedial alternatives, it is necessary to identify Standards, Criteria and Guidelines (SCGs). SCGs are standards and criteria that are generally applicable, consistently applied, and officially promulgated, that are either directly applicable or, relevant and appropriate to the site. SCGs must be given due consideration to assist in determining the appropriate extent of site cleanup, to scope and formulate remedial action alternatives, and to govern the implementation of a selected response action.

In the absence of federal- or state-promulgated standards, or in the case where standards are judged to be inadequately protective, certain criteria, advisories, guidance values, and proposed standards may be used for developing remedial action alternatives or for determining what is protective of human health and the environment (i.e., to set preliminary remediation goals). These criteria, advisories, guidance values, and proposed standards are identified by USEPA as "to-be considered" (TBC) criteria. TBCs are not legally binding and do not have the status of standards.

According to 6 NYCRR Subpart 375-1.10(c)(1), a site's program must be designed so as to conform to standards and criteria that are generally applicable, consistently applied, and officially promulgated that are either directly applicable, or that are not directly applicable but are relevant and appropriate, unless good cause exists why conformity should be dispensed with. Such good cause exists if any of the following is present:

- The proposed action is only part of a complete program that will conform to such standard or criterion upon completion;
- Conformance to such standard or criterion will result in greater risk to human health or to the environment than alternatives;

- Conformity to such standard or criterion is technically impracticable from an engineering perspective; or

- The program will attain a level of performance that is equivalent to that required by the standard or criterion through the use of another method or approach.

Under the description of SCGs set forth in 6 NYCRR Subpart 375-1, the terms SCGs include both those of New York State and those of the United States to the extent that they are more stringent than those of New York State.

SCGs fall into three broad categories, based on the manner in which they are applied at a site:

- Chemical-specific. Chemical-specific SCGs provide either actual cleanup levels or a basis for calculating such levels for particular contaminants. For example, surface water standards, as well as sediment guidance values, provide cleanup goals for the Brookfield Avenue Landfill OU2 contamination. Chemical-specific SCGs must be compared to area wide background concentrations and objectives for regional improvement.

  Chemical-specific SCGs are also used to indicate acceptable levels of discharge to determine treatment and disposal requirements and to assess the effectiveness of remedial alternatives. Table 2-1 lists and summarizes potential federal and state chemical-specific SCGs.

- Location-specific. Location-specific SCGs are requirements that are associated with a remedy because of where it is located. Examples of natural site features include wetlands, scenic rivers, and floodplains. Examples of man-made features include historic districts and archaeological sites. Some remedial action alternatives may be restricted or precluded depending on the location or characteristics of the site and the requirements that apply. Potential location-specific SCGs are presented in Table 2-2.

  The most important of these location-specific standards is the designation of Richmond Creek and marsh, as part of the Arthur Kill complex, as a Significant Habitat by the U.S. Fish and Wildlife Service and New York State Coastal Management Program (CMP). This program has recommended that protection of the heronries, wetland foraging areas, and rare plants and communities of this regionally significant habitat complex should be accorded high priority. The CMP program states that protective measures should be taken to restore, maintain, enhance, and protect the significant aquatic, wetland, and upland habitats of this complex to ensure that these areas continue to support the regionally significant populations of waterfowl, fish, colonial breeding wading birds, and rare plants that utilize and depend upon them. The CMP further indicates that in addition to protection and conservation actions along the tributaries, restoration and enhancement of wetlands and

Table 2-1
Chemical-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance To Be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
SURFACE WATER			
Clean Water Act [Federal Water Pollution Control Act, as amended], 33 U.S.C. §§ 1251-1387	40 CFR § 129.105(a)(4)	SCG	Ambient water criterion for various contaminants.
New York Water Classifications and Quality Standards/ State Environmental Conservation Law (ECL) Article 15, Title 3 and Article 17, Title 3 and 8	6 NYCRR Parts 609; 700 through 706	SCG	Describes classification system for surface water and groundwater. Establishes New York Ambient Water Quality Standards for almost 200 contaminants for protection of health of human consumers of fish, for protection of human health and drinking water sources, and for protection of wildlife.
New York State Technical and Operation Guidance Series-Ambient Water Quality Standards & Guidance Values	TOGS 1.1.1 (October 1993)	TBC	Includes water quality standards/guidance values for the protection of aquatic life.
SEDIMENT			
No promulgated chemical-specific SCGs identified for sediment			
NOAA - Damage Assessment, Remediation, and Restoration Program (DARRP)	Development and Evaluation of Consensus-Based Sediment Effect Concentrations for PCBs in the Hudson River, MacDonald Environmental Services Ltd., March 1999	TBC	Estuarine, freshwater and saltwater sediment effects concentrations for total PCBs: Threshold Effect Concentration: 0.04 mg/kg Mid-range Effect Concentration: 0.4 mg/kg Extreme Effect Concentration: 1.7 mg/kg
NOAA	Screening Quick Reference Tables for Organics (SQRTs)	TBC	Concentrations in freshwater and marine sediment (dry weight basis) includes Threshold Effects Level, Probable Effects Level, Upper Effects Threshold.
EPA Great Lakes National Program Office, Assessment and Remediation of Contaminated Sediments (ARCS) Program	Calculation and Evaluation of Sediment Effect Concentrations for the *Amphipod Hyalella* azteca and the midge *Chironomus riparian* , EPA 905-R96-008, September 1996	TBC	Provides sediment effects concentrations (SECs), which are defined as the concentrations of a contaminant in sediment below which toxicity is rarely observed and above which toxicity is frequently observed. Freshwater: Threshold Effect Level, Probable Effect Level, No Effect Concentration.
NYSDEC Division of Fish, Wildlife and Marine Resources (DFWMR)	Technical Guidance for Screening Contaminated Sediment, January 1999	TBC	Includes a methodology to establish sediment criteria for the purpose of identifying contaminated sediments. Provides sediment quality screening values for non-polar organic compounds and metals to determine whether sediments are contaminated (above screening criteria) or clean (below screening criteria). Screening values are not cleanup goals. Also discusses the use of sediment criteria in risk management decisions.

Table 2-1
Chemical-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance To Be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
BIOTA			
USEPA	Region 3 Risk Based Concentrations	TBC	Provides risk based concentrations of chemicals in fish tissue assuming default human consumption patterns.
NYSDEC Division of Fish and Wildlife	Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife, Technical Report 87-3, July 1987, pp.41-48 and Table 26 (Newell *et al.*)	TBC	Provides a method for calculating PCB concentration in fish flesh for protection of wildlife. The final fish flesh criterion is 0.11 mg/kg PCBs wet weight.

Table 2-2
Location-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance To Be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
Clean Water Act Section 404, 33 U.S.C. § 1344	40 CFR Part 230	SCG	No activity which adversely affects an aquatic ecosystem, including wetlands, shall be permitted if a practicable alternative that has less adverse impact is available. If there is no other practical alternative, impacts must be minimized.
Wetland Excecutive Order United States Department of Transportation Federal Highway Administration	Executive Order No 11990	SCG	Details requirements for the preservation of wetlands.
Section 404 of the Clean Water Act [Federal Water Pollution Control Act, as amended], 33 U.S.C. § 1344	33 CFR Parts 320-329	SCG	Includes requirements for issuing permits for the discharge of dredged or fill material into navigable waters of the United States. A permit is required for construction of any structure in a navigable water.
Statement of Procedures on Floodplain Management and Wetlands Protection	40 CFR Part 6, Appendix A	SCG	Sets forth EPA policy and guidance for carrying out Executive Orders 11988 and 11990. Executive Order 11988: Floodplain Management requires federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid, to the extent possible, adverse effects associated with direct and indirect development of a floodplain. Federal agencies are required to avoid adverse impacts or minimize them if no practicable alternative exists. Executive Order 11990: Protection of Wetlands requires federal agencies conducting certain activities to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands if a practicable alternative exists. Federal agencies are required to avoid adverse impacts or minimize them if no practicable alternative exists.
Coastal Zone Management Act	Coastal Zone Management Act of 1972	SCG	Develops comprehensive processes to coordinate various levels of government and resolve conflicts between resource protection and development demands within designated coastal zones.

Table 2-2
Location-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance To Be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
Endangered Species Act of 1973, as amended, 16 U.S.C. §§ 1531 - 1544	50 CFR Part 17, Subpart I; 50 CFR Part 402	SCG	Federal agencies are required to verify that any action authorized, funded, or carried out by them is not likely to jeopardize the continued existence of any endangered species or threatened species, or result in the destruction or adverse modification of a critical habitat of such species, unless such agency has been granted an appropriate exemption by the Endangered Species Committee (16 U.S.C. § 1536). The only federally-listed species known to exist near the site is the peregrin falcon, known by U.S. Fish and Wildlife to be present within the Arthur Kill complex. In addition, the northern diamondback terrapin and cerulen warbler are considered Federal species of concern also living in the Arthur Kill complex. Further consultation with the Fish and Wildlife Service may be necessary to determine the need for any additional consideration under the ESA.
Toxic Substances Control Act (TSCA), Title I, 15 U.S.C. § 2601	40 CFR §§ 761.65 - 761.75	SCG	TSCA facility requirements: Establishes sitting guidance and criteria for storage (761.65), chemical waste landfills (761.75), and incinerators (761.70).
Fish and Wildlife Coordination Act, 16 U.S.C. § 662	N/A	SCG	Whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose, by any department or agency of the United States, such department or agency first shall consult with the United States Fish and Wildlife Service, Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular State in which the impoundment, diversion, or other control facility is to be constructed, with a view to the conservation of wildlife resources by preventing loss of and damage to such resources.
National Historic Preservation Act, 16 U.S.C. § 470 et seq.	36 CFR Part 800	SCG	Proposed remedial actions must take into account effect on properties in or eligible for inclusion in the National Registry of Historic Places. Federal agencies undertaking a project having an effect on a listed or eligible property must provide the Advisory Council on Historic Preservation a reasonable opportunity to comment pursuant to section 106 of the National Historic Preservation Act of 1966, as amended. While the Advisory Council comments must be taken into account and integrated into the decision-making process, program decisions rest with the agency implementing the undertaking. A Stage 1A cultural resource survey is expected to be necessary for any active remediation to identify historic properties along the river banks and to determine if any areas should be the subject of further consideration under NHPA.

Table 2-2
Location-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance To Be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
New York State Freshwater Wetlands Law, Environmental Conservation Law (ECL) Article 24, Title 7	6 NYCRR Parts 662 - 665	SCG	Defines procedural requirements for undertaking different activities in and adjacent to freshwater wetlands, and establishes standards governing the issuance of permits to alter or fill freshwater wetlands.
Tidal Wetlands Act	Article 25 ECL, 6 NYCRR Part 661	SCG	Establishes requirements for the protection of tidal wetlands
Use and Protection of Waters	Article 15 ECL, 6 NYCRR Part 608	SCG	Establishes requirements of the use and protection of streams and navigable water bodies
New York State ECL Article 3, Title 3; Article 27, Title 7 and 9	6 NYCRR § 373-2.2	SCG	Establishes construction requirements for hazardous waste facilities in 100-year floodplain.
Waterfront Revitalization and Coastal Resources Act	Executive Law of New York, Article 42	SCG	Addresses competing objectives within or affecting coastal areas through a total of 44 policies.
New York State ECL Article 11, Title 5	6 NYCRR Part 182	SCG	Fresh Kills is designated a significant Fish and Wildlife Habitat with the highest Significance Value. It is known as the wintering areas for the least tern, rose pink, Virginia pine, Nantucket juneberry (all endangered); eastern mud turtle, northern harrier, American bittern, opsrey, wingstem, (all threatened), and short-eared owl, southern leaboardd frog, common barn owl and common nighthawk (all special concern species). The taking of any endangered or threatened species is prohibited, except under a permit or license issued by NYSDEC. The destroying or degrading the habitat of a protected animal likely constitutes a "taking" of that animal under NY ECL § 11-0535.
Waterfront Revitalization Program	New York City Waterfront Revitalization Program	SCG	Incorporates the existing 44 State policies and an additional 12 policies specific to New York City
EPA Office of Solid Waste and Emergency Response	Policy on Floodplains and Wetland Assessments for CERCLA Actions, August 1985	TBC	Superfund actions must meet the substantive requirements of the Floodplain Management Executive Order (E.O. 11988) and the Protection of Wetlands Executive Order (E.O. 11990) (see Table 2-3: Location-Specific SCGs). This memorandum discusses situations that require preparation of a floodplains or wetlands assessment, and the factors that should be considered in preparing an assessment, for response actions taken pursuant to Section 104 or 106 of CERCLA. For remedial actions, a floodplain/wetlands assessment must be incorporated into the analysis conducted during the planning of the remedial action.
No other Location-Specific To-Be-Considered Criteria Identified.			

adjacent uplands is beneficial in many locations. Restoration actions include removing or controlling common reed, reestablishing salt marsh areas, and enhancing and restoring riparian habitats.

- Action-specific. Action-specific SCGs are usually technology- or activity-based limitations related to the management of hazardous substances, pollutants, or contaminants that control actions at sites. After remedial alternatives are developed, action-specific SCGs pertaining to proposed site remedies provide a basis for assessing the feasibility and effectiveness of the remedies. For example, action-specific SCGs may include hazardous waste transportation and handling requirements, air and water emissions standards, and landfilling and treatment requirements of TSCA and RCRA. Potential action-specific SCGs are presented in Table 2-3.

SCGs pertaining both to contaminant levels and to performance or design standards should be attained at all points of potential exposure, or at the point specified by the SCG itself. Where the SCG does not specify the point of compliance, discretion is allowed to determine where the requirement shall be attained to be protective.

2.2 Remedial Action Objectives

Remedial action objectives (RAOs) are medium-specific and operable-unit specific objectives for the protection of public health and the environment. RAOs serve as the primary basis upon which remedial alternatives are developed and evaluated. Guidance for establishing RAOs is provided in NYSDEC's Draft DER-10 Technical Guidance for Site Investigation and Remediation, Section 4 and Appendix A4 (NYSDEC 12/2002).

For the Brookfield Avenue Landfill OU2 site RAOs are established for sediment and surface water and address protection of human health and the environment.

1. Minimize direct contact with contaminated sediment;

2. Prevent releases of contaminants from sediments that would result in surface water levels in excess of ambient water quality criteria;

3. Prevent or minimize human consumption of aquatic biota that is incompatible with existing health advisories;

4. Preserve productive ecological habitat of the existing wetlands, marshes and open water areas; and

Table 2-3
Action-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance to be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
Section 10, Rivers and Harbors Act, 33 U.S.C. § 403	33 CFR Part 322	SCG	U.S. Army Corps of Engineers approval is generally required to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of the channel of any navigable water of the United States.
Section 404(b) of the Clean Water Act, 33 U.S.C. § 1344(b)	40 CFR Part 230	SCG	Guidelines for Specification of Disposal Sites for Dredged or Fill Material. Except as otherwise provided under Clean Water Act Section 404(b)(2), no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. Includes criteria for evaluating whether a particular discharge site may be specified.
Section 404(c) of the Clean Water Act, 33 U.S.C. § 1344(c)	40 CFR Part 231, 33 CFR Parts 320, 323, and 325	SCG	These regulations apply to all existing, proposed, or potential disposal sites for discharges of dredged or fill materials into U.S. waters, which include wetlands. Includes special policies, practices, and procedures to be followed by the U.S. Army Corps of Engineers in connection with the review of applications for permits to authorize the discharge of dredged or fill material into waters of the United States pursuant to Section 404 of the Clean Water Act.
Hazardous Materials Transportation Act, as amended, 49 U.S.C. §§ 5101 - 5127	49 CFR Part 171	SCG	Department of Transportation Rules for Transportation of Hazardous Materials, including procedures for the packaging, labeling, manifesting and transporting of hazardous materials.
Toxic Substances Control Act (TSCA), Title I, 15 U.S.C. § 2605	40 CFR § 761.50, 761.63, 761.65, 761.70, 761.75, 761.79	SCG	Identifies disposal, cleanup, storage, incineration, chemical landfill and decontamination requirements for various PCB waste type.
Section 3004 of the Resource Conservation and Recovery Act [Solid Waste Disposal Act], as amended, 42 U.S.C. § 6924	40 CFR § 264.232	SCG	Owners and operators of a facility that treats, stores or disposes of hazardous wastes must develop and follow a written waste analysis plan.
Section 3004 of the Resource Conservation and Recovery Act, as amended, 42 U.S.C. § 6924	40 CFR Part 230	SCG	Owners and operators shall manage all hazardous waste placed in surface impoundments in accordance with 40 CFR Subparts BB (Air Emission Standards for Equipment Leaks) and CC (Air Emission Standards for Tanks, Surface Impoundments and Containers).
New York State ECL Article 27, Title 7	6 NYCRR Part 360 Solid Waste Management Facilities	SCG	New York State regulations for design, construction, operation, and closure requirements for solid waste management facilities.

Table 2-3
Action-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance to be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
New York State ECL Article 27, Title 11	6 NYCRR Part 361 Siting of Industrial Hazardous Waste Facilities	SCG	Establishes criteria for siting industrial hazardous waste treatment, storage and disposal facilities. Regulates the siting of new industrial hazardous waste facilities located wholly or partially within New York State. Identifies criteria by which the facilities siting board will determine whether to approve a proposed industrial hazardous waste facility.
New York State ECL Article 27, Title 3	6 NYCRR Part 364 Standards for Waste Transportation	SCG	Regulations governing the collection, transport and delivery of regulated wastes, including hazardous wastes.
New York State ECL Article 27, Title 9	6 NYCRR Part 370 and 371, Standards for Hazardous Waste Management	SCG	New York State regulations for activities associated with hazardous waste management. All dredged materials and other solid wastes containing 50 ppm by weight (on a dry weight basis for other than liquid wastes) or greater of PCBs are listed hazardous wastes, excluding small capacitors and PCB articles drained in accordance with applicable NY State regulations.
New York State ECL Article 11, Title 3; Article 27, Title 7 and 9	6 NYCRR Part 372 Hazardous Waste Manifest System and Related Standards for Generators, Transporters and Facilities	SCG	Includes Hazardous Waste Manifest System requirements for generators, transporters, and treatment, storage or disposal facilities, and other requirements applicable to generators and transporters of hazardous waste.
New York State ECL Article 11, Title 3; Article 27, Title 7 and 9	6 NYCRR Part 373 Hazardous Waste Management Facilities	SCG	These regulations establish requirements for treatment, storage, and disposal of hazardous waste; permit requirements; and construction and operation standards for hazardous waste management facilities.
New York State ECL Article 27, Title 13 Hazardous Waste Site Remediation Projects	6 NYCRR Part 375 Inactive Hazardous Waste Disposal Sites	SCG	Establishes standards for the development and implementation of inactive hazardous waste disposal site remedial programs.
New York State ECL Article 27, Title 9	6 NYCRR Part 376	SCG	Land Disposal Restrictions. PCB wastes including dredge spoils containing PCBs greater than 50 ppm must be disposed of in accordance with federal regulations at 40 CFR Part 761.
New York State ECL Article 19, Title 3 - Air Pollution Control Law. Promulgated pursuant to the Federal Clean Air Act, 42 USC § 7401	6 NYCRR Part 200, 202, 205, 211, 212, 219, and 257. Air Pollution Control Regulations	SCG	The emission of air contaminants that jeopardize human, plant, or animal life, or is ruinous to property, or causes a level of discomfort is strictly prohibited.

Table 2-3
Action-Specific Standards, Criteria and Guidelines (SCGs), Advisories and Guidance to be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
New York State ECL Article 15, Title 5; Article 17, Title 3	6 NYCRR Part 608 Use and Protection of Waters	SCG	A permit is required to change, modify, or disturb any protected stream, its bed or banks, or remove from its bed or banks sand or gravel or any other material; or to excavate or place fill in any of the navigable waters of the state. Any applicant for a federal license or permit to conduct any activity which may result in any discharge into navigable waters must obtain a State Water Quality Certification under Section 401 of the Federal Water Pollution Control Act, 33 USC § 1341.
New York State ECL Article 17, Title 8	6 NYCRR Part 750 - 758 New York State Pollutant Discharge Elimination System (SPDES) Requirements	SCG	Standards for Storm Water Runoff, Surface Water, and Groundwater Discharges. In general, no person shall discharge or cause a discharge to NY State waters of any pollutant without a permit under the New York State Pollutant Discharge Elimination System (SPDES) program.
New York State ECL Article 17, Title 5	N/A	SCG	It shall be unlawful for any person, directly or indirectly, to throw, drain, run or otherwise discharge into such waters organic or inorganic matter that shall cause or contribute to a condition in contravention of applicable standards identified at 6 NYCRR § 701.1.
New York State ECL Article 17, Title 5	NY ECL § 11-0503	SCG	Fish & Wildlife Law against water pollution. No deleterious or poisonous substances shall be thrown or allowed to run into any public or private waters in quantities injurious to fish life, protected wildlife or waterfowl inhabiting those waters, or injurious to the propagation of fish, protected wildlife or waterfowl therein.
USEPA	Covers for Uncontrolled Hazardous Waste Sites (EPA/540/2-85-002; September 1985)	TBC	Covers for Uncontrolled Hazardous Waste Sites should include a vegetated top cover, middle drainage layer, and low permeability layer.
USEPA	Rules of Thumb for Superfund Remedy Selection (EPA 540-R-97-013, August 1997)	TBC	Describes key principles and expectations, as well as "best practices" based on program experience, for the remedy selection process under Superfund. Major policy areas covered are risk assessment and risk management, developing remedial alternatives, and ground-water response actions.
USEPA	Land Use in the CERCLA Remedy Selection Process (OSWER Directive No. 9355.7-04, May 1995)	TBC	Presents information for considering land use in making remedy selection decisions at NPL sites.

Table 2-3
Action-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance to be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
USEPA	Contaminated Sediment Strategy (EPA-823-R-98-001, April 1998)	TBC	Establishes an Agency-wide strategy for contaminated sediments, with the following four goals: 1) prevent the volume of contaminated sediments from increasing; 2) reduce the volume of existing contaminated sediment; 3) ensure that sediment dredging and dredged material disposal are managed in an environmentally sound manner; and 4) develop scientifically sound sediment management tools for use in pollution prevention, source control, remediation, and dredged material management. The strategy includes the Hudson River in its case studies of human health risks.
USEPA	Structure and Components of Five-Year Reviews (OSWER Directive 9355.7-02, May 1991) Supplemental Five-Year Review Guidance (OSWER Directive 9355.7-02A, July 1994) Second Supplemental Five-Year Review Guidance (OSWER 9355.7-03A,	TBC	Provides guidance on conducting Five-Year Reviews for sites at which hazardous substances, pollutants, or contaminants remain on-site above levels that allow for unrestricted use and unlimited exposure. The purpose of the Five-Year Review is to evaluate whether the selected response action continues to be protective of public health and the environment and is functioning as designed.
NYSDEC	Air Guide 1 - Guidelines for the Control of Toxic Ambient Air Contaminants, 2000	TBC	Provides guidance for the control of toxic ambient air contaminants in New York State. Current annual guideline concentrations (AGCs) for PCBs are 0.01 $\mu g/m^3$ for inhalation of inhalation of evaporative congeners (Aroclor 1242 and below) and 0.002 $\mu g/m^3$ for inhalation of persistent highly chlorinated congeners (Aroclor 1248 and above) in the form of dust or aerosols.
NYSDEC	Technical and Operational Guidance Series (TOGS) 1.1.1 Ambient Water Quality Standards and Guidance Values	TBC	Provides guidance for ambient water quality standards and guidance values for pollutants.
NYSDEC	Technical and Operational Guidance Series (TOGS) 1.2.1 Industrial SPDES Permit Drafting Strategy for Surface Waters	TBC	Provides guidance for writing permits for discharge or wastewater from industrial facilities and for writing requirements equivalent to SPDES permits for discharges from remediation sites.
NYSDEC	Technical and Operational Guidance Series (TOGS) 1.3.1 Waste Assimilative Capacity Analysis & Allocation for Setting Water Quality Based Effluent Limits	TBC	Provides guidance to water quality control engineers in determining whether discharges to waterbodies have a reasonable potential to violate water quality standards and guidance values.
NYSDEC	Technical and Operational Guidance Series (TOGS) 1.3.2 Toxicity Testing in the SPDES Permit Program	TBC	Describes the criteria for deciding when toxicity testing will be required in a permit and the procedures which should be followed when including toxicity testing requirements in a permit.

Table 2-3
Action-Specific Standards, Criteria and Guidelines (SCGs),
Advisories and Guidance to be Considered (TBCs)
Brookfield Avenue Landfill OU2

MEDIUM/ AUTHORITY	CITATION	STATUS	REQUIREMENT SYNOPSIS
NYSDEC	Technical and Operational Guidance Series (TOGS) 1.3.7 Analytical Detectability & Quantitation Guidelines for Selected Environmental Parameters	TBC	Provides method detection limits and practical quantitation limits for pollutants in distilled water.
NYSDEC	Technical and Administrative Guidance Memorandum (TAGM) 4031 Fugitive Dust Suppression and Particulate Monitoring Program at Inactive Hazardous Waste Sites	TBC	Provides guidance on fugitive dust suppression and particulate monitoring for inactive hazardous waste sites.
NYSDEC	Interim Guidance on Freshwater Navigational Dredging, October 1994	TBC	Provides guidance for navigational dredging activities in freshwater areas.
NYSDEC Division of Fish, Wildlife and Marine Resources	Fish and Wildlife Impact Analysis for Inactive Hazardous Waste Sites (FWIA), October 1994	TBC	Provides rationale and methods for sampling and evaluating impacts of a site on fish and wildlife during the remedial investigation and other stages of the remedial process.

5. Ensure compatibility with the Operable Unit 1 remedy and the End Use Plan for the Site.

These RAOs serve as the primary basis upon which the remedial alternatives are developed and evaluated. A limited number of media -specific remedial technologies are identified and screened for site-specific feasibility, technical implementability, and practicality based on readily available information from the site RI and from similar sites.

The RAOs developed above are specific for OU2, Richmond Creek and the marsh areas adjacent to the Brookfield Avenue Landfill. However, the two Operable Units are invariably linked and remediation of OU1, the landfill, via capping, leachate barrier wall and collection system, etc., is part of the remedy for OU2 and closure activities at OU1 are expected to contribute to obtaining the RAOs established for OU2.

2.3 Development of Site-Specific Remediation Goals

As stated in 6 NYCRR Part 375, the goal of the remediation program for a specific site is to restore that site to pre-disposal conditions, to the extent feasible and authorized by law and at a minimum, the remedy selected shall eliminate or mitigate all significant threats to the public health and to the environment.

As summarized in Section 1, most risks to human health at the Brookfield Avenue Landfill site are through the consumption of finfish and shellfish which are the subject of NYSDOH consumption advisories. Human health risks posed by exposure to surface water and sediment are not considered significant except potentially for a child exposed to upper marsh sediment and the estimated non-cancer hazard index for that exposure was only 2 compared to the EPA non-cancer health threshold of 1. Ecological risks are predicted based on surface water concentrations of copper and elevated concentrations of constituents in sediment. The Brookfield Avenue Landfill's contribution of contaminants to surface water will be removed through the completion of the OU1 remedy. Sediments with similar concentrations exist throughout the estuary.

Surface water standards exist for contaminants measured at the site. Both NYSDEC and EPA have promulgated surface water standards for different water bodies for their best use. These surface water standards will be used as chemical specific remediation goals for the Brookfield Avenue Landfill OU2 site.

No cleanup standards, criteria, or limitations are currently promulgated under federal or state law that specifically address concentrations of hazardous substances in sediment. Technical guidance for screening impacted sediment has been established by the NYSDEC Division of Fish and Wildlife (NYSDEC, 1999a). The 1999 NYSDEC guidance provides a methodology for establishing screening criteria to be used to

identify sediment that may potentially result in harmful effects to marine and aquatic ecosystems. Based on the NYSDEC guidance, if sediment screening criteria are exceeded, additional assessment, as was performed on the Brookfield Avenue Landfill OU2 project, is generally required to assess the potential level of impact or risk to aquatic ecological receptors.

2.3.1 Chemicals Present above SCGs

Table 2-4 presents a list of chemicals detected above SCGs in each medium with the respective standards, criteria or guidelines that are considered remediation goals for the site. For biota, chemicals were added that were found to bioaccumulate during the sediment toxicity study but were not analyzed for during the OU2 RI. For organic contaminants, sediment concentrations were compared to the chronic toxicity criteria and, based on NYSDEC guidance (NYSDEC 1999a), they were also compared to 50 times the aquatic chronic toxicity criteria. For inorganic contaminants, sediment concentrations were compared to the effects range - median.

2.3.2 Areas and Volumes Exceeding Remediation Goals

To evaluate potential remedial technologies and alternatives, it is necessary to establish quantities of the various media (soil, sediment, etc) that could be addressed by remediation. The aerial portions of the creek and marsh sediment above SCGs and remediation goals have been determined by comparing the analytical data and the description of sediment type to the remediation goals. A combination of existing sample data, knowledge of stream flow characteristics, OU2 boundaries, wetland processes, contaminant concentration trends, and sediment depositional characteristics was used to estimate the aerial limits of creek and marsh sediment potentially requiring remediation. The width of the creek was based on the 1 foot MSL elevation lines in the main branch(es) of the creek.

The total area of Richmond Creek within OU2 with sediment concentrations greater than remediation goals is estimated to be 25 acres. The total estimated volume of OU2 creek sediments above remediation goals is 82,000 cubic yards (cy). The creek sediment volume was estimated using a nominal depth of 2 feet for the main branch of the creek (west to east) plus the portion of the creek extending from the Sweet Brook storm water outfall. Many locations in the creek showed exceedances of remediation goals in only the first 12 inches. The contaminated volume overestimate for these areas is balanced by the underestimate for locations where cohesive sediments have accumulated in excess of remediation goals to depths of 54 inches. Due to the high water content of these sediments, their actual volume is much less than their depths would indicate.

The total area of marsh sediment with concentrations above remediation goals is estimated to be 64 acres. The estimated volume is 206,300 cy. Again, this volume was estimated using a nominal 2-foot depth estimate for the entire area of marsh sediments within OU2 south of Richmond Creek. The marsh areas north of Richmond Creek were not included in OU2. As explained in Section 1.3.4.3, the locations and

Table 2-4
Chemicals Detected Above SCGs
Brookfield Avenue Landfill
Operable Unit 2

SURFACE WATER	Chemical	Concentration Range Detected (ppb)[b]	SCG[a] and Remediation Goal (ppb)[b]	Frequency of Detections Exceeding SCGs
Volatile Organics (VOCs)	Chlorobenzene	3.9 - 5.2	5[(3)]	1 of 19
Inorganics: Metals	Copper	3.7 J - 15.1 J	3.4[(3)(5)]	18 of 19
	Lead	3 N - 13	8[(3)]	3 of 14
	Mercury	0.2 J - 0.36 J	0.0007[(2)]	2 of 19
	Nickel	2 JN - 12.1 J	8.2[(3)]	1 of 14

CREEK AND MARSH SEDIMENT	Chemical	Concentration Range Detected (ppb)[b]	SCG[a] and Remediation Goal (ppb)[b]	Frequency of Detections Exceeding SCGs
VOCs	*none*	-	-	-
Semivolatile Organic Compounds (SVOCS)	2-Methylnapthalene	75 J - 570 J	70/ 670 [(4)]	0 of 88
	Acenaphthene	48 J - 75 J	16/ 500 [(4)]	0 of 88
	Acenaphthylene	48 J - 75 J	44/ 640 [(4)]	0 of 88
	Benzo(a)anthracene	490 J - 780	261/ 1,600 [(4)]	1 of 88
	Benzo(a)pyrene	750	430/ 1,600 [(4)]	0 of 88
	Dibenz(a,h)anthracene	66 J - 96 J	63.4/ 260 [(4)]	0 of 88
	Fluoranthene	850 J - 1,700	600/ 5,100 [(4)]	0 of 88
	Fluorene	44 J - 70 J	19/ 540 [(4)]	0 of 88
	Hexachloro-1,3-Butadiene	60 J - 95 J	16/ 800 [(5)]	0 of 88
	Hexachloro-cyclopentadiene	150 J - 240 J	7/ 350 [(5)]	0 of 88
	Phenanthrene	300 J - 790	240/ 1,500 [(4)]	0 of 88
	Pyrene	920 J - 1,400	665/ 2,600 [(4)]	0 of 88
PCB/ Pesticides	4,4'-DDD	0.42 J - 60 J	2.2/ 27 [(4)]	3 of 88
	4,4'-DDE	0.28 J - 530 JD	2.2/ 27 [(4)]	3 of 88
	4,4'-DDT	042 J - 190 JD	1.58/ 46.1 [(4)]	2 of 88
	alpha-BHC (Lindane)	1.7 J - 12 J	0.32/ 0.99 [(6)]	15 of 88
	Total PCBs	2.8 J - 250 J	22.7/ 180 [(4)]	4 of 88
	Dieldrin	20 P	0.02/ 8 [(6)]	1 of 88
	Endosulfan I	0.7 J - 5 J	0.04/ 2 [(5)]	7 of 88
	Endosulfan II	0.42 J - 3 J	0.04/ 2 [(5)]	2 of 88
	Gamma-Chlordane	0.42 J - 3 J	0.02/ 1 [(5)]	7 of 88
	Heptachlor	1.4 J - 9.9 J	0.9/ 45 [(5)]	0 of 88
	Heptachlor epoxide	0.42 J - 3 J	0.9/ 45 [(5)]	0 of 88
Inorganics: Metals	Antimony	0.39 J 41.7 J	2/ 25 [(5)]	1 of 88
	Arsenic	0.57 J - 365 J	8.2/ 70 [(4)]	9 of 88
	Cadmium	0.1 J - 9.6 J	1.2/ 9.6 [(4)]	1 of 88
	Chromium	4.2 - 275 J	81/ 370 [(4)]	1 of 88
	Copper	2.7 J - 936 J	34/ 270 [(4)]	28 of 88
	Iron	2,310 J - 182,000 J	20,000/ 400,000 [(5)]	0 of 88
	Lead	2.5 J - 984 J	46.7/ 218 [(4)]	27 of 88
	Manganese	12 j - 7,680 J	460/ 1,100 [(5)]	4 of 88
	Mercury	0.02 J - 9.8	0.15/ 0.71 [(4)]	39 of 88
	Nickel	2 J - 288 J	20.9/ 51.6 [(4)]	47 of 88
	Silver	0.46 J - 6.3 J	1/ 3.7 [(4)]	14 of 88
	Zinc	10.1 JN - 1,010 JN	150/ 410 [(4)]	21 of 88

Table 2-4
Chemicals Detected Above SCGs
Brookfield Avenue Landfill
Operable Unit 2

Table 2-4 Notes:
[a] SCG = standards, criteria, and guidance values.
[b] ppb = parts per billion, which is equivalent to micrograms per liter, µg/L, in water.

Surface water SCGs are taken from *NYSDEC 6 NYCRR Part 703, Surface Water and Groundwater Quality Standards and Groundwater Effluent Limits* and *NYSDEC Technical and Operational Guidance Series 1.1.1 Ambient Water Quality Standards and Guidance Values.* The following notes apply for surface water SCGs:

(2) Applies to standard of protection of human health from fish consumption
(3) Protection of fish propagation (chronic)
(5) Standard 3.4 µg/L except in New York/New Jersey Harbor where it is 5.6 µg/L.

SCGs and Remediation Goals for sediment taken from NYSDEC Division of Fish, Wildlife and Marine Resources, Technical Guidance for Screening Contaminated Sediment, 1999. For remediation goals, the guidance on pg.18 was followed: for non-polar organic contaminants, exceedance of sediment criteria based on aquatic life chronic toxicity by a factor of 50 in significant size areas indicates probable impairment and was selected as the remediation goal. The following notes apply for sediment SCGs for specific compounds:

(4) Taken from Appendix 4 of Change in the Guidance for Marine and Estuarine Sediments, Table 3 or Table 4 which are reproduced from 1995 revisions of Long and Morgan's "effects range low" (ER-L) and "effects range median" (ER-M). The lower number presented is the ER-L which is considered the SCG. The higher number is ER-M, considered to be the remediation goal.
(5) For non-polar organics not listed in Table 4 of Appendix 4, criteria were taken from Table 1. SCG is from the benthic aquatic life chronic toxicity to wildlife bioaccumulation for salt water (if available) in µg/g OC assuming a conservative 1% OC/kg sediment.
(6) For chemicals not present in NYSDEC Sediment Guidance, the USFWS NOAA SQRT (Screening Quick Reference Tables, updated September 1999) were used.

Data Qualifiers Definitions:

NA - Not applicable

Organic Qualifiers:
J - Estimated data due to exceeded quality control criteria
P - The difference for the detected concentration of a pesticide/ Aroclor target analyte is greater than 25 % between the two GC columns

Inorganic Qualifiers:
J - Estimated data due to exceeded quality control criteria.
N - Sample recovery is not within control limits.
D - Compound is identified at a secondary dilution factor.

depths of contamination within marsh sediment appear to be related to the time period of their deposition within the marsh, with the recent deltaic deposits closer to the creek showing exceedances of remediation goals at depths greater than 24 inches and the older ('high marsh') deposits showing exceedances in only the first 6 inches. While sediment contamination deeper than 24 inches was detected in a few locations in the marsh, due to the much lower human and biota exposure potential, the deeper sediments were not included in the marsh sediment volume estimate.

Sediment contaminant concentrations in OU2 are generally consistent with sediment contaminant concentrations found in NY Harbor and are consistent with exceedances of SCGs throughout the NY Harbor.

2.4 General Response Actions

General response actions (GRAs) are categories of actions that may be implemented to achieve the project-specific RAOs. GRAs may include (but are not limited to) such categories as treatment, containment, disposal, or combinations of these categories.

General response actions identified for potential remediation of Brookfield Avenue Landfill OU2 include the following:

- No Action;
- Monitoring with Natural Improvement;
- Institutional Controls;
- Engineering Controls;
- Containment;
- In situ Treatment;
- Removal;
- Ex situ Treatment;
- Beneficial Use; and
- Disposal.

A brief description of each of the general response actions is provided below.

2.4.1 No Action

No Action will be considered throughout each phase of the FS, as required by NYS Part 375 regulations. Under the No Action alternative, contaminated river sediments would be left in place without treatment or containment. No additional institutional

controls or monitoring would be implemented as part of the No Action alternative. No Action is generally considered appropriate if the site poses no current or potential threat to human health or the environment.

In the case of OU2, remediation of OU1 including landfill capping, leachate barrier wall and collection system, etc., will remove sources of impacts to OU2. Therefore, remediation of OU1 is part of the remedy for OU2 even under "No Action" alternative evaluated for OU2. Closure activities at OU1 are expected to contribute to obtaining the RAOs established for OU2.

2.4.2 Monitoring with Natural Improvement

Monitoring with Natural Improvement includes monitoring to assess the improvement in surface water quality resulting from OU1 remedial actions and the pending removal of other contributing sources in the area (e.g., Fresh Kills Landfill), and the improvement associated with natural wetlands function once external sources are reduced. This alternative does not include active remedial measures other than OU1 remedial actions. Present fish advisory institutional controls would not be affected. This response action may be appropriate if source removal and in situ processes would achieve site-specific RAOs in a time frame that is reasonable compared to active remedial measures. For the Brookfield Avenue Landfill Site, monitoring is an appropriate response action to consider for OU2 because the extensive source control, i.e., landfill capping, landfill gas controls, barrier wall construction and leachate collection, to be implemented for OU1 will control the release of contaminants into the marsh and creek. It is believed that since the observed surface water SCG exceedances are partially due to the flux to the creek and marsh from the shallow groundwater and leachate beneath the landfill, the slurry wall and leachate collection systems that will be constructed as part of the OU1 remedy will allow surface water to improve compliance with SCGs. Additionally, source control and the natural wetland processes of the Richmond Creek estuary and marsh will further reduce some contaminant concentrations and their availability.

Both laboratory and field-scale studies have shown successful treatment of organic compounds and metals using aquatic plants or sediment microbial activities. Accordingly, the wetlands and marshes associated with Richmond Creek are capable of removing pollutants through physical, chemical, and/or biological processes. These processes include microbial metabolism, plant uptake, nitrification/denitrification, adsorption, precipitation, volatilization, and sedimentation.

2.4.3 Institutional Controls

Institutional controls are administrative and/or legal controls intended to prevent or reduce human exposure to on-site hazardous substances. They can be guidelines or restrictions established to reduce exposure to contaminants of concern on a community and regional basis. Institutional controls for the Brookfield Avenue

Landfill OU2 site may include fishing or other recreational use restrictions. Institutional controls are typically utilized in conjunction with other remedy components, and not as a stand-alone remedy.

At the Brookfield Avenue Landfill site, institutional controls are currently applied to limit human health risks associated with consumption of contaminated fin fish and shell fish which were shown to constitute the majority of the potential risk posed by the site. Access restrictions to limit exposures may also be implemented. Institutional controls at this site would be applied in conjunction with the significant source control realized through the remedial activities at OU1 and the pending closure of the Fresh Kills Landfill.

2.4.4 Engineering Controls

Engineering controls are physical means to prevent exposure to source material or contamination. These could include signage, fencing, patrolling or other physical access restrictions, capping or other forms of containment. The source control remedial activities at OU1, (landfill capping, leachate collection, subsurface barrier wall installation, landfill gas control, wetlands enhancements, etc.) are engineering controls that will address sources of contamination to OU2. Sediment containment via capping is discussed separately below.

2.4.5 Containment

Containment involves the physical isolation or immobilization of contaminated sediment for example, by an engineered cap. It does not include treatment. Containment technologies can be used to isolate contaminated sediment, thereby limiting the potential exposure to, and mobility and bioavailability of, contaminants in the sediments.

2.4.6 In situ Treatment

In situ treatment technologies may be used to reduce contaminant concentrations without removal or containment of the contaminated sediments. Also, some in situ processes such as stabilization or solidification may reduce contaminant mobility or bioavailability. The wetlands provide a natural means of performing these functions.

2.4.7 Removal

Gross removal of sediments from Richmond Creek would consist of dredging of contaminated sediments and vegetation for subsequent treatment or disposal. Contaminants would be removed from the river bed by this response action.

2.4.8 Ex situ Treatment

Ex situ treatment is treatment of contaminated sediments after removal (subsection 3.1.9) of the contaminated sediments but prior to disposal. Numerous ex situ treatment options are available. Sediments may be disposed of on land after treatment

to meet disposal criteria; or offered for beneficial use after treatment (including reuse as backfill for excavated sediments in the river) to meet beneficial use criteria.

2.4.9 Beneficial Use

Beneficial use means that sediments removed from Richmond Creek and meeting relevant criteria (either with or without treatment) are used or placed in a manner that provides some benefit to the public.

2.4.10 Disposal

Disposal is the placement of material (after removal) into a site, structure, or facility on a temporary or permanent basis. Depending on the type of disposal, the excavated material may undergo limited or extensive treatment prior to disposal. The disposal options vary depending upon the characteristics of the excavated material and the degree and type of treatment of the material prior to disposal. Disposal is differentiated from beneficial use in that the contaminated material is isolated from human and ecological receptors to prevent adverse health or environmental effects.

Section 3
Identification and Screening of Remedial Technologies

3.1 Identification of Technologies

Technologies are presented here grouped by general response action type in the same order as presented in Section 2:

- No Action
- Monitoring with Natural Improvement
- Institutional Controls
- Engineering Controls
- Containment
- In situ Treatment Technologies
- Removal Methods
- Ex situ Treatment Techniques
- Beneficial Use
- Disposal.

In this section, potential technologies are evaluated as to their applicability to the documented environmental conditions, remedial goals and general conditions of the site. This screening evaluates whether the technology is technically feasible and does not consider any other evaluation criteria such as environmental acceptability, public acceptance or cost.

3.1.1 No Action

Under No Action, no remedial action, such as removal or containment of contaminated sediment, treatment, engineering controls, or institutional controls, is implemented. No Action also does not include monitoring. The No Action alternative is generally appropriate in situations where contamination at a site presents no current or potential threat to human health or the environment, when NYS regulations do not provide the authority to take remedial action, or when a previous response action has eliminated the need for additional remedial action at a site. The NYS regulations require the No Action alternative to be developed as one of the potential remedial actions to be considered in the Feasibility Study as a baseline against which other alternatives will be evaluated. The complete lack of remedial

action is easily implemented technically and administratively. No Action is retained for further evaluation.

In the case of OU2, remediation of OU1 including landfill capping, leachate barrier wall and collection system, etc., will remove sources of impacts to OU2 and thereby constitutes a "previous response action". Therefore, remediation of OU1 is part of the remedy for OU2 even under "No Action" alternative evaluated for OU2. Closure activities at OU1 are expected to contribute to obtaining the RAOs established for OU2. In addition, processes occurring in wetlands such as those described in Section 3.1.2 are also assumed to occur under the No Action alternative.

Finally, the No Action alternative assumes no additional activities will occur that will change the existing environment in ways that are different from "pre-disposal conditions"

3.1.2 Monitoring with Natural Improvement

This alternative utilizes monitoring of surface water and sediment to follow the expected reduction of contaminant levels as a result of remedial actions implemented in OU1, and the on-going contaminant reduction processes promoted by the OU2 wetlands. Consistent improvement toward compliance with SCGs is predicted. Contamination reduction is achieved through leachate collection, landfill capping, landfill gas controls and wetland enhancements of OU1 and other source control measures taken throughout New York Harbor including the Staten Island BlueBelt Program and the pending closure of the Fresh Kills Landfill.

Wetland Functions

Natural contaminant removal processes in the wetlands are physical, chemical, and biological. They include biodegradation, biotransformation, bioturbation, diffusion, dilution, adsorption, volatilization, chemical reaction or destruction, resuspension, downstream transport, and burial by clean material. Some or all of the processes may be occurring at any given time and location within the creek and marsh. In some cases, these processes transfer some or all of the mass of contaminants (or derivative end-products) to and from the sediment and overlying water. The net result of such processes is a reduction in the concentration of the contaminants within the sediment and surface water, and an improvement in the estuary. In addition, this alternative prevents the destruction of wildlife habitats and allows for continued stormwater control.

Biological processes play a major role in pollutant removal in wetlands. Microorganisms in marsh deposits can provide organic contaminant uptake and storage by utilizing the carbon in the organic matter as a source of energy and then converting it to carbon dioxide or methane gases. Wetland plants and vegetation, such as woody and herbaceous plants, uptake excess nutrients (nitrate, ammonium, and phosphate) as well as organic compounds and metals. This uptake helps check the proliferation of algal blooms which cause a depletion of oxygen levels and can

result in fish kills. Woody plants can offer long-term storage of contaminants, and herbaceous plants have high contaminant uptake rates per unit area. This uptake and storage on organic matter and sediment can result in increased concentrations of some compounds and metals in the sediment. However, the general trend and impact of these processes is that the sequestering of these compounds makes them less bioavailable.

Peat formed by slow anaerobic decomposition of organic matter in wetland soil store pollutants long-term. Certain bacteria can permanently remove inorganic nitrogen, such as nitrate, by metabolically transforming nitrate into nitrogen gas (denitrification). Ammonium, a major environmental product of landfills, can be removed in wetlands through sequential nitrification and denitrification processes by microbial transformation of ammonium to nitrate in aerobic soil and surface water and then denitrification in deeper anaerobic soil.

Chemical processes also play a role in pollutant removal in wetlands. Sorption causes long-term immobilization of contaminants via transfer of ions from solution phase to solid phase. This two-reaction process consists of adsorption and precipitation. Adsorption is the attachment of ions to soil particles (clay and organic matter) by either cation exchange or chemisorption. Phosphate and calcium in the wetland soil can precipitate with metals to form mineral compounds. Volatilization is diffusion of a dissolved compound from the water into the atmosphere. Sedimentation is a physical removal mechanism. The laminar flow of surface water in wetlands helps to settle particulate matter. Mats of floating plants serve as sediment traps and limit resuspension of settled particulates. All these unique characteristics have made natural and constructed wetlands a successful wastewater treatment alternative.

Monitoring with Natural Improvement could be implemented alone, along with an active remedial action, or after an active remediation is completed (in this case the OU1 closure). In addition, engineering controls and institutional controls (i.e., fencing and site use restrictions) may be implemented as long-term control measures as part of a monitoring alternative.

Under this response action, site monitoring would be performed to demonstrate that improvement is occurring as a result of the OU1 remedial actions, control of other area sources and wetland contaminant removal processes. Monitoring would be conducted in the water column. Two consecutive years of surface water quality monitoring are to be performed three years after the OU1 remedy is complete to assess changes in surface water quality. Surface water monitoring results will be compared to existing SCGs. Biota monitoring is regularly performed by NYSDEC and the data is used by the NYSDOH in their evaluation of the need for consumption advisories. Therefore, biota monitoring is assumed to occur but is not included in OU2 remedy performance monitoring by NYCDEP. Monitoring may also include review of other available data that pertains to contaminant concentrations of shallow

sediment and water column in OU2 (monitoring of a location in Richmond Creek is performed by IT as part of a long-term monitoring program for Fresh Kills Landfill).

Additional monitoring will be performed as part of post-closure monitoring of the OU1 final remedial system (landfill cap, barrier wall, leachate and gas collection systems). This monitoring is to occur for the typical 30-year post closure-monitoring period, and will include: groundwater sampling of 26 wells, surface water sampling at 5 locations, and landfill gas monitoring. This post-closure monitoring will be performed quarterly for the initial 5 years and then annually.

The Monitoring with Natural Improvement response action is most appropriate as a remedy for sites where natural processes have been observed or are strongly expected, and where there are no significant adverse impacts on potential human or ecological receptors. The wetlands in the Brookfield Avenue Landfill OU2 provide a suitable environment for the natural contaminant removal processes. As described in Chapter 1, significant reduction in concentrations of organic contaminants have already occurred within OU2 and even the most recent metal data show reduction of contamination. Exposure of humans to contaminated fin fish and shell fish can be most readily addressed through institutional and/or engineering controls such as access restrictions and consumption advisories. Richmond Creek and the wetland marsh are one part of a larger ecosystem used by foraging species and as such forms only a part of their foraging range.

Where there is a source present, USEPA guidance (USEPA, 2005) recommends that monitoring should be considered only when source removal or control is also implemented; however, this is not the guidance of New York State. Source control of the Brookfield Avenue Landfill will be implemented as the OU1 remediation. In summary, Monitoring with Natural Improvement is technically and administratively feasible and is retained for further evaluation.

3.1.3 Institutional Controls

Institutional controls are defined as non-engineering, administrative, and/or legal controls at a site, intended to prevent or reduce human exposure to hazardous substances. Site use restrictions may be applied to control exposure to the contaminants that would potentially affect human health or the environment. Restrictions may include continuation or extension of existing NYS fish consumption advisories, restrictions on use of creek water, limitations on recreational use, restrictions on private sediment disturbance activities such as waterfront improvement or small craft access, and controls on sediment removal (i.e., dredging).

These restrictions are enforceable by NYSDEC or the City of New York. Fish consumption advisories can be applied area wide. Restriction of access points to Richmond Creek and marsh from OU1 and from the north, east and west can limit exposure to sediment and recreational fishing. Posting of fish consumption advisories are applied area wide. Implementation of such restrictions is technically

and administratively feasible; therefore, institutional controls are retained for further evaluation.

3.1.4 Engineering Controls

Engineering controls are physical means to prevent exposure to source material or contamination. These could include fencing or other physical access restrictions, capping or other forms of containment. The source control remedial activities at OU1, (landfill capping, leachate collection, landfill gas controls, subsurface barrier wall installation, wetlands enhancements, etc.) are engineering controls that will address sources of contamination to OU2. Containment via capping of sediment is discussed separately below.

3.1.5 Containment

There are two types of technologies evaluated for the sediment containment response action: in-situ capping (using various materials and process options) and retaining dikes and berms.

3.1.5.1 In Situ Capping

In situ capping refers to the placement of a subaqueous covering of clean material over contaminated sediment that remains in place. A cap is designed to reduce risk through isolation of the contaminated sediment from the aquatic environment; through stabilization/erosion protection of contaminated sediment, preventing re-suspension and transport to other sites; and/or through chemical isolation/reduction of the movement of dissolved and colloidally transported contaminants into the water body. Therefore, the placement of a cap on top of the contaminated sediments prevents direct human contact and exposure of benthic organisms and demersal (bottom dwelling) fish to contaminated material.

In situ capping is evaluated here as a long-term remedial option. It is different from the temporary sediment control options implemented during dredging or excavation that are discussed in later subsections.

In situ capping can be applied as the primary approach for sediment control or it can be combined with sediment removal (i.e., dredging or excavation) or monitoring and institutional controls. Capping is sometimes used following partial sediment removal where capping alone is not feasible due to a need to preserve water depth for navigation or flood control. Placement of a thin layer of clean material is sometimes used when natural sedimentation rates are not sufficient. Placement of a thin layer of clean material is also sometimes used to backfill dredged areas where it mixes with dredging residuals and further reduces risk from contamination that remains after dredging.

Site conditions that need to be evaluated for the applicability of in situ capping at the study site are listed below:

1. Water depth is adequate to accommodate cap with anticipated uses

2. Rates of groundwater flow in cap area are low and not likely to create unacceptable contaminant releases

3. Hydrodynamic conditions (e.g. , floods, ice scour) are not likely to compromise the cap or can be accommodated in design, and recontamination is not a concern.

4. Weight of the cap can be supported by the underlying sediment without slope failure

5. Sediment has sufficient strength to support cap (e.g., has high density/low water content)

6. Contaminants have low rates of flux through cap

The most frequently used thickness for in situ capping as the primary remedy is between two and three feet. This thickness is practical from an engineering (placement) perspective and is considered adequate for long term burial of contaminated sediment and to prevent biological exposure to buried sediment through bioturbidation. The water depth in the Richmond Creek study area is too shallow to apply in situ capping as the only remedy. At low tide the water depth in parts of Richmond Creek is as low as 1.5 feet and the depth in the Sweet Brook and the small tributary of the creek east of the landfill is even less. In the OU2 wetlands environment, the addition of capping material, raising the grade of the area, would negatively impact the existing wetlands both beneath and adjacent to the capped area since maintaining existing bottom elevations is critical to the survival of the coastal marsh environments.

Furthermore, although Richmond Creek is not used for navigation, it provides a natural storm water management function and altering the creek bottom would alter its ability to perform this valuable function. Applying in situ capping of two feet thick material without removal of sediment is not feasible, for this will make the creek bottom higher than the surrounding marsh. However, in situ capping might still be applicable after partial removal of contaminated sediment.

Groundwater seepage directly into the creek between Richmond Avenue and the weir at St. Andrew's Church (Old Mill Pond) was estimated at between 0.62 and 1.8 cubic feet per second (cfs) in the EIS for Richmond Creek Drainage Plan (NYCDEP 1997). The leachate discharge into Richmond Creek and marsh from the 132 acre landfill was estimated at 0.12 cfs using the site groundwater model developed during the OU1 RI. After the completion of the OU1 remedy, this groundwater seepage is expected to be reduced. Therefore with such low hydraulic head, the possibility of contaminants under sediment caps being released into the water body through advection with groundwater seepage is low.

The bottom slope of Richmond Creek is flat, dropping two to three feet in the more than 5,800 feet long section within the OU2 study area. The bottom elevation difference between the creek bank and the creek center varies from one foot to two feet. This physical dimension is suitable for in situ capping and its installation.

Richmond Creek is tidally influenced up to the weir at Mill Pond. It is classified as a vertically homogenous estuary with strong tidal influences compared to creek flow and a high "width to depth ratio. " The creek section in the OU2 study area is considered micro-tidal estuarine system, which is defined as having tidal range of less than 4 to 5 feet. It is a low energy environment that is suitable for in situ capping.

Although the base flow and the tidal current in the study section of the creek is not considered high energy, the storm water discharge from upstream and from the future capping of the Brookfield Avenue Landfill may cause erosion of the creek bottom and the cap. Proper design and selection of capping material would need to be evaluated for the portion of the creek directly receiving water from the stormwater outfalls if in situ capping is applied following sediment removal.

Bioturbation is defined as the movement and mixing of sediment as a result of the activities of burrowing benthic organisms. Evaluation of bioturbation is important, as benthic activity may result in mixing capping materials with underlying contaminated sediment, thereby re-exposing the contaminants to the water column. Bioturbation also provides mechanisms for contaminant uptake by burrowing organisms with subsequent transfer up the food chain. Fish nesting behavior may also result in mixing of capping materials with underlying contaminated sediments. The extent of benthic activity needs to be defined to select a cap thickness that minimizes or prevents mixing of the cap materials with the underlying sediment.

A wide variety of materials can theoretically be used to cap contaminated sediments to minimize or reduce leaching (soluble diffusion), bioturbation, and erosive (convective) transport. Capping materials may be divided into three basic categories: inert materials; active materials; and sealing agents. Capping options evaluated for use in the Richmond Creek are presented below.

3.1.5.1.1 In Situ Capping Using Inert Materials

Inert materials include clay, silt, sand, and AquaBlok when placed in lifts, at or near the optimum moisture content and subsequently compacted to a predetermined density, such as a Modified Proctor density of 90 to 95 percent, will form a low permeability (1×10^{-8} cm/sec or less) cap. However, bulky clay is very difficult to place and compact in a river environment. Thus, a clay cap alone is eliminated from further evaluation.

A silt cap is a layer of silt placed on top of the remaining sediments. Silt consists of fine grained sediments that have a relatively low permeability (on the order of

1 x 10^{-7}cm/sec). The placement of a silt cap is also difficult, as the silt may disperse and float downstream with the current. Thus, a silt cap for the creek is eliminated from further evaluation.

A sand cap is a layer of sand placed on top of the remaining sediments. The placement of clean material on top of the existing contaminated sediments means that the benthic organisms repopulate clean sediments. At locations that receive the discharge from storm outfalls, gravel and cobble may be added to the sand to provide better erosion resistance. Therefore, sand caps are feasible and will be retained and evaluated further.

AquaBlok is a capping system consisting of gravel particles to which bentonite clay is bonded. The composite particles are spread from the surface of the water and sink quickly to the bottom of the creek on top of the sediment. As the bentonite hydrates, a uniform, continuous, cohesive low permeability cap is formed over the contaminated sediments. This technology may be applicable for isolating the contamination. Therefore the use of AquaBlok may be considered further.

Capping using inert materials is retained for further evaluation, with sand as the selected process option, and with gravel and cobble or AquaBlok and gravel considered to increase erosion resistance at storm water discharge locations.

3.1.5.1.2. In Situ Capping Using Active Materials

Active materials such as activated carbon can be applied to the surface of subaqueous sediment or mixed with the sediment in an attempt to limit contaminant mobility. Active materials need to be combined or covered with inert materials to provide stability, erosion resistance, and, in some cases, protection for benthic organisms (USEPA, 1994)). For some contaminated sediments, chemically active materials may be added that neutralize or reduce toxicity of the contaminants. Capping using activated carbon or other active materials can be effective, but has the disadvantage of potential future release of capped (adsorbed) contaminants due to breakthrough in the active materials. The use of active materials in the application of capping is not retained for further evaluation.

3.1.5.1.3 In Situ Capping Using Sealing Agents

Sealing agents such as cement, quicklime, or grout may be applied to the surface of subaqueous sediments or mixed with the uppermost layer to form a crust upon curing. This technique stabilizes the surface, preventing erosion and resuspension of the contaminated material, and reduces or eliminates leaching of contaminants into the water column. However, the crusty surface is not a desirable habitat for biota. Therefore, capping with sealing agents is not retained for further evaluation.

3.1.5.1.4 Thin-Layer Capping

Thin-layer capping, or "particle broadcasting," is a remedial technology that consists of placing a thin cap over contaminated sediments. For purposes of this FS, thin-layer

capping refers to cap thickness of six inches or less. The purpose of the thin-layer capping would be to provide a barrier to isolate biota and reduce water column concentrations over the cap. Caps with higher organic content have been shown more effective due to chemical sorption of capping sediment.

The results from larger scale projects over relatively short time periods demonstrate that thin-layer capping does not appear to be very effective or reliable due to the thinness of the cap not being adequate for isolating sediment from potential scour or bioturbidation. Particle broadcasting laboratory studies conducted by ALCOA for the Grasse River sediments have yielded questionable results (USEPA, 2005)).

It is believed that the conditions in Richmond Creek, including the known site specific hydrodynamic forces, hydrologic conditions, contaminant concentrations, and bioturbation caused by native biota (approximately top 18 to 24 inches of the surface sediments) make the site inappropriate for the use of thin-layer capping as a containment technology. A thin-layer cap typically has a thickness of six inches or less. After considering the potential for scouring of sediments due to major storm events, ice-rafting, boat anchors, and the mixing of the upper four inches of the cap material due to bioturbation, it appears that there would be insufficient thickness for such a cap to contain the potential migration of organic and inorganic contaminants from the sediments to the water column. Therefore, thin-layer capping will not be considered further in this FS.

3.1.6 Retaining Dikes and Berms

These types of structures include subaqueous or full-depth compacted earth (or sediment) embankments, bulkheads, sheet piling, earth-filled sheet-pile cells, and armored spur dikes used to minimize downstream transport of suspended contaminated sediments. In tidal creeks they would serve to minimize transport of sediments to upstream areas as well. These structures are implemented as long-term sediment containment options, and are different from sediment barriers set up temporarily to control resuspended sediments during sediment removal activities. Dikes and berms may also be constructed as components of in-river, near-shore, or upland confined disposal facilities. Dikes and berms may be constructed in the creek perpendicular to stream flow to impede downstream sediment movement, or parallel to the shore to isolate contaminated sediments from the creek channel flow. Locations for dikes and/or berms would be developed during conceptual design based on hydraulic modeling.

When constructed perpendicular to the creek bank, retaining dikes and berms may be effective in trapping and increasing deposition of sediments suspended in the water column, thereby interrupting downstream transport and scour. Dikes and berms constructed parallel to the shoreline may be used to isolate contaminated sediments left in place in depositional areas from the convective forces of the stream. This technique could be used to prevent or reduce the erosion of materials from depositional areas during periods of high flow and flooding, such as the winter

storms and spring tides that affect the Richmond Creek area. Retaining dikes and berms are technically implementable and are retained for further evaluation.

3.1.7 In Situ Treatment

In situ technologies involve the treatment of contaminated sediments without removal. In situ treatment technologies for the contaminants specific to the OU2 site include biological and physical/chemical methods. Biological methods include enhanced aerobic or anaerobic bioremediation and phytoremediation. Physical/chemical methods include manipulation of the sediment and or the addition of additives in situ. The primary advantages of in situ treatment over alternatives involving removal of contaminated sediments are the potentially lower release of sediment-borne contaminants to the surrounding environment and the minimal sediment handling requirements. The main limitation of in situ treatment is the difficulty in delivery of additives and lack of process control during treatment, which can lead to incomplete or ineffective treatment and release of treatment by-products to the water column. Physical disturbance of sediment to add and mix treatment products can result in destruction of wetlands habitat and suspension of resuspended sediment. Phytoremediation, the use of plants to destroy or sequester contaminants, is a form of in situ remediation that does not require disruption of the sediment. As discussed in Section 3.1.2, many of the benefits of phytoremediation are performed by wetlands vegetation such as currently exists in Richmond Creek and marsh.

Techniques for in-situ treatment of sediment are in the early stages of development, and few methods are currently commercially available. Experiences gained to date in experimental or small-scale applications of in-situ remedies have indicated that technical limitations to the effectiveness of available in-situ treatments continue to exist. For example, in-situ remedies relying on the addition of required substrates and nutrients, reagents, or catalysts have been developed for some contaminants, such as polychlorinated biphenyls (PCBs), but developing an effective in-situ delivery system to add and mix the needed levels of reagents to contaminated sediment is more problematic. The lack of an effective delivery system has also hindered the application of in-situ stabilization systems [National Research Council (NRC) 2001]. For these reasons, in-situ treatment is screened out as not feasible for the Brookfield Avenue Landfill OU2 site.

3.1.8 Removal Technologies

Removal technologies permanently remove contaminated sediment from the environmental and are employed in those cases where contaminated sediments are to be withdrawn for ex situ treatment, confinement, or disposal. Sediment removal can be conducted "in the dry" (i.e., by excavation methods), or by dredging techniques. Numerous excavation and dredging technologies are available to address site-specific conditions and constraints that would be encountered at the Brookfield Avenue Landfill OU2 site. Factors that would influence equipment selection for projects involving estuarian sites include: bed characteristics, water depth, sediment

characteristics, volume of material being removed, the hydrodynamic environment, accessibility, availability of upland areas for sediment processing and storage, and ultimate disposal options.

Sediment removal activities would likely result in an increase in suspended matter in the water column. In addition, sediment removal would result in destruction of existing habitat and wetlands. Suspended sediment control measures would need to be implemented to control the amount of sediment resuspension and transport expected from a particular remedial alternative. Some of these potential suspended sediment control options are intended to block suspended sediment movement, while others are intended to limit or redirect water currents at the work site during sediment removal activities. To be effective, barriers must be deployed around the dredging operation and must remain in place until the operation is completed at that area. Wetlands vegetation can be replanted but experience has shown that it is difficult to replicate the full functionality of an existing wetland environment.

The most common method of containing suspended sediments involves the use of silt screens and curtains. These barriers generally consist of vertically hung geotextile fabrics that may either be impermeable (curtain) or porous (screen). The barriers are installed around the work area and secured by anchoring to the Creek bed. Effectiveness rests on a number of site conditions that may disrupt the securing process, including local currents (barriers will have diminished effectiveness at currents exceeding 1.5 ft/sec), water depth, wind, tides, boat wakes, waves, and the presence of debris.

Another suspended sediment control method, applicable to shallow locations, involves physical isolation of the work area. Isolation can be accomplished using various physical barriers, steel sheet piling and cofferdams have been the most commonly used methods to date. Once installed, barge-mounted dredging can be performed inside the isolated area, or the area can be dewatered and its sediments excavated "in the dry."

3.1.8.1 Excavation

Excavation methods would apply to sediment removal from shallow, near-shore areas where the work zone can be isolated from the adjacent water body and dewatered to the point where the contaminated sediments are exposed for removal. Excavation technologies can also be employed in the creek during low-flow periods. Excavation methods can also be effective for removal of contaminated sediments in the marsh where access by dredging equipment may be difficult. In such cases, the excavation equipment would be coupled with one of the containment technologies so that the work can be accomplished in relatively dry conditions. Excavation is technically implementable and is retained for further evaluation.

3.1.8.2 Dredging

Dredging technologies have been evaluated extensively by the United States Army Corps of Engineers (USACE) and by USEPA for their applicability to specific Superfund projects. With the growing demand for equipment tailored to the specific needs of remedial projects, a wide variety of specialty dredging equipment has been developed. Classifying this equipment is complicated by the fact that hybrid machines are now being fabricated with the characteristics of both mechanical and hydraulic dredges. A description of the principal systems follows (USACE, 1994).

Dredging Using Conventional Dredges
Both conventional hydraulic and mechanical dredges have applicability to remove Richmond Creek and marsh sediments. These machines come in a range of capacities and are currently being fabricated at a scale that is consistent with the access limitations of the creek. Consideration of water depth and bridge clearance must be evaluated and would likely limit the equipment size.

Mechanical Systems: Mechanical systems can be categorized into two types: those that use various types of buckets suspended from barge-mounted derricks ("bucket-on-rope" systems), and those systems that are hydraulically actuated (e.g., backhoes). "Bucket-on-rope" systems (i.e., wire supported) includes conventional open clamshell bucket dredges, enclosed bucket dredges (e.g. the Cable Arm dredge) and articulated mechanical systems (which have backhoe type design and hydraulic closing mechanisms). Examples of this type include Ham Visor Gram Dredge and the DryDredge. An advantage of a hydraulically actuated machine is the positive action that allows for greater removal precision and permits handling of a wide range of sediment types and debris. On the other hand, "bucket-on-rope" systems might be preferable when dredging softer contaminated sediments overlying a harder or impermeable noncontaminated layer. Both "bucket-on-rope" and hydraulically actuated machines have been fitted with various types of covers, enclosures, and seals to minimize the release of sediments during removal operations.

Hydraulic Systems: Hydraulic dredges use pump suction to withdraw sediments. When a hydraulic dredge is fitted with a rotating cutting head, it acquires the ability to remove a wide range of sediment types including, in some cases, consolidated materials. Hydraulic cutterheads come in numerous configurations, depending on the manufacturer, and can be sized to conform to the spatial constraints of the river. One disadvantage of these machines is that they tend to entrain substantial quantities of water, thereby requiring dewatering of sediments before further processing is possible. In addition, relatively cumbersome and costly slurry lines and pumping stations may be needed to convey sediments to shore-side processing facilities. This disadvantage of hydraulic methods may be outweighed by cost savings if sufficient bank area is available for near-shore passive dewatering of the dredged slurry and disposal of dewatered sediments with overland transportation. Examples of hydraulic dredges most commonly used include: conventional cutterhead dredge (conventional hydraulic pipeline with cutterhead), horizontal auger (hydraulic pipeline with

horizontal auger dredge, e.g., Mudcat), plain suction (hydraulic pipeline with no cutting action, just suction), pneumatic systems (air operated submersible pumps, with pipeline transport), and diver assisted (hand-held suction with pipeline transport).

Both mechanical dredges and hydraulic units are retained for further evaluation in this feasibility study. The equipment in this category that will be given further consideration includes hydraulically-actuated mechanical dredges like the DryDredge and hydraulic systems including horizontal augers and plain suction dredges.

3.1.8.3 Removal by Soil Freezing

A derivative of soil freezing technology has been given some consideration for possible applicability to contaminated sediments. According to initial reports from a project in Canada (OCETA, 1999), a sediment freezing demonstration was undertaken to remove contaminated sediment, under water, in two-square-meter blocks. The sediment blocks were frozen by injecting a refrigerant into a series of cells that had been lowered into the target material. Final evaluation of the demonstration effort is not yet available. However, it is expected that the process would be costly, provide relatively low removal rates, and apply only to fine-grained sediments where hydrodynamic conditions would permit freezing to occur. In addition, due to the factors such as high energy consumption and potential leakage of refrigerant (OCETA, 1999), sediment freezing technology will not be retained for further evaluation.

3.1.9 Ex Situ Treatment

Following dredging, sediments could be dewatered and/or treated onsite and either recycled for a beneficial use or disposed of according to solid waste rules. The effectiveness and practicality of treating sediments onsite or offsite can only be determined after further assessing the quantity, level of contamination, and end-use of the sediment. Existing sediment treatment technologies include bioremediation, sediment washing, solvent extraction, chemical treatment and immobilization.

The transport and pretreatment of excavated or dredged sediment would be dependent on the site specific conditions as well as treatment and disposal decisions. As discussed in previous sections, Richmond Creek is not a navigation channel and is bordered by marsh. The low water level can be as low as 1.5 feet at certain locations during low tide. This would limit the capacity to use barges to transport dredged sediment off-site. Currently, there is no access road to the creek or the marsh in the study area. However, a road will be built for the construction of the slurry wall between the landfill and the marsh. In addition, paths and roads currently on the landfill (such as the road to the sewer outfall or road over the 42-inch interceptor sewer) may be upgraded during construction. However, the roads would be trafficked by OU1 closure vehicles. Finally, there are locations offsite that might potentially be used for treatment or staging of the excavated sediment. However, the increased traffic concerns would be a concern for the community.

3.1.9.1 Sediment Pretreatment

Sediment pretreatment technologies, which refers to processes that modify or condition dredged or excavated sediments prior to final treatment or disposal, are described first, followed by a discussion of ex situ treatment technologies.

Sediment pretreatment, including such technologies as dewatering and solids classification, is typically utilized to facilitate the efficacy of subsequent sediment treatment processes. These pretreatment technologies are not, in themselves, generally effective in removing or reducing contamination levels in the sediment. In addition, they constitute double-handling. However, by improving the sediment characteristics or reducing the volume of the material to be treated, such technologies may reduce the overall cost of ex situ treatment alternatives. While they are not screened in this chapter, these supporting technologies are briefly discussed below. More detailed descriptions and evaluations are provided by USEPA (2005).

Dewatering
Dewatering is normally required to reduce the moisture content of sediment, enhancing the handling characteristics, and preparing the sediment for further treatment and disposal. The water generated during dewatering generally contains low levels of contaminants and requires treatment.

The method(s) used in dredging or excavation of the sediment affect the extent of dewatering. Mechanically dredged sediment will have a moisture content of 50 to 60 percent by weight. In contrast, hydraulically dredged sediment could potentially have a moisture content of 85 percent by weight or more. Such material is a slurry or suspension, and retains no structural soil properties.

A variety of dewatering processes is available, the selection of which is dependent on the volume of the sediment, the amount of available land space, the moisture content of the influent, and the desired moisture content of the effluent. The ARCS Remediation Guidance Document (USEPA, 1994) has classified dewatering technologies into three general types: passive dewatering technologies; mechanical dewatering technologies; and active evaporative technologies.

Effective passive dewatering of sediments requires significant land and time compared to mechanical and active evaporative technologies. Depending on access issues, the parkland north of Richmond Creek, adjacent to the interceptor sewer, may be potentially used with required approvals to create drying beds for dewatering the sediment. Mechanical dewatering is most suitable where land is not available for a passive dewatering facility. Disadvantages of mechanical dewatering processes are the potentially high operation and maintenance costs. Active evaporative processes rely on artificial energy sources to heat sediments and remove moisture. They can achieve approximately 90 percent solid content and are mostly used as pretreatment for incineration. However, active evaporative processes have high energy costs due

to high energy requirements, and capture and treatment of potential air emissions. They will not be considered further.

Solids Classification

Solids classification is used to separate the sediment solids based on such characteristics as size, density, and mass, and can be important in managing contaminated sediments because PCBs, PAHs, metals tend to preferentially adsorb to the fine-grained sediments. Therefore, separation of the relatively non-contaminated coarse-grained fraction might potentially reduce the volume of material that requires additional treatment. The effectiveness of solids classification is dependent on such factors as the volume of contaminated sediments, the particle size distribution of the material, and the characteristics of the contaminants. Typical solids classification processes include stationary screens and sieves, vibratory screens, hydraulic classifiers, spiral classifiers, and cyclones/hydrocyclones.

Selection of a solids classification technology depends on the objective of the pretreatment. Besides minimizing the volume of material for subsequent treatment, solids classification can be used to remove oversized material that may interfere with subsequent treatment processes. However, since most of the contaminated sediment at the OU2 site is fine grained, solids classification is not useful for the sediment from Richmond Creek and will not be considered further.

3.1.9.2 Bioremediation

Bioremediation uses microorganisms to reduce, eliminate, contain or transform contaminants into benign products. The physical, chemical, and biological conditions of a contaminated medium are manipulated to accelerate the natural biodegradation and mineralization processes. Biological treatment can effectively treat a wide range of organic contaminants. Metals are not biodegradable but may be transformed into less toxic or bioavailable forms or sequestered into sediment through sorption, co-precipitation, complexation, and change in valence state. As discussed in Section 3.1.2 viable wetland communities can perform many bioremediation functions. This option is not retained for further consideration as a separate stand alone remedy but is assumed to take place as part of natural improvement with source removal and control.

3.1.9.3 Sediment Washing

Sediment washing is a water-based volume minimization process in which the sediment is mechanically scrubbed to remove such contaminants as halogenated solvents, aromatics, fuel oils, PCBs, chlorinated phenols, and metals (USEPA, 1993b). Sediment washing is based on the same principle as solids classification; that is, organic and inorganic contaminants tend to preferentially bind, either chemically or physically, to smaller-sized particles such as clay and silt. Sediment washing separates the fine fraction of sediments from the coarser particles, thereby concentrating the contaminants and reducing the volume of material requiring additional treatment or disposal. Consequently, sediment washing has limited

effectiveness in treating sediments with large fractions of fine-grained particles. This technology has not been retained due to the predominance of fine-grained particles in OU2.

3.1.9.4 Solvent Extraction

Solvent extraction involves the dissolution of contaminants from the sediment matrix and recovery and treatment of the contaminant-bearing solvent. It has been demonstrated to be effective in treating sediments contaminated with organics such as PCBs, PAHs, but it is not effective for treating inorganic contaminants. Solvent extraction will not be retained for further evaluation.

3.1.9.5 Chemical Treatment

Chemical treatment refers to processes in which reagents are added to the dredged or excavated material for the purpose of contaminant destruction. Contaminants may be destroyed completely, or may be altered to a less toxic form. For example, dechlorination processes remove chlorine atoms from chlorinated contaminants such as PCBs or other halogen content pesticides through the addition of a chemical reagent under alkaline conditions at increased temperatures. Chemical oxidation processes such as using Fenton's reagent, generating hydroxyl radical that can oxidize wide variety organic contaminants.

Chemical treatment generally requires mixing of the chemical reagent homogenously with sediment to achieve its targeted results. This results in high operation cost, especially when the contaminants are at low level. Furthermore, insufficient contact between the reagent and sediment contaminant from poor mixing may result in incomplete reaction. This technology is not retained for further evaluation.

3.1.9.6 Thermal Desorption

Thermal desorption involves the application of heat to below-combustion temperatures, typically 200 to 1,000 degrees F, to volatilize water and organic contaminants. Dewatering prior to treatment is often appropriate to avoid excess costs associated with thermally driving off moisture. Thermal desorption processes take place under anoxic conditions to prevent combustion. The vaporized organics are then recovered by condensation or carbon adsorption for additional treatment. This method cannot treat metal contamination. Thermal desorption is not retained for further evaluation.

3.1.9.7 Thermal Destruction

Thermal destruction is a controlled process that uses high temperatures to destroy hazardous contaminants. The specific products of thermal destruction vary depending on the types of wastes that are burned and the operating parameters. Most thermal destruction units consist of a waste feed system, an air or oxygen-fed burner system, a combustion chamber, a combustion monitoring system, and equipment for air pollution treatment and control and ash removal. Thermal destruction can be

effective to treat organic contaminants; it is not effective for metals. Thermal destruction is not retained for further evaluation.

3.1.9.8 Immobilization

Immobilization refers to a broad class of treatment processes that physically or chemically reduces the mobility of hazardous constituents in a contaminated material. Immobilization treatment of contaminated sediments improves material handling characteristics, decreases the area through which contaminant transport can occur, and limits the contaminant solubility and toxicity. Immobilization includes solidification, stabilization, and encapsulation processes.

Ex situ solidification/stabilization involves mixing setting agents such as cement, quicklime, grout, pozzolanic materials, and reagents with sediments in a treatment unit. A treatment unit typically consists of a materials feed system, a reaction vessel equipped with mixing equipment, and an area for curing. Sediments may require some pre-processing, such as screening of oversized material, prior to solidification/stabilization treatment.

The effectiveness of solidification/stabilization technologies is variable depending on the characteristics of the contaminated soil and the particular additives used. This technology is technically implementable at the site because PCBs and pesticides have characteristics of strong adsorption to sediments. Solidification and stabilization have been used for metal contaminants with addition of suitable additives. Ex situ immobilization technologies are retained for further evaluation.

3.1.10 Beneficial Use

Beneficial use of dredged contaminated sediments includes two main options, using the dredged sediment in their original form, or treating the sediments and processing the treated material to create a useable product.

It is unlikely that options that bring exposed sediments - even if treated - into close physical proximity to humans, domestic animals, or wildlife would be acceptable for consideration due to the perception of risk. For these reasons, beneficial use options for habitat (e.g., wetlands) development, park and recreational uses, and agricultural uses are not evaluated for this project. Options for beneficial use that do not bring exposed sediment into close physical proximity to humans may include the following:

- Landfill cover material
- Construction fill
- Mine land reclamation
- Subgrade cap material or subgrade in a restoration fill project (topped with clean sediment or other fill)

- Road and bridge construction
- Manufacture of commercial products

It is unlikely that private parties would accept treated sediment for construction purposes due to the nature of the contamination. Potential beneficial use, other than made land, is therefore likely to be limited to solid waste landfill cover material, fill material for large government construction projects, such as highways and airports, and strip mine reclamation fill material.

Beneficial use may be applicable to raw sediments, to coarser-grained sediments separated from fine-grained sediments through solids classification pretreatment, or soil washing treatment, or to treated sediments. It is also likely that beneficial use options would require meeting certain appropriate criteria for the specific use.

Solid Waste Landfill Cover
Soils are used in the operation of solid waste landfills to provide daily cover, interim cover, and final cover. This material must be amenable to handling by typical earth moving equipment such as front end loaders and dump trucks; must be spreadable; and must be able to be compacted under the wheels or tracks of trucks and bulldozers.

The contaminated sediments from Richmond Creek and marsh are largely clays, silts, and sandy silts. Therefore, given their small grain size, they are not appropriate as daily or interim cover at a landfill since such materials are more likely to become airborne or erode. If mixed with sand, the material may be acceptable.

A comparison was made between the maximum concentration of contaminants within the first two feet of the creek and marsh bottom to NYS TAGM recommended soil cleanup criteria (based on residential use) and/or EPA risk-based soil cleanup (RBCs) levels for industrial use scenarios (NYSDEC, 1994 and USEPA, 2005c). Tables 3-1 and 3-2 present this data. For the creek sediment, the maximum concentration of benzo(a)anthracene, benzo(a) pyrene and all 13 inorganic compounds exceeded the NYSDEC TAGM soil cleanup criteria, which are based on residential use exposure assumptions. In contrast, all chemicals but benzo(a) pyrene and arsenic met the EPA Region 3 RBC for industrial use. For the marsh sediment, 12 inorganic compounds exceeded the NYSDEC TAGM soil cleanup criteria for residential use exposure assumptions but met the EPA Region 3 RBC for industrial use. However, again, the arsenic concentrations in the marsh exceeded the EPA industrial use cleanup criteria.

Therefore, due to the elevated benzo(a)pyrene and arsenic concentrations, the sediments would probably not be allowed as final landfill cover material unless they were mixed (i.e. diluted) with other non-contaminated material (e.g., sands or organic loams). Given the concentration of arsenic present, and the most likely mass-weighted average concentrations present on site, a mixture of offsite "clean" soil to onsite sediments in a ratio of 1000 to 1 would be required.

Table 3-1

Comparison of COPC Results in Creek Sediment with NYSDEC TAGM and EPA Region 3 RBCs for Industrial Use
Brookfield Avenue Landfill OU 2 Feasibility Study

CAS NO.	Chemical	Min	Q	Max	Q	Units	NYSDEC TAGM		EPA Region 3
							Based on GW protection	Rec. Cleanup Objective	RBCs Industrial use
	SVOCs								
56-55-3	Benzo(a)anthracene	63	J	780		µg/kg	3000	224 OR MDL	3.90E+03
50-32-8	Benzo(a)pyrene	70	J	750		µg/kg	11000	61 or MDL	3.90E+02
	PESTICIDES/PCBs								
50-29-3	4,4'-DDT	0.42	J	120	D	µg/kg	2,500	2,100	8.40E+03
319-84-6	alpha-BHC	2.5	J	3.1	J	µg/kg	200	110	4.50E+02
	Chlordane						2,000	540	
5103-71-9	alpha-Chlordane	0.64	J	14	J	µg/kg			8.20E+03
5103-74-2	gamma-Chlordane	0.64	J	0.77	J	µg/kg			8.20E+03
	PCBs						10,000	1,000 (surface) or 10,000 (subsurface)	1.40E+03
12674-11-2	Aroclor-1016	11	J	13	J	µg/kg			4.10E+04
11104-28-2	Aroclor-1221	2.8	J	3.3	J	µg/kg			1.40E+03
11141-16-5	Aroclor-1232	17	J	20	J	µg/kg			1.40E+03
53469-21-9	Aroclor-1242	4.7	J	5.6	J	µg/kg			1.40E+03
12672-29-6	Aroclor-1248	12	J	14	J	µg/kg			1.40E+03
11097-69-1	Aroclor-1254	22	J	160		µg/kg			1.40E+03
11096-82-5	Aroclor-1260	4.2	J	5.1	J	µg/kg			1.40E+03
959-98-8	Endosulfan I	1.1	J	1.3	J	µg/kg	900	900	6.10E+06
33213-65-9	Endosulfan II	0.64	J	0.77	J	µg/kg	900	900	6.10E+06
1031-07-8	Endosulfan Sulfate	1.3	J	1.5	J	µg/kg	1,000	1,000	6.10E+06
	INORGANICS								
7440-36-0	Antimony	0.39	J	5.3	J	mg/kg	NA	SB (2.18)	4.10E+02
7440-38-2	Arsenic	0.57	J	60.3		mg/kg	NA	7.5 or SB (13.8)	1.90E+00
7440-43-9	Cadmium	0.1	J	9.3	J	mg/kg	NA	1 or SB (0.79)	5.10E+02
7440-47-3	Chromium	4.8	J	178	J	mg/kg	NA	10 or SB (66.5)	3.10E+03
7440-50-8	Copper	3.2	J	453	J	mg/kg	NA	25 or SB (88.9)	4.10E+04
7439-89-6	Iron	2,310	J	47,200	J	mg/kg	NA	2,000 or SB (22,300)	3.10E+05
7439-92-1	Lead	2.5	J*	304	J	mg/kg	NA	SB (165)	
7439-96-5	Manganese	12	J	652	J	mg/kg	NA	SB (200)	2.00E+04
7439-97-6	Mercury	0.04	J	9.8		mg/kg	NA	0.1 (0.81)	1.00E+02
7440-02-0	Nickel	5.3	J	97.1	J	mg/kg	NA	13 or SB (153)	2.00E+04
7440-22-4	Silver	0.48	J	5.8	J	mg/kg	NA	SB (1.2)	5.10E+03
7440-66-6	Zinc	10.1	JN	620	J	mg/kg	NA	20 or SB (195)	3.10E+05

= the maximum concentration of the COPC exceeds NYSDEC TAGM recommended cleanup criteria (residential use).
= the maximum concentration of the COPC in sediment exceeds the EPA Region 3 RBC for industrial use.

Abbreviation

COPC: Chemical of potential concern identified in risk assessments
MDL: Method detection limit
NYSDEC: New York State Department of Environmental Conservation
TAGM:Technical and Administrative Guidance memorandum
GW: Groundwater
Min.: Minimum
Q: lab qualifier
Ref.: Reference
RBC: Risk based concentration
Max.: Maximum
NA: Not available
Rec.: Recommended
SB: Site background

Note:
(number) is the mean background value from OU2 Remedial Investigation Report Table 6-19.
Data based on sediment samples from 0-12 inches.
Only chemicals detected at FD>6.5% included (i.e., detected in 3 or more samples of 31 total samples).

Qualifiers:
J: Estimated data due to exceeded quality control criteria
D: Compound is identified as a secondary dilution factor

Table 3-2

Comparison of COPC Results in Marsh Sediment with NYSDEC TAGM and EPA Region 3 RBCs for Industrial Use

CAS NO.	Chemical	Min	Q	Max	Q	Units	NYSDEC TAGM		EPA Region 3
							Based on GW protection	Rec. cleanup objective	RBCs Industrial Use
	PESTICIDES/PCBs								
72-54-8	4,4'-DDD	0.9	J	60	J	µg/kg	7,700	2,900	1.20E+04
72-55-9	4,4'-DDE	0.9	J	530	JD	µg/kg	4,400	2,100	8.40E+03
50-29-3	4,4'-DDT	0.9	J	190	JD	µg/kg	2,500	2,100	8.40E+03
319-84-6	alpha-BHC	3.9	J	7	J	µg/kg	200	110	4.50E+02
	Chlordane						2,000	540	
5103-74-2	gamma-Chlordane	0.96	J	1.8	J	µg/kg			8.20E+03
5103-71-9	alpha-Chlordane	0.96	J	1.8	J	µg/kg			8.20E+03
	PCBs						10,000	1,000 (surface), 10,000 (subsurface)	
12674-11-2	Aroclor-1016	17	J	30	J	µg/kg			1.40E+03
11104-28-2	Aroclor-1221	4.2	J	7.6	J	µg/kg			1.40E+03
11141-16-5	Aroclor-1232	26	J	47	J	µg/kg			1.40E+03
53469-21-9	Aroclor-1242	7.1	J	13	J	µg/kg			1.40E+03
12672-29-6	Aroclor-1248	18	J	32	J	µg/kg			1.40E+03
11097-69-1	Aroclor-1254	34	J	250	J	µg/kg			1.40E+03
11096-82-5	Aroclor-1260	6.4	J	12	J	µg/kg			1.40E+03
319-86-8	delta-BHC	0.64	J	1.2	J	µg/kg	300	300	4.50E+02
959-98-8	Endosulfan I	1.6	J	2.9	J	µg/kg	900	900	6.10E+06
33213-65-9	Endosulfan II	0.96	J	1.8	J	µg/kg	900	900	6.10E+06
1031-07-8	Endosulfan Sulfate	1.9	J	3.5	J	µg/kg	1,000	1,000	6.10E+06
76-44-8	Heptachlor	3.2	J	5.8	J	µg/kg	100	100	6.40E+02
	INORGANICS								
7440-36-0	Antimony	1.8	J	19.7	J	mg/kg	NA	SB (2.18)	4.10E+02
7440-38-2	Arsenic	2.4		349	J	mg/kg	NA	7.5 or SB (13.8)	1.90E+00
7440-43-9	Cadmium	0.25	J	4.2	J	mg/kg	NA	1 or SB (0.79)	5.10E+02
7440-47-3	Chromium	5.2		269		mg/kg	NA	10 or SB (66.5)	3.10E+03
7440-50-8	Copper	12.1		936	J	mg/kg	NA	25 or SB (88.9)	4.10E+04
7439-89-6	Iron	5,380		51,400		mg/kg	NA	2,000 or SB (22,300)	3.10E+05
7439-92-1	Lead	11.3		984		mg/kg	NA	SB (165)	
7439-96-5	Manganese	30.9	J	7,680	J	mg/kg	NA	SB (200)	2.00E+04
7439-97-6	Mercury	0.08		7.9	J	mg/kg	NA	0.1 (0.81)	1.00E+02
7440-02-0	Nickel	6.3	J	224	J	mg/kg	NA	13 or SB (153)	2.00E+04
7440-22-4	Silver	0.9	J	6.3	J	mg/kg	NA	SB (1.2)	5.10E+03
7440-66-6	Zinc	26.8		601	J	mg/kg	NA	20 or SB (195)	3.10E+05

= the maximum concentration of the COPC exceeds NYSDEC TAGM recommended cleanup criteria (residential use).

= the maximum concentration of the COPC in sediment exceeds the EPA Region 3 RBC for industrial use.

Abbreviation

COPC: Chemical of potential concern identified in risk assessments
Min.: Minimum
NYSDEC: New York State Department of Environmental Conservation
TAGM:Technical and Administrative Guidance memorandum
GW: Groundwater
NA: Not available
Rec.: Recommended
SB: Site background
RBC: Risk based concentration
Max.: Maximum
Min.: Minimum
Q: lab qualifier
Ref.: Reference

Note:

(number) is the mean background value from OU2 Remedial Investigation Report Table 6-19
Data based on sediment samples from 0-12 inches.
Only chemicals detected at FD>6.5% included (i.e., detected in 3 or more samples of 31 total samples)

Qualifiers:

J: Estimated data due to exceeded quality control criteria
D: Compound is identified as a secondary dilution factor

Table 3-3

Summary of Remedial Technologies Screening
Brookfield Avenue Landfill OU2

Response Actions	Technologies	Process Options	Types
No Action			
Monitoring with Natural Improvement			
Institutional Controls			
Containment	In situ capping Retaining dikes and barriers	Inert Materials ~~Active Materials~~ ~~Sealing Agents~~ ~~Thin Layer Capping~~	~~clay, silt~~, sand, Aquablock
~~**In Situ Treatment**~~			
Removal	Excavation Dredging ~~Soil Freezing~~	Conventional: Mechanical Hydraulic	DryDredge, Horizontal auger (e.g.: Mud Cat) Plain Suction dredge
Ex Situ Treatment	Sediment Pretreatment	Dewatering ~~Solids Classification~~ ~~Bioremediation~~ ~~Sediment Washing~~ ~~Solvent Extraction~~ ~~Chemical Treatment~~ ~~Thermal Desorption~~ ~~Thermal Destruction~~ Immobilization	
Beneficial Use	~~Landfill Cover~~ Landfill Subgrade Construction Fill ~~Abandoned Mine Reclamation~~ Commercial Products		
Disposal	Off Site Landfill ~~Confined Disposal Facility~~ ~~Contained Aquatic Disposal~~		

In summary, the OU2 sediments are not appropriate for beneficial use as landfill cover unless they are blended with other materials. Therefore, use as landfill cover is not retained for further evaluation.

Solid Waste Landfill Subgrade Material

The chemical concentration of the sediments would not prevent them from being used as landfill subgrade material (i.e., material placed beneath the cap to improve the grading prior to capping the landfill). The subgrade of most municipal waste landfills is usually a native foundation material which is graded to promote drainage to a collection point. The subgrade is smoothed and firmed, preparing it for construction and placement of the subsequent liners. The subgrade may have a minimum hydraulic conductivity requirement and geotechnical requirements. Subgrade is below the final single or double composite cap liner system.

The NYCDEP has received approval from NYSDEC for a specification defining the suitability of post-dredge materials for placement on the Pennsylvania Avenue and Fountain Avenue Landfills as subgrade material. The specification details specific testing requirements and criteria for assessing the suitability of materials. Assuming the same criteria are approved for Brookfield Avenue Landfill, for placement under the cap, additional Toxicity Characteristic Leachate Procedure (TCLP), asbestos, reactive sulfides, and ammonia testing would need to be performed. The OU1 design specifications included the option that NYCDEP may provide a volume of dredged material for possible use as intermediate cover.

For the OU2 dredged material to be considered, additional TCLP testing would probably be necessary. While some TCLP testing was performed during the OU2 RI and none of the samples showed hazardous characteristics, two samples of sediments in the 0 to 2-foot depth range (the material that would be excavated/dredged) were tested. Physical testing would also need to be performed to assess the geotechnical suitability of dredge materials. It is expected that some of the sediments (the "muck") would require blending with another material to meet the geotechnical requirements.

According to current design estimates, Brookfield Avenue Landfill OU1 will require about 440,000 tons (or approximately 600,000 cubic yards) of off-site fill material to meet planned closure subgrades. Therefore, there is a need and a financial incentive for utilizing site-generated material to meet the closure requirements. However, for the OU2 sediment to be used as landfill subgrade material for the OU1 remedy, the schedules for OU2 dredging remedy and the OU1 landfill construction would need to be synchronized. Current construction plans for OU1 are that remediation will start in 2007 with remedial construction completed by 2011. Therefore, subgrade material will most likely be needed later in 2007. Since it is unlikely that an active remedy for OU2 could begin by that time period, another nearby landfill undergoing closure would need to be considered.

The October 2004 NYC Department of Sanitation (NYCDOS) Solid Waste Management Plan indicates that Fresh Kills Landfill cells 1/9 will be undergoing closure until 2012. It also indicates that the preliminary estimate of material needed for sub-base grading at Section 1/9 is approximately 4 million cubic yards. In February 2004, NYSDOS received a Beneficial Use Determination (BUD) from NYSDEC to allow processed dredge material from the New York-New Jersey Harbor Estuary as grading fill beneath the final cover.

Conversations with contractors who have bid on recent Arthur Kill dredging projects indicate that NYSDOS requirements for receiving the material at Fresh Kills include treatment/dewatering at an interim facility, barging the material to the landfill and placement of the material at the landfill.

Since both Fresh Kills and Brookfield landfills are under the closure process and will require a large amount of soil for subgrade fill, it may be possible to use the excavated/dredged sediment as part of the landfill closure. Therefore, beneficial use of sediment as subgrade is retained for further evaluation.

Construction Fill

Utilization of sediments derived from maintenance dredging projects as fill for construction projects is a sediment reuse historically practiced in the NY region. Sediment associated with remediation projects would likely restrict potential demand for these materials to state or federal government projects. However, treated solidified/stabilized sediments from Newark Bay were used as construction fill at the Jersey Gardens Mall project, which is privately owned. Treated or minimally contaminated sediments can also be used in major highway or airport construction where they would be encapsulated safely within pavements or beneath structures. Beneficial use as construction fill is retained for further evaluation.

Abandoned Mine Reclamation

This beneficial use option involves using dredged sediments to reclaim abandoned mine lands. The focus of abandoned mine reclamation is to reduce health and safety issues related to the unreclaimed mines. Pennsylvania, for example, which in the past was a leading coal producer, has many abandoned mines statewide that could potentially use dredged sediments for reclamation. Reclamation can involve filling open mine pits, open shafts, and undermined areas with subsidence problems, and grading surface mine areas to minimize erosion. Prior to use as mine reclamation material, the dredged sediments may be blended with other materials such as biosolids, paper waste, and coal ash to provide products that inhibit acid mine drainage production and facilitate enhanced reclamation and revegetation of abandoned mine lands. Abandoned mine reclamation has benefits, including elimination of physical hazards to people living and working near these sites. The environmental benefits of abandoned mine reclamation include restoration of land for future use and improvement of water quality. Restoration of the land can result in increased pasture land and recreational areas, and enhanced wildlife habitat.

Currently, the use of dredged sediments as mine reclamation material is being evaluated at an abandoned surface mine in the central part of Pennsylvania in a pilot project sponsored by the Office of New Jersey Maritime Resources (USEPA, 2005a). Pending evaluation of groundwater monitoring results from this project, which may require several years, the Pennsylvania Bureau of Abandoned Mine Reclamation (USEPA, 2005a) is not authorizing other reclamation projects using dredged material. Abandoned mine reclamation will not be retained for further evaluation.

Manufacture of Commercial Products

It is possible to combine treatment processes discussed above that would destroy organics or immobilize metals in the sediments with some further physical/chemical processing to convert the decontaminated sediment into a useable commercial product. Potential treatment processes are thermal destruction processes that may involve oxidation and destruction of organic contaminants in an oxygen-rich environment, or pyrolysis and destruction of organic contaminants in an oxygen-poor environment. Additives to stabilize metal can be added in the process. Along with contaminant destruction, other technologies evaluated in this group include further processing such as heating the sediment matrix to the melting point to fuse the matrix into a homogenous glassy liquid, then quenching the melt to make a glass tile product or glass fibers for use in the manufacturing of construction grade cement. Alternately, thermal destruction has been demonstrated to be effective in destroying PCBs in soils and sediments. Thermal destruction, combined with further processing to manufacture a useable product, has an advantage over simple thermal destruction processes in that there is no final product for disposal. Furthermore, processing costs may be recovered when the useable product can be sold commercially. Combined treatment technologies/manufacture of commercial products is technically implementable and will be retained for further evaluation.

3.1.11 Disposal Technologies

Should an active removal remedy be considered, some means would need to be employed to provide final disposal of any sediments that are physically removed from Richmond creek and marsh. Some disposal technologies may require dewatering prior to implementation and, depending on the particular technology and contaminant concentrations, some form of ex situ treatment may be required. Disposal technologies that may be considered include land disposal and aquatic disposal.

Land Disposal

Land disposal of contaminated sediments may be accomplished in landfills or in confined disposal facilities (CDFs). CDFs can accommodate hydraulically dredged sediments and are designed and operated to accomplish both dewatering and encapsulation. USEPA (2005) notes that CDFs are cost-effective, and with proper location, design, and construction can perform well in isolating contaminants from the environment.

Due to typical restrictions on liquids in landfills, the sediment needs to be dewatered before disposal in a landfill. Methods for dewatering are discussed in previous Section 3.1.8.2. There are several landfills near the study area, these landfills are under closure and no longer accept waste. The use of off-site landfills is also considered. However, the additional handling and transportation of the material to an off-site landfill would add significantly to the cost.

Off-Site Landfill

Dredged material may legally be disposed of in a municipal or solid waste landfill. Sediment from Richmond Creek has low levels of contaminants. While some material exceeds industrial use standards, the sediment could potentially be disposed in a municipal landfill. Off-site landfill disposal may require transportation, potentially to great distances. This option is technically implementable and is retained for further evaluation.

Confined Disposal Facility

The confined disposal facility (CDF) is an engineered structure enclosed by dikes and specifically designed to contain contaminated sediment. The facility must be large enough to provide adequate capacity to meet dredging requirements and must efficiently retain solids while allowing supernatant to be released. CDFs are usually used with hydraulic dredges. If it is possible that land north of Richmond Creek in the location of the current interceptor sewer could be used to build a CDF, a CDF option could be considered. However, since the land is currently owned by NYC Parks and planning for the area includes parks and open space land use, disposal at a CDF is not considered further.

Contained Aquatic Disposal

Contained aquatic disposal is a type of subaqueous capping in which the contaminated dredged sediment is placed into a natural or excavated depression elsewhere in the water body. It involves subaqueous covering or capping of dredged sediments. These disposal options are rarely considered for environmental dredging projects, largely due to risk concerns. The presence of arsenic, mercury, pesticides, and PCBs in the Richmond Creek sediment and the toxic effect of the creek sediment to burrowing benthic organisms indicate that contained aquatic disposal is not a suitable option for disposal. Contained aquatic disposal is not retained for further evaluation.

3.1.12 Summary of Initial Screening of Technologies

A summary of the identification and screening of potential remedial technologies for the Brookfield Avenue Landfill OU2 site is presented on Table 3-3. Aside from No Action, Monitoring with Natural Improvement, and Institutional Controls, there are five categories of general response actions feasible for remediation of the sediment from Richmond Creek and marsh. These are containment, removal, ex situ treatment, beneficial use, and disposal. In connection with these five general response actions, several technologies with various process options have been evaluated for

effectiveness and technical implementability. Five technologies were considered and excluded during this evaluation: soil freezing, landfill cover, abandoned mine reclamation, confined disposal facility and contained aquatic disposal.

All of the active potential remedies involve at least temporary destruction of wetland function. Containment of the sediments in place without dredging is the active remedial response least destructive to the sediment wetland environment. Containment systems such as capping and retaining structures are methods for controlling sediment resuspension under the range of expected hydraulic conditions. While retaining dikes and berms may be used as part of a containment scheme, it is most likely that capping with inert materials would provide more long-term effectiveness and stability than dikes or berms alone.

Technologies applicable to treating the Richmond Creek sediments in situ have also been considered. In situ treatment technologies would likely be more destructive to wetland functions than containment but less so than removal. The main limitation of in situ treatment is the lack of process control during treatment, which can lead to incomplete or ineffective treatment and contaminant release to the water column. All active in situ treatment technologies were eliminated in this first stage of screening for these reasons. As discussed previously, existing wetlands can perform many in situ remediation functions (e.g., phytoremediation) without disruption of the natural habitat and its associated benefits.

Bottom sediments may be removed if other less destructive technologies are not cost-effective or protective. Excavation and environmental dredging using conventional or specialty dredges has been retained for further evaluation. Equipment modifications and operational controls to reduce sediment dispersion during dredging, such as using cutterhead dredge shrouds, adjusting cutterhead rotational speed, employing scow-filling controls, and setting limitations on cutterhead swing speed, are important considerations. Excavation may generate less sediment resuspension than dredging because the work zone can be isolated from the adjacent water body or dewatered prior to removal of contaminated sediments.

If contaminated bottom materials are removed, it would be necessary to dispose of the removed materials directly or to treat those materials and dispose of the treated residuals. Physical, chemical, biological, and thermal processes or technologies, or combinations thereof, have been proposed for treatment of the contaminated solids. Of the treatment technologies evaluated, only solidification/stabilization technologies were retained for further consideration because, based on results from other sites, treatment for the variety of contaminants present in Richmond Creek may be difficult to achieve within a reasonable time frame for the large volume of dredged sediments.

Beneficial use options of either using the dredged sediment in its original form or processing the treated material to create a useable commercial product, were evaluated and retained. Using the material as solid waste landfill cover was ruled out

due to its contaminants. However, use as subgrade capping material, construction fill and in consumer products were all retained for further evaluation.

The final category of remedial technologies considered involves disposal of either untreated contaminated sediments or the residuals from treatment of contaminated sediments. Land disposal options have been retained for further assessment. Upland disposal, which would involve obtaining approval to construct a near-by CDF specifically for contaminated sediments removed from the creek, and near-shore disposal in a facility located within the 100-year floodplain or in shallow, non-navigation areas of the river, are two land disposal options that were ruled out. Aquatic disposal has also been ruled out based on the lack of suitable area to accommodate the quantity of material expected.

Section 4
Development and Detailed Evaluation of Site Remediation Alternatives

4.1 Development of Remedial Alternatives

The remedial goal for all remedial actions conducted under NYSDEC's Inactive Hazardous Waste Disposal Program is the restoration of the site to pre-disposal conditions, to the extent feasible and authorized by law. At a minimum, the remedy shall eliminate or mitigate all significant threats to the public health and the environment presented by the contaminants disposed at the site through the proper application of scientific and engineering principles (6 NYCRR Subpart 375-1.10).

As indicated in Chapter 2, the RAOs developed for the Brookfield Avenue Landfill OU2 site include:

1. Minimize direct contact with contaminated sediment

2. Prevent releases of contaminants from sediments that would result in surface water levels in excess of ambient water quality criteria;

3. Prevent or minimize human consumption of aquatic biota that is incompatible with existing health advisories

4. Preserve productive ecological habitat of the existing wetlands, marshes and open water areas

5. Ensure compatibility with the Operable Unit 1 remedy and the End Use Plan for the Site.

USEPA's Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (January 2005 Draft, Peer Reviewed Document) states that all remedies for contaminated sediment should be considered only after adequate source control has been accomplished. The remedial actions planned for OU1 (Landfill Capping, Leachate Collection, Subsurface Barrier Wall Installation, Landfill Gas Collection and Wetland Enhancements) constitute source control of contributions of contaminants from OU1 to OU2. Therefore, all alternatives carried forward in this FS have assumed that the OU1 remedy of landfill capping, leachate collection, landfill gas recovery, slurry wall construction, and wetland upgrades is implemented. Contaminant loading to area waterways including Richmond Creek is also expected to occur.

NYSDEC regulations (6 NYCRR Subpart 375-1.10), specify that remedies be selected upon due consideration of the following seven factors:

- Compliance with standards, criteria and guidance (SCGs);

- Overall protectiveness of public health and the environment;
- Short-term effectiveness;
- Long-term effectiveness;
- Reduction of toxicity, mobility, and volume with treatment;
- Feasibility (i.e. implementability and cost-effectiveness); and
- Community Acceptance.

Per NYSDEC's DER-10 Technical Guidance for Site Investigation and Remediation (NYSDEC 2002) the first six criteria are employed in the detailed analysis of alternatives for remediation of Brookfield Avenue Landfill OU2. The last criteria (Community Acceptance) would be addressed in NYSDEC's ROD.

The alternatives described in the following analyses are conceptual. Any characteristics of these alternatives (such as remediation locations, depths, and removal/capping rates), while based on the available data and information, should be considered preliminary. In addition, some of the alternatives would impact wetlands. If necessary, estimates of the wetland impacts would be refined, and replacement and mitigation methods would be developed during remedial design.

The five candidate alternatives for remediation of the contaminated sediments in Richmond Creek are listed below and discussed in the following sections.

Alternative 1: No Action (except for the OU1 Remediation, i.e., Landfill Capping, Leachate Collection, Subsurface Barrier Wall Installation, Landfill Gas Collection, Wetland Enhancements)

Alternative 2: Institutional Controls and Monitoring (includes OU1 Remediation, i.e. Landfill Capping, Leachate Collection, Subsurface Barrier Wall Installation, Landfill Gas Collection, Wetland Enhancements)

Alternative 3: Sediment Removal in Creek and Marsh, Restoration, and Beneficial Use/Disposal (includes OU1 Remediation and Institutional Controls)

Alternative 4: Sediment Removal in Creek and Intertidal Marsh, Restoration, and Beneficial Use/Disposal (includes OU1 Remediation and Institutional Controls)

Alternative 5: Sediment Removal in Creek and Beneficial Use/Disposal (includes OU1 Remediation and Institutional Controls)

4.2 Alternative 1: No Action (except for OU1 Remediation including Landfill Capping, Leachate Collection, Subsurface Barrier Wall Installation, Landfill Gas Collection, Wetland Enhancements)

4.2.1 Description

Alternative 1, the No Action alternative, consists of no active remediation of sediments in Richmond Creek and marsh. There would be no removal, disposal, treatment or containment of contaminated sediments. While Alternative 1 assumes that the source control remedy of OU1 is implemented, as per NYSDEC guidance, the No Action alternative also assumes that non-project institutional controls currently in place, such as area -wide fish consumption advisories, are continued but additional institutional controls are not put into place. No monitoring is assumed to take place under Alternative 1. There is no cost associated with this alternative.

4.2.2 Analysis

4.2.2.1 Overall Protection of Human Health and the Environment

For the No Action alternative, cancer and non-cancer health hazards exceed the EPA acceptable range of 10^{-4} to 10^{-6} and HI's of 1 almost exclusively due to the assumed consumption of finfish and shellfish. Unacceptable human health risks to adults and children due to exposure to surface water were not identified. Unacceptable risks to adults due to exposure to sediment were also not identified. A hazard index of 2 (considered significant but relatively low) was calculated for children directly exposed to the highest concentrations in marsh sediment. Public access to OU2 adjacent to the landfill is limited since the landfill is enclosed by fencing. In the future, following implementation of the OU1 remedy, there will not be direct public access to the creek. Therefore, opportunities for direct contact with sediment are limited.

The ecological toxicity quotients exceed the acceptable level of one. Surface water risks were considered low (HQ < 10) for all detected chemicals except for mercury (HQ = 170) and barium (HQ = 22). HQs of all detected chemicals from the Richmond Creek sediment were below 10, except for copper (HQ = 12) and mercury (HQ = 13). Marsh sediment-based risks were low (HQ < 10) for all of the detected chemicals.

Sediment samples were tested for acute toxicity in the fish *Menidia beryllina*, the sandworm *Neries virens*, and the grass shrimp *Palaemonetus pugio* in 96-hour and 10-day flow through exposures. The results indicated there was no measurable acute toxicity to the three test organisms. A second round of acute (10-day) toxicity testing was performed on the amphipod, *Ampelisca abdita*. Amphipod survival after completion of the 10 day tests was between 52% and 59%, however, amphipod densities and abundance have been linked to levels of degradation in the sediments of New York Harbor (Cristini, 1990).

Fish and shellfish obtained from the creek contain concentrations of site-related chemicals that have prompted NYS to issue consumption advisories to address protection of human health. The No Action Alternative includes the continuation of existing area wide fish consumption advisories but does not include imposition of additional advisories or restrictions, if warranted.

Protection of the existing estuary and wetlands would be realized under the No Action alternative. This alternative is protective of the environment because it achieves the NYSDEC's goal of "Do No Harm". Recent studies have indicated that the functionality of wetlands is difficult to recreate (National Academy of Sciences, 2001); therefore, by attempting to rebuild a wetland, existing functionality may be lost. In addition, the No Action alternative, like the Monitoring and Natural Improvement alternative (discussed below) would do nothing to alter the environment further from pre-disposal site conditions. It is expected that natural improvements will occur with the removal of sources such as leachate from OU1. Alternatives involving removal of sediment material will result in some associated damage to or destruction of the wetland and result in eventual recontamination. As cited in Section 1.3.1.2 restoration of wetlands is possible but they rarely recover full functionality. Therefore, the two non-active, non-intrusive alternatives are considered to be more effective at returning OU2 to pre-disposal conditions than the sediment removal alternatives.

4.2.2.2 Compliance with SCGs

Alternative 1 is expected to improve compliance with the chemical-specific SCGs for surface water and sediment due to the implementation of the OU1 remedy and eventual control of other sources. Since there is no active remedial action associated with this alternative, action-specific SCGs do not apply. Notably, Alternative 1 would meet the location-specific federal and state SCGs for wetlands and habitat protection, since no action would be taken that could disrupt the existing ecosystem. Thus there would be no potential for disrupting the natural functionality of this system. The ability of the ecosystem to improve surface water and sediment concentrations after source control is similar under Alternatives 1 and 2 where no active removal or wetlands destruction would occur.

4.2.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

For Alternative 1, surface water quality would improve as a result of the source control implemented by capping the landfill (OU1). Also, the change in the geochemistry of the marsh and creek may reduce the solubility and bioavailability of the contaminants in the sediments immediately adjacent to the landfill. The contamination levels within the surficial creek and marsh sediments and within the tissue of biota from Richmond Creek are anticipated to gradually improve over several decades. Residual risks to human health and ecological receptors (fish-eating birds and mammals) posed by the contaminated sediments should gradually decrease over time.

Adequacy of Controls
Alternative 1 will take advantage of the substantial source control provided by the OU1 remedy (capping, groundwater barrier wall, landfill gas collection and leachate collection at the landfill). Furthermore, the No Action alternative also includes the continuation of existing institutional controls put in place to reduce public health risks, but does not include any additional institutional controls (beyond those planned for OU1) to limit exposure to local citizens (consumption advisories, use restrictions, etc.). In addition, Alternative 1 does not include monitoring to assess the impact of source controls or the adequacy of institutional controls.

Reliability of Controls
The OU1 controls are anticipated to be reliable. However, since no additional institutional controls would be put in place, the overall reliability of the effectiveness of Alternative 1 is moderate.

4.2.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 does not involve any active containment, treatment or removal of contaminants from Richmond Creek sediments and does not include any treatment. However, the separate source control achieved by the OU1 remedy and other source control efforts in the area are expected to reduce the water column concentrations of heavy metals, PCBs and pesticides in OU2. Alternative 1 allows the naturally-occurring wetland processes such as sediment deposition, dispersion, advection, and biotransformation processes to sequester, destroy, or dilute the sediment contaminant inventories of the creek, resulting in a decline in surface sediment and water column contaminant concentrations. Biodegradation processes convert some of the more toxic persistent organic chemicals (PCBs, DDT) into less toxic contaminants and may serve to complex the heavy metals into less bioavailable forms. Natural dilution of the contaminated sediments would also reduce the toxicity, but the overall volume of sediments with concentrations in excess of background would increase for the short term as contaminants are dispersed within the estuary. However, some of these contaminants would be flushed from the creek. Concentrations of PCBs, pesticides and heavy metals in fish, and thus the toxicity and volume, would respond slowly over time to decreases in the concentrations in sediments and surface water. This assumes that the fish receive their exposures solely from the area of Richmond Creek adjacent to Brookfield Landfill. Reductions of sediment concentrations are expected to improve compliance with specific SCGs.

4.2.2.5 Short-Term Effectiveness

Short-term effectiveness is assessed through review of the four components: protection of the community during remedial actions; protection of workers during remedial actions; potential adverse environmental impacts resulting from construction and implementation; and time until remedial response objectives are achieved.

Protection of the Community During Remedial Actions
No construction activities are associated with Alternative 1; therefore, this alternative is unlikely to pose any risk to the community during its implementation. However, with respect to community protection, since no additional institutional controls are implemented under Alternative 1, implementation of this alternative would result in exposures similar to those currently experienced. Therefore, the short term effectiveness of this alternative is neutral, with minor improvements achieved through wetlands functionality.

Protection of Workers during Remedial Actions
No construction activities are associated with Alternative 1; therefore, this alternative is unlikely to pose any risk to workers.

Potential Adverse Environmental Impacts Resulting from Construction and Implementation
No construction activities are conducted for Alternative 1, therefore, this alternative is unlikely to pose any adverse environmental impacts from construction. The existing ecosystem will not be disturbed and thus there is no potential for upsetting the natural functionality of the system.

Time until Remedial Response Objectives Are Achieved
Implementation of the OU1 remedy will reduce the amount of landfill leachate flowing into the creek and marsh almost immediately, resulting in gradually improving conditions in surface water. Changes in concentrations of contaminants in sediment will occur more slowly. Additional improvement is expected as other source control efforts in the area are completed, such as final capping and closure of sections of the Fresh Kills Landfill. As demonstrated in Section 1, the Fresh Kills Landfill has been a much larger source of contaminants to surface water and sediment over the years. The observed reduction in surface water concentrations over the last five to seven years are a likely result of the leachate control systems that were completed in 1997 at the Fresh Kills Landfill.

4.2.2.6 Implementability

Technical Feasibility
Alternative 1 only requires standard documentation and reporting to implement; therefore, it is technically feasible and readily implementable.

Administrative Feasibility
Alternative 1 only does not require any administrative tasks to implement; therefore, it is administratively feasible and readily implementable.

Availability of Services and Materials
All the services and materials needed to implement Alternative 1 are readily available.

4.2.2.7 Cost

There are no capital or O&M costs associated with Alternative 1.

4.3 Alternative 2: Institutional Controls and Monitoring (including Source Control of OU1, i.e., Landfill Capping, Leachate Collection, Gas Collection, Subsurface Barrier Wall Installation, Wetland Enhancements)

4.3.1 Description

Alternative 2, Institutional Controls and Monitoring consists of no active removal, disposal, treatment or containment of contaminated sediments, so that the existing functioning estuary and coastal wetlands as well as the habitat for aquatic and terrestrial animals and plants supported by these systems are maintained and protected. Alternative 2 does include source control of OU1 and assumes continuing reduction of other area sources of contaminants. The landfill capping, slurry wall construction, landfill gas and leachate collection will stop the flow of contaminated groundwater and leachate from entering the creek and marsh and prevent the transport of contaminated soil and waste into the creek and marsh from overland flow. In addition, Alternative 2 includes the continuation of the current institutional controls such as the New York State fish consumption advisories. It may also include new (additional) institutional and/or engineering controls.

These principal components of the Institutional Controls and Monitoring alternative include, as described below:

- Source control of the landfill contaminants through the completion of the OU1 remedy;
- Natural reduction of contamination within the sediments;
- Institutional controls to limit human health exposures; and
- A surface water monitoring program.

This alternative will allow the natural reduction of volume and toxicity of contaminants in the sediments by naturally occurring biological, chemical, and physical processes. Some wetland processes known to achieve this reduction in contaminant concentrations include biodegradation, biotransformation, bioturbation, diffusion, dilution, adsorption, volatilization, chemical reaction or destruction, resuspension, and burial by cleaner material. For biological processes, microorganisms in marsh deposits can provide organic contaminant uptake and storage by utilizing the carbon in the organic matters as a source of energy and then converting it to carbon dioxide or methane gases. Wetland plants and vegetation, such as woody and herbaceous plants and algae, can uptake excess nutrients (nitrate, ammonium, and phosphate) as well as organic compounds and metals. Woody plants can offer long-term storage of contaminants and herbaceous plants have high

contaminant uptake rate per unit area. Peat formed by slow anaerobic decomposition of organic matters in wetland soil can store pollutants long-term. Certain bacteria can permanently remove inorganic nitrogen, such as nitrate, by metabolically transforming nitrate into nitrogen gas (denitrification). Ammonium can be removed in wetlands through sequential nitrification and denitrification processes by microbial transformation of ammonium to nitrate in aerobic soil and surface water and then denitrification in deeper anaerobic soil.

Chemical processes also play a role in pollutant removal in wetlands. Sorption causes long-term immobilization of contaminants via transfer of ions from solution phase to solid phase. This two-reaction process consists of adsorption and precipitation. Adsorption is the attachment of ions to soil particles (clay and organic matters) by either cation exchange or chemisorption. Phosphate and calcium in the wetland soil can precipitate with metals to form mineral compounds. Volatilization is diffusion of a dissolved compound from the water into the atmosphere. Sedimentation is a physical removal mechanism. The laminar flow of surface water in wetlands helps to settle particulate matters. Mats of floating plants serve as sediment traps and limit resuspension of settled particulates.

Institutional controls (*e.g.*, site use restrictions) would be implemented as long-term control measures as part of this alternative. These restrictions include continuation or modification of the existing fish consumption advisories. Also, given the end use plan for the OU1 landfill and the neighboring Fresh Kills, future recreational opportunities in Richmond Creek may warrant the development of additional institutional controls/restrictions. For example, swimming restrictions may need to be imposed. There may be the need for restrictions on the type of boating allowed in the creek.

Monitoring would be conducted in the water column as part of this alternative. Monitoring would consist of two consecutive years of surface water quality monitoring to be performed three years after the OU1 remedy is complete. The purpose of the monitoring is to demonstrate the effectiveneness of the OU1 remedy, the reduction of other area sources, and the natural improvement resulting from the function of the established wetlands once external sources are removed. Biota monitoring is regularly performed by NYSDEC and the data is used by the NYSDOH in their evaluation of the need for consumption advisories. Therefore, biota monitoring is assumed to occur but is not included in OU2 remedy performance monitoring by NYCDEP. Monitoring may also include review of other available data that pertains to contaminant concentrations of shallow sediment and water column in OU2 and elsewhere in the estuary (monitoring of a location in Richmond Creek is performed by IT as part of a long-term monitoring program for Fresh Kills Landfill)..

Additional monitoring will be performed as part of post-closure monitoring of the OU1 final remedial system (landfill cap, barrier wall, leachate and gas collection systems). This monitoring is projected to occur for the typical 30-year post closure-monitoring period, and will include: groundwater sampling of 26 wells, surface water

sampling at 5 locations, and landfill gas monitoring. This post-closure monitoring will be performed quarterly for the initial 5 years and then annually.

Reductions in contaminant concentrations inventory would be documented by laboratory analysis similar to that conducted in the OU2 RI. Water column samples would be analyzed for site-specific contaminants, total suspended solids (TSS), and fraction of organic carbon on the suspended solids.

4.3.2 Analysis

4.3.2.1 Overall Protection of Human Health and the Environment

Alternative 2 takes advantage of the naturally-occurring wetland processes such as sediment deposition, bioturbation, dispersion, advection, and biotransformation to sequester, destroy, or dilute the sediment contaminant inventories in the Richmond Creek and marsh, resulting in a decline in surface sediment and water column contaminant concentrations. Protection of the existing estuary and wetlands would be realized under the Institutional Controls and Monitoring alternative. It also avoids destruction of the functioning wetlands and the flora and fauna habitats it provides. In this respect, this alternative is protective of the environment because it achieves the NYSDEC's goal of "Do No Harm".

Alternative 2 will address the human health risks posed by the site through the use of fish consumption advisories and other institutional controls to limit the public's exposure to site-related organic contaminants and metals. This alternative builds upon the separate source control provided by the OU1 remedy, which would eliminate the current flux of contaminants emanating from the landfill in the dissolved phase as well as prevent future contamination from overland flow. While it would not immediately remove the contaminated sediments present in the creek and marsh due to historic releases at the landfill, it is anticipated that over time these contaminated sediments will become buried, degraded, and/or dispersed and flushed.

The OU2 sampling conducted in Richmond Creek and the marsh has suggested that biodegradation, dispersion, sediment deposition, and other processes have already reduced the concentrations of metals and persistent organics within the creek. Appendix A presents the historical trend of mean, maximum and minimum sediment concentrations for each contaminant in sediment and surface water samples collected near the site over the past 15 years. IT sample results from station WC-12 (located just north of the west cell of OU1) are compared to the OU1 and OU2 sample results from surface water (low tide) and sediment samples obtained within Richmond Creek. The results for metals in surface water are mixed with the concentrations for some chemicals decreasing (e.g. antimony and nickel) since the OU1 sampling event in 1997 and the concentrations for arsenic, iron, lead, mercury, silver and zinc staying about the same. It is expected that the capping, barrier wall and leachate controls of the OU1 remedy will reduce the concentration of these chemicals within the surface water. For sediment, an overall reduction of mean concentrations is evident for all organic contaminants. In addition, the mean concentrations of all metal contaminants in

sediment have decreased from the levels measured in the OU1 sampling (1994 and 1997).

4.3.2.2 Compliance with SCGs

Due to the source control of the OU1 remedy, the flux of dissolved contaminants from the landfill would be eliminated and surface water SCGs should improve after completion of the OU1 remedy. With the source control of the OU1 remedy, landfill leachate would be prevented from entering the groundwater and surface waters of the marsh and creek, and the geochemistry of the estuary would return to a more natural state, potentially reducing the bioavailability of the contaminants in the sediment at the site. It is believed that with this change in geochemistry, and assuming deposition and dispersion continue within the estuary at rates seen over the last 10 years, the Institutional Controls and Monitoring alternative would allow the site to improve compliance with biota SCGs.

Since there is no active remedial action associated with this alternative, action-specific SCGs do not apply. Importantly, Alternative 2 would meet all the location-specific federal and state SCGs for coastal estuaries and wetlands, since no action would be taken that could disrupt the existing ecosystem. Thus, there would be no potential for upsetting the natural functionality of the system. In addition, the Institutional Controls and Monitoring alternative would do nothing to alter the environment further from pre-disposal site conditions. Alternatives involving removal of sediment material will result in some associated damage to or destruction of the wetland. As cited in Section 1.3.1.2 restoration of wetlands is possible but they rarely recover full functionality. Therefore, the two non-active, non-intrusive alternatives are considered to be more effective at returning OU2 to pre-disposal conditions than the sediment removal alternatives.

4.3.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

Surface water quality will improve as a result of the source control implemented by capping the landfill and collecting the leachate (OU1).. Control of other area sources of surface water and sediment contamination are also expected to occur. The change in the geochemistry of the marsh and creek may reduce the solubility and bioavailability of the contaminants in the sediments immediately adjacent to the landfill.

Unacceptable human health risks to adults and children due to exposure to surface water were not identified. Unacceptable risks to adults due to exposure to sediment were also not identified. A hazard index of 2 (considered significant but relatively low) was calculated for children directly exposed to the highest concentrations in marsh sediment.

Surface water risks were considered low (HQ < 10) for all detected chemicals except for mercury (HQ = 170) and barium (HQ = 22). HQs of all detected chemicals from the Richmond Creek sediment were below 10, except for copper (HQ = 12) and

mercury (HQ = 13). Marsh sediment-based risks were low (HQ < 10) for all of the detected chemicals. Sediment was generally found to be not toxic.

The contamination levels within the surficial creek and marsh sediments and within the tissue of biota from Richmond Creek will gradually improve over time. Residual risks to human health and ecological receptors (fish-eating birds and mammals) should gradually decrease.

Adequacy of Controls
Alternative 2 takes advantage of the substantial source control provided by the OU1 remedy (capping, groundwater barrier wall, and leachate collection at the landfill. This alternative also includes the existing institutional controls to reduce public health exposures, and consideration would be given to additional institutional and/or engineering controls to limit exposure to local citizens (consumption advisories, use restrictions, etc.).

Reliability of Controls
Institutional controls, such as the existing fish consumption advisories, would continue to provide protection for human health from the consumption of contaminated fish which was identified as the primary exposure pathway and risk to humans. The NYSDOH notes that institutional controls which rely on voluntary compliance are not always fully adequate in achieving desired outcomes (Guastella, 2005). The monitoring and institutional control alternative is more protective of human health than the No Action alternative because additional controls or actions would be implemented, if warranted. Institutional controls associated with this alternative do not address ecological receptors. However, the absence of an active and intrusive remedial response will allow the contaminant removal processes of the wetlands to continue and lower the ecological risks to fish, fish-eating birds and fish-eating mammals. The planned monitoring program (two consecutive years of surface water quality monitoring to be performed three years after the OU1 remedy is complete) provides a basis for demonstrating the effectiveness of the OU1 implementation, reduction in OU1 and other area sources and natural improvement resulting from the function of the established wetlands once external sources are removed. The Institutional Controls and Monitoring alternative will not damage the existing functioning wetland habitat which would happen under any of the active remedial alternatives.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 does not involve any active containment, removal, or artificial treatment of contaminants from Richmond Creek sediments. However, the separate source control effected by the OU1 remedy and contaminant reduction processes of the wetlands are expected to reduce the on site water column concentrations of heavy metals, PCBs and pesticides. Alternative 2 relies on naturally-occurring wetland processes such as sediment deposition, dispersion, advection, and biotransformation processes to sequester, destroy, or dilute the sediment contaminant inventories of the creek, resulting in a decline in surface sediment and water column contaminant

concentrations. Biodegradation processes convert some of the more toxic persistent organic chemicals (PCBs, DDT) into less toxic contaminants and may serve to complex the heavy metals into less bioavailable forms. Natural dilution of the contaminated sediments would also reduce the toxicity of contaminated sediments as contaminants are dispersed within the estuary. Concentrations of PCBs, pesticides and heavy metals in fish, and thus the toxicity and volume, would respond slowly over time to decreases in the concentrations in sediments and surface water. Reductions of sediment concentrations sufficient to improve compliance with specific SCGs are expected to be aided by implementation of OU1 remedies.

4.3.2.5 Short-Term Effectiveness

Short-term effectiveness is assessed through review of the four components: protection of the community during remedial actions; protection of workers during remedial actions; potential adverse environmental impacts resulting from construction and implementation; and time until remedial response objectives are achieved.

Protection of the Community During Remedial Actions

No construction activities are associated with Alternative 2. The monitoring program associated with this alternative does not pose any risk to the community. The implementation of the Institutional Controls and Monitoring alternative would not increase the potential for direct contact and ingestion of contaminants from the surface water and the sediments. Unacceptable human health risks to adults and children due to exposure to surface water were not identified. Unacceptable risks to adults due to exposure to sediment were also not identified. A hazard index of 2 (considered significant but relatively low) was calculated for children directly exposed to the highest concentrations in marsh sediment. Opportunities for direct contact with sediment are assumed to be limited. The risks to human health and to ecological receptors due to the contaminated sediments would not increase during the short term. Due to the separate source control offered by OU1 and wetland processes, the near landfill water column concentrations are expected to be reduced. Since institutional controls will be continued and additional controls may be implemented as part of this alternative, risks to the community for Alternative 2 are similar to or lower than those under the No Action alternative in the short term.

Protection of Workers During Remedial Actions

The persons performing the sampling activities would follow OSHA health and safety procedures and wear the necessary personal protective equipment. A slight increase in occupational risk may be associated with the Monitoring and Institutional Control alternative compared to the No Action alternative due to the greater degree of sampling involved in the creek. There are potential short-term risks to site workers from contact with or accidental ingestion of contaminated surface water and sediments; however, these risks are small. Limited risks also may arise from physical hazards associated with the work (*e.g.*, boating accidents).

Potential Adverse Environmental Impacts Resulting from Construction and Implementation

No construction activities are conducted for Alternative 2. The monitoring program for this alternative is not anticipated to have any adverse effect on the environment. The existing ecosystem will not be disturbed and thus there is no potential for upsetting the natural functionality of this system.

Time until Remedial Response Objectives Are Achieved

It is believed that given the rate of dispersion and deposition documented by historic data, these objectives would take several decades to be achieved.

4.3.2.6 Implementability

Technical Feasibility

Alternative 2 only requires standard sampling and analytical methods to implement; therefore, it is technically feasible and readily implementable.

Administrative Feasibility

In general, the principal administrative task under the Institutional Controls and Monitoring alternative is the continuation of institutional controls, such as the fish consumption advisories. Those tasks are currently being performed and are straightforward to implement.

Availability of Services and Materials

All the services and materials needed to implement this alternative are readily available.

4.3.2.7 Cost

A summary of the details of the cost estimate for Alternative 2, Institutional Controls and Monitoring, is given in Table 4-1. The estimated net present worth cost of this alternative, calculated at a 3.1 percent discount rate, is $749,000.

Capital Costs

There are no capital construction costs associated with this alternative.

O&M Costs

The annual average O&M costs for this alternative are estimated to be about $39,800 and represent the monitoring costs for two sampling events, reporting, and upkeep of signs and fencing. This cost has been estimated for a 30-year period. The present value of the O&M costs is about $749,000. The additional monitoring of the OU1 remedial action that will occur as described above is not included in the OU2 O&M costs.

Table 4-1
Cost Analysis
Alternative 1 No Action (except OU1 Remediation)

Cost Item	Quantity	Unit Cost	Unit	Cost	Reference
Review Costs					
Five-Year Review 2011,2016,2021,2026, 2031,2036	6	$49,300	Event	$295,800	1
Total O&M Costs				$295,800	
Annual Avg. O&M (over 30 years O&M period of 2006 through 2036)				$9,860	
Present Worth of Costs					
Review - Every 5 Years (Years 2011,2016, 2021, 2026, 2031, 2036)				$179,318	
Total Present Worth Costs for Alternative				$179,318	
Round To				$179,000	

Cost Estimate date April 2006
ROD and Design Support assume to start in 2006, Year 0

Sources:
1 Hudson River PCB FS (NYSDOH, 2005)

No Action, monitoring costed for 30 years, first 5 yr review in 2011

"Real" discount (interest) rate (after adjustment for inflation) of 3.1% (based on 30-year Treasury maturities), taken from OMB Circular No. A-94 Appendix C (Revised January 2005)
Present worth costs determined using Microsoft Office Excel "PV" formula

4.4 Alternative 3: Sediment Removal in Creek and Marsh, Restoration, and Beneficial Use/Disposal (includes OU1 Remediation and Institutional Controls)

4.4.1 Description

Alternative 3 would include the complete removal/dredging of the first two feet of sediment from Richmond Creek and the surrounding marsh, selected engineered capping of the areas of the creek where contaminants would remain in place, placement of marsh substrate material within the marsh to appropriate bottom elevations, followed by wetland species revegetation, and beneficial use or offsite disposal of the excavated/dredged sediments.

The principal components of this alternative include, as described below:

- Source control via OU1 Remediation including Landfill Capping, Leachate Collection, Subsurface Barrier Wall Installation, Landfill Gas Collection, and Wetland Enhancements;
- Institutional Controls as for Alternative 2;
- In-stream dewatering and excavation of sediments in Richmond Creek and marsh using conventional earth moving equipment with the use of suction dredges as needed;
- Dewatering excavated sediments with drying beds (and dewatered dredged sediments with geotubes®), collection of supernatant and testing to ensure water meets NYS discharge criteria (addition of polymers to pumped sediment, if necessary, to accelerate dewatering and reduce amount of contaminants in effluent);
- Capping of creek sediments in selected areas;
- Placement of marsh substrate material in marsh area to appropriate elevations followed by vegetative habitat replacement;
- Transportation of dewatered sediments to nearby Brookfield or Fresh Kills landfills for beneficial use under the cap or transportation/disposal at a regional facility; and
- A performance monitoring program.

The total area of sediments that would be remediated is 89 acres. The estimated volume of sediments that would be removed is conservatively estimated to be 288,300 cubic yards. In the creek, approximately 25 acres or 82,000 cubic yards of contaminated sediment would be removed. In the marsh, about 64 acres or 206,300 cubic yards of contaminated sediment would be excavated. The estimated length of Richmond Creek and its branches that are to be remediated is about 7000 linear feet.

Sediment removal would be accomplished by isolating and dewatering sections of the creek and marsh through the placement of temporary upstream and downstream dams. While conventional steel sheeting can be used, it is anticipated that there would be cost efficiencies in using flexible water-filled geotextiles such as Aquadam® or Aqua Barrier™. Isolated sections would be dewatered using a system of sumps, submersible dewatering pumps, and discharge piping. Flow from the upstream side would be captured by a sump and pumped to the downstream side of the downstream dam to bypass the isolated section. To reduce the amount of water entering the excavated area, sediment excavation would occur at low tide, from mid-tide to mid-tide, and excavation of the creek would be postponed during large storms, particularly within and further west of the Sweet Brook tributary.

Appropriate erosion control measures would be provided at the discharge end of the dewatering pumps due to the increase in flow velocity at the discharge. Dewatered sections would be approximately 1000 feet long, depending upon marsh topography and channel flow characteristics. Advantages of dewatering the stream in sections prior to sediment removal include enhanced bed grade control, access to all areas of the marsh and channel beds and reduction in sediment resuspension. To minimize turbidity downstream, silt screens would be utilized as necessary.

Sediment would be excavated using conventional earth-moving equipment. To reduce impacts to the marsh, all construction would be conducted with low ground pressure (LGP) equipment or "swamp buggy" chassis. In general, removal would be accomplished using a combination of backhoe, grade-all and bulldozer. From the sediment cores, about half of the sediment in the creek is expected to be unconsolidated cohesive sediments (fine-grained, silty material called "organic muck in boring logs"). If during design it is determined that some of the cohesive sediments are too "soupy" to excavate conventionally, the material would be suctioned up using a suction dredge or DryDredge™ , a patented sealed clamshell dredge with positive displacement pump, and pumped to the dewatering area.

To allow for truck and equipment access to each excavation/dewatering area within the creek and marsh, there may be a need to prepare temporary access roads using geotextile mats and gravel.

The staging/drying bed would be constructed in an existing open area on the landfill side of the marsh. There is a flat portion of land between the two cells, north of the pump station (between the road to the interceptor and the road to the storm water outfall for a drying bed/dewatering area). If this is not possible due to OU1 construction timing, the dewatering area could possibly be located north of Richmond Creek in the area of the current sewer interceptor. This area could potentially be accessed off of Forest Hill Road using the current service road for the 48-inch sewer interceptor. However, to reach this area from the south side of the creek would require the construction of a temporary bridge (such as a Bailey bridge) to span the creek.

For the "dry" excavation of marsh and creek sediments, using either a front end loader or backhoe, the excavated materials would be loaded into trucks (10-15 cy capacity) with off-road capability and hauled to the dewatering area/drying bed. The rate of excavation and staging is assumed to be approximately 1000 cubic yards per day. Sediment from the suction dredging areas would be pumped into geotubes® in the dewatering area. Within the drying beds, the supernatant from the dredged material would be allowed to settle and discharged back to the creek/marsh through filters to meet NYSPDES discharge criteria.

Current waste characterization data indicates that no stabilization or additional treatment of the dewatered sediment would be required but a process area that would blend the dewatered sediment with Portland cement could be added, if necessary.

The dewatered material would then be loaded into trucks (20 yd) for beneficial use or disposal. Options evaluated include placing under the final cap of Brookfield Avenue Landfill, at the nearby Fresh Kills landfill undergoing closure at a cost of $16 per cubic yard, and, in the event these options are not available, then off-site beneficial use or disposal has also been considered at a cost of $40 per cubic yard assuming non-hazardous material (e.g., as approved fill material in New Jersey).

About 5 acres of engineered capping (sand) would be placed in selected areas of the creek where contamination would be left behind after the 2-foot layer of sediment is removed (e.g. in the marsh near the interceptor sewer).

In the marsh, about 25% less volume of sediment and vegetation would be replaced than is removed. This would serve to increase the amount of open water areas in the marsh and help promote the natural flow of saltwater over marsh sediments. This would also enable transitions between the creek and channel bottoms to be kept gradual. Therefore, marsh areas would be capped with a silt/sand mixture to the same or lower bottom elevations and restored with marine wetland vegetation. The cap material (up to 24 inches of clean fill consisting of sand and silt) would be placed in an alternating patchwork of varying amounts of sand/silt to provide a range of habitat types for a variety of aquatic biota, especially the resident fish. Restoration of marsh areas would be completed before moving to the next construction zone. Beyond physical replacement of the marsh bottom substrate, it is also anticipated that a spectrum of in-marsh plantings would be undertaken to further reduce the time for the creek to return to a productive ecological condition. The plantings would consist of various types of wetland and aquatic species; primarily smooth cordgrass (*Spartina alterniflora*) in the Intertidal Marsh and salt-meadow cordgrass (*Spartina patens*) in the High Marsh.

For salt marsh restoration, a number of geomorphic, hydrologic, and biotic factors would be considered during the design phase of the project. Care must be taken to ensure that replacement soils do not contain seed banks or rhizome material from undesirable plants (e.g., *phragmites*). Revegetation with desired intertidal vegetation (e.g., *Spartina alterniflora*) should follow established techniques for propagation and

planting, such as those developed by NYSDEC (New York State Salt Marsh Restoration and Monitoring Guidelines, 2000). Tidal channel morphology and the natural dendritic patterns of creeks and channels are important considerations in designing a salt marsh. Tidal creeks and ponds provide "edge" habitat, which is important in maintaining adequate drainage, facilitating nutrient exchange between groundwater and surface waters. Tidal creeks are the pathways for predatory fish to gain access to abundant forage resources within the marsh. Depositional edges of tidal creeks provide access points for smaller finfish and crustaceans, which move on and off the flooded marsh surface to forage and avoid predators. Existing channel size and sinuosity would be matched to that observed at the site today or in reference wetlands.

This alternative also relies on naturally occurring attenuation processes to reduce the toxicity, mobility, and volume of the remaining contaminants in Richmond Creek and the marsh after the construction is completed. Institutional controls (*e.g.*, site use restrictions) are implemented as long term control measures as part of this alternative. These restrictions include continuation or modification of the existing fish consumption advisories and restrictions on disturbing the creek caps and marsh substrate for future construction efforts within the marsh and creek. A review of site conditions would be conducted at five-year intervals, as required by NYSDEC regulations.

4.4.1.1 Implementation Schedule and Sequence of Operations

Assuming design for Alternative 3 would occur in 2007, remediation would commence in 2008 and is estimated to be completed in two years. To the extent practicable, sediments at the eastern part of OU2 would be remediated first, and the work would progress downstream towards Richmond Avenue. If required by NYSDEC, dredging and marsh excavation operations would take place in the fall/winter months only (October through March) to reduce the impacts on the surrounding ecosystem. If so, sediment removal, capping and restoration would continue for approximately three years.

Access to the creek and marsh would be coordinated with the ongoing OU1 remediation activities so that construction efforts for OU1 are not impacted. Access to the eastern portion of the creek and marsh could potentially occur via the road that would be built along the eastern edge of the landfill, adjacent to Colonial Square apartments. Access to the central and western portions of OU2 could potentially be via the road in the central portion of the landfill between the two cells.

4.4.1.2 Design Support Investigation (Pre-Construction Studies)

A pre-design would be required for the sediment removal alternatives. The purpose of the pre-design investigation program would be to provide current data on sediment conditions prior to initiation of sediment remediation. The intent of the design support investigation program would be to reduce the amount of sediment that is removed (and thereby reduce the amount of ecosystem disturbed).

Because the information to be gathered on the sediments would be needed for all three active remediation categories, the number of samples and the sampling density are about the same for these alternatives. For example, the marsh areas would require the same number of samples for both full removal of marsh (Alternative 3) and removal of intertidal marsh (Alternative 4) and removal of creek sediments only (Alternative 5). This is because all three alternatives require knowledge of the horizontal and vertical extent of contamination. However, the sampling in the high marsh conducted for Alternatives 4 and 5 would be performed for the sole purpose of confirming the conceptual model that little contamination is present in the high marsh and the sampling in the intertidal marsh conducted for Alternative 5 would be to determine how much contamination is left behind that needs to be monitored.

The design support program would involve about 200 coring locations. Cores are nominally estimated at three feet in length.

4.4.1.3 Performance Monitoring Program

The performance monitoring program would consist of two components: monitoring during construction of the alternative and post-construction monitoring.

Construction Monitoring: During construction of Alternative 3, monitoring would be implemented. The purpose of this monitoring is to assure that water column concentrations of dissolved and suspended contaminants are not excessive and to confirm that removal, capping, and restoration of areas targeted for remediation has been performed as designed. The construction monitoring program would begin with construction and last for two to three years. This program includes collection of samples from the sediment with bathymetric/topographic surveys.

Post-Construction Monitoring: The post-construction performance of this alternative would be monitored through the implementation of the sampling program that would be similar in content to the program conducted for Alternative 2. Two surface water sampling events would occur following construction. Annual operations and maintenance (O&M) monitoring would also take place for Alternative 3. This would entail examining OU2 for indications of any cap/marsh substrate disturbance and routine repair and/or replacement of the cap and/or marsh restoration areas should natural or man-made conditions (e.g., storms or construction activities) cause the cap to become eroded or breached.

4.4.2 Analysis

4.4.2.1 Overall Protection of Human Health and the Environment

The overall protection of human health achieved by Alternative 3 based on comparison of concentrations and volumes to SCGs would be increased relative to Alternatives 1 and 2 because this alternative involves both containment and removal of contaminated sediments from Richmond Creek and the marsh. However, the wetland would be destroyed and the habitats of flora and fauna disrupted. At the completion of Alternative 3, there would be little contamination present on the creek

bottom or at the surface of the marsh sediment. However, after Alternative 3 is implemented, the creek and marsh would be recontaminated from the various offsite sources including stormwater outfalls from the east and south and Fresh Kills landfill from the west.

Alternative 3 would address the scour of contaminated sediments associated with one-in-five-year (and greater) flow events, and would reduce the contaminant load to the estuary.

With respect to surface water contamination, Alternative 3 provides similar protection of both human health and the environment as Alternatives 1 and 2 because it assumes the separate source control of the OU1 remedy. In addition, like Alternative 2, this alternative also utilizes the fish consumption advisories and possibly other institutional/engineering controls to protect human health until contamination within the biota is reduced. Biota monitoring is regularly performed by NYSDEC and the data is used by the NYSDOH in their evaluation of the need for consumption advisories. Therefore biota monitoring is assumed to occur but is not included in OU2 remedy performance monitoring by NYCDEP.

In summary, risks to human health would be reduced through implementation of the OU1 remedy and the excavation/dredging of approximately 288,300 cubic yards of sediment, capping 5 acres of creek sediment and restoring 64 acres of marsh sediments. However, as summarized in Section 1, most of the risk to human health and to ecological receptors (fish-eating birds and mammals) results from consumption of finfish and shellfish, not from contaminated sediments. Birds and mammals would experience disruption to the established food chain due to the dredging. For Alternative 3, the concentrations of contaminants in wide-ranging fish (relevant to protection of human health) are anticipated to continue to be similar to those found throughout NY Harbor. Cancer risks and non-cancer health hazards due to exposures to sediment would be within the EPA-acceptable risk range (i.e., cancer risk of 10^{-4} to 10^{-6} and hazard index of 1 for non-cancer health hazards) by the end of construction activities (2011). Site-related contaminants in fish and shellfish should be reduced within a few years, depending on influences external to OU2.

The currently well vegetated and stable coastal wetland could be potentially lost forever with the implementation of Alternative 3. The overall long-term reduction in ecologic risk achieved by the three active alternatives must be balanced against the short-term destruction to the aquatic community, the estuary and protected wetlands, and the significant habitats of the major nesting colonies of herons and colonial wading birds caused by the removal of sediment and marsh vegetation. Disturbance of the benthic community could cause more adverse impacts to aquatic life than the presence of contaminated sediment. NYSDEC's wetlands restoration experience indicates that it is difficult to fully replicate the functionality of established wetlands. In addition, several of the location-specific SCGs require agencies and private entities to avoid disturbance of wetlands unless there are no practical alternatives (see below).

4.4.2.2 Compliance with SCGs

Compliance with the chemical-specific SCGs for site-related contaminants in the water-column and sediment are anticipated to improve after implementation of the OU1 remedy and sediment removal. However, there would be a substantial increase in water column concentrations of contaminants during the implementation of Alternative 3. Alternative 3 would be problematic due to the need to comply with action-specific SCGs involving actions in surface water bodies, habitat protection and wetlands preservation (*e.g.*, CWA Sections 401 and 404; Section 3004 of RCRA; Section 10 of the Rivers and Harbors Act; New York State ECL Article 3, Title 3, and Article 27, Titles 7 and 9) and location-specific SCGs (*e.g.*, Endangered Species Act; Fish and Wildlife Coordination Act; National Historic Preservation Act; and Federal and New York State Coastal Wetlands Laws).

To fully remediate the sediments as specified by Alternative 3 would require that the existing habitat and wetlands be destroyed. Therefore, Alternative 3 does not comply with location-specific SCGs for the site.

4.4.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

For Alternative 3, residual risk would be reduced through removal of 288,300 cubic yards of contaminated sediments. In most areas, these shallow sediments contain the highest concentrations of site related constituents. However, Alternative 3 would not completely eliminate long-term risks for selected areas in the creek or for certain marsh sediments (e.g., near SM-5) that retain contamination after the 2 feet of upper sediments are removed and replaced. In addition, sediments elsewhere in the estuary contain concentrations above SCGs and this sediment over time would be redistributed causing recontamination. Anthropogenic or natural processes (*e.g.*, future construction activities, severe storms, or longer-term changes in the depositional/erosional regime in a given location) may damage or erode and scour the cap and marsh substrate materials and redistribute contaminated capped sediments over wider areas of the estuary. Non-routine repair or replacement of large sections of the cap and marsh substrate may have to be undertaken if a breach occurs in a contaminated area due to catastrophic events such as a major flood. Depositional buildup of sediments adjacent to the cap could shift currents over the cap creating the potential for erosion in an unexpected area.

It is noted that with the Arthur Kill undergoing continual maintenance dredging and the potential maintenance dredging of the Fresh Kills during the closure of cells 1 and 9, the sediment within the creek and marsh will become recontaminated as suspended contaminants are spread throughout the estuary during the flood tides.

Adequacy of Controls

Alternative 3 provides for excavating or dredging of contaminated sediments throughout the creek and marsh, placement of marsh substrate and vegetation over the marsh sediments and placement of an engineered cap over selected target areas within Richmond Creek. Excavation and dredging are proven technologies to remove

contaminants and capping is a control that is anticipated to be effective. Fish consumption advisories are the established procedure for addressing human health risks associated with consumption of contaminated fish. This alternative also assumes that the OU1 remedy of landfill capping, barrier wall installation, landfill gas collection and leachate control would proceed and provides for engineering controls and institutional controls such as the fish consumption advisories.

The planned post-construction water column monitoring program allows for assessment of the effects of the OU1 remediation. Additional monitoring will be performed as part of post-closure monitoring of the OU1 final remedial system (landfill cap, barrier wall, leachate and gas collection systems). This monitoring is to occur for the typical 30-year post closure-monitoring period, and will include: groundwater sampling of 26 wells, surface water sampling at 5 locations, and landfill gas monitoring. This post-closure monitoring will be performed quarterly for the initial 5 years and then annually.. As previously discussed, the State conducts biota monitoring regularly.

Reliability of Controls
Sediment removal (dredging and excavation), and off-site disposal/treatment of removed sediments are reliable and proven technologies. Capping is also a proven technology for isolating contaminated sediments from the water column and biota. However, proper design, placement, and maintenance of the cap would be required for cap effectiveness, continued performance, and reliability. The cap would require a monitoring and maintenance program to be implemented to assure its integrity.

The fish consumption advisories issued by NYS are expected to continue to address protection of human health until contaminant concentrations in fish are reduced and the tissue concentrations for protection of human health is attained.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under Alternative 3, the mass of contaminants and the volume of contaminated sediments within the estuary would be permanently reduced because approximately 300,000 cubic yards of contaminated sediment would be removed. Alternative 3 also assumes the separate source control of the OU1 remedy. Therefore, additional contributions of contaminants from the landfill will be controlled. Capping reduces the mobility of contaminants in the creek and marsh but does not affect their toxicity or volume, except for those contaminants whose degradation is enhanced by anaerobic conditions. After construction is completed and wetlands are restored, natural processes may once again act to reduce the toxicity and volume of contaminants in sediments (*e.g.*, through biodegradation) or reduce their mobility (*e.g.*, through burial by cleaner sediments or sequestration of heavy metals within organic/inorganic complexes). However, capping does not satisfy the NYSDEC statutory preference for treatment (NYSDEC, 1990). In addition, there is little reduction in the toxicity or volume of the contaminants under the cap/marsh substrate material. Sediment remediation would serve to greatly reduce future sediment-to-water transfer of contaminants by removal or isolation of the

contaminated sediments. In addition, after construction of the alternative is completed, natural attenuation processes of the recovered wetlands would provide further reductions in the toxicity of contaminants in the remaining sediments and surface water. However, recontamination is expected from off-site sources.

4.4.2.5 Short-Term Effectiveness

Short-term effectiveness is assessed through review of the four components described previously: protection of the community during remedial actions; protection of the workers during remedial actions; potential adverse environmental impacts resulting from construction and implementation; and time until remedial response objectives are achieved.

Protection of the Community During Remedial Actions

Risks to the community posed by the construction activities would be increased during remedial actions of Alternative 3 due to the resuspension of sediments that would occur. While there may be a brief increase in tissue concentrations following the dredging due to the resuspension of contaminants during construction, the fish consumption advisories and restricted access to portions of the creek and marsh undergoing remediation would provide protection for the local community and the general public in the short term. Transfer facilities and treatment areas present potential short-term risks to the community. Therefore, access to these areas would be restricted to authorized personnel. In addition, monitoring and engineering controls would be employed to minimize short-term effects due to material processing activities. Should road transport of the dewatered sediments be necessary, increased traffic would also present an incremental risk to the community. The potential for traffic accidents may increase marginally as additional vehicles are on the road.

Protection of Workers During Remedial Actions

For Alternative 3, there will be potential occupational risks to site workers from direct contact, ingestion, and inhalation of contaminants from the surface water and sediments, and routine physical hazards associated with construction work and working on water. For this alternative, site personnel would follow a site-specific health and safety plan, OSHA health and safety procedures, and wear the necessary personal protective equipment.

Potential Adverse Environmental Impacts Resulting from Construction and Implementation

For Alternative 3, the release of heavy metals, pesticides, and PCBs from the contaminated sediments into the water column during construction (excavation/dredging and cap placement), as well as the transport of these sediments throughout the estuary, would be controlled to the extent practicable by operational practices (*e.g.*, dewatering stream and excavating most of the sediments under "dry" conditions, control of sediment removal rates; use of enclosed dredge buckets; and use of sediment barriers). Although precautions to minimize resuspension would be taken, it is likely that there would be a transient increase of suspended contaminant

concentrations in the water column, and possibly in contaminant concentrations in fish.

Remedial activities would result in major impacts to aquatic and wildlife habitat of Richmond Creek and marsh. Habitat replacement measures would need to be implemented to mitigate these impacts. A monitoring program would be established to verify the attainment of the habitat replacement objectives. The degree of impact is directly related to the area remediated and volume dredged. Since construction activities would take place throughout the entire creek and marsh, the impacts of these modifications are considered to be significant. While mitigation measures will be utilized, studies have indicated that the functionality of the system may be difficult to restore (National Academy of Sciences, 2001).

While the removal of sediments associated with Alternative 3 would yield substantively higher levels of contaminants in the water and/or fish of Richmond Creek during remedial construction, it is unlikely that the residual effects after the construction would last more than a few years.

In addition to the ecological effects on the marsh, the truck traffic of approximately 100 truckloads per day depositing sediment at the landfill or other location will increase noise and air pollution within the immediate vicinity of the landfill.

Time until Remedial Response Objectives Are Achieved
For Alternative 3, and similar to Alternatives 1 and 2, compliance with the surface water SCGs is expected to improve following completion of the OU1 remedy. The risk-based concentrations of contaminants in fish fillet and shellfish for protection of human health will continue to be influenced by contamination sources other than OU2 even after implementation of this alternative.

Therefore, in the short term, many RAOs and SCGs are not expected to be met for Alternative 3, and this alternative is not expected to be protective of human health or the environment during the construction period. Subsequent to the implementation, conditions would improve substantively relative to the Monitoring and Institutional Control Alternative as discussed under long-term effectiveness pending wetlands recovery and limited recontamination. These caveats create uncertainty regarding long-term success. In addition, the damage to the existing ecosystem as a result of the excavation/dredging is not acceptable since this is habitat of high value.

4.4.2.6 Implementability

Technical Feasibility
Technical feasibility for Alternative 3 is discussed below in terms of the main components of the alternative. Principal elements of the overall system that must be constructed, operated, and otherwise be available in order to cap and selectively remove targeted sediments, are as follows:

Removal Equipment: Removal work under this alternative would be accomplished by means of conventional excavators and/or suction dredges. In general, the mechanical systems needed to implement this alternative are either available or can be fabricated.

Transfer Facilities: Under Alternative 3, transfer facilities would be established at the OU1 site or potentially to the north of the creek to process sediments generated by removal operations. These transfer facilities would require adequate land area to process incoming sediments and temporary road construction for access to roads offsite and coordination with OU1 activities. The preparation of a dewatering facility at a location north of Richmond Creek is technically feasible since there is vacant land and access along the existing maintenance road for the sewer interceptor. However, because this location is parkland it is not likely to be well accepted by the community. It would also be administratively problematic. The use of geotubes® for dewatering of the dredged sediment has been proven technically feasible and efficient, but required additional handling.

Transportation and Disposal: Trucking would be the principal transportation mode considered for moving dredged sediments to Brookfield OU1, Fresh Kills or regional landfills. Approximately 100 truckloads of processed sediment would be transferred from the dewatering facility each day (2000 cy) through a route not yet identified. This would add truck traffic to the already burdened local roads and increase air pollution within this neighborhood in the short term.

Administrative Feasibility
Alternative 3 would be difficult to implement from an administration standpoint. While permits are not required, the remedial activities must meet the substantive technical requirements of several permit programs. It is expected that the dewatering facility, located at OU1, would be considered "on-site" for the purposes of the permit exemption under NYSDEC regulations, although any such facilities would have to comply with the substantive requirements of any other necessary permits.

Operations under this alternative would have to be performed in conformance with substantive requirements of regulatory programs implemented by USACE (dredge and fill) under Section 10 of the Rivers and Harbors Act and Sections 401 and 404 (wetlands) of the CWA. In addition, discharges during remediation would have to conform to NYS regulations related to maintenance of Richmond Creek water quality. Habitat replacement would need to be implemented in accordance with federal and state SCGs.

Contract documents for this alternative would need to contain substantial restrictions on construction activity, including controls on the types of dredging and capping equipment to be used, restrictions on the speed of operations, trucking, constraints on barge filling practices, and controls on temporary storage of contaminated dredge spoils. Finally, requirements of other regulatory programs would need to be incorporated as necessary on the basis of information developed during remedial design.

Each active alternative may require that a dewatering facility be established at a location north of Richmond Creek. Several acres may be needed to house these systems and any associated equipment. This land is currently administered by the NYC Department of Parks and Recreation (DPR). Therefore, the availability of property and the receipt of permission for a temporary divergence of the land near the creek for the remedial action may be difficult to obtain.

The use of Brookfield or Fresh Kills landfills for the beneficial use of the sediments as landfill subgrade material would require NYSDEC approval of the material and issue a beneficial use determination (BUD) for this application at these locations.

Also, to use the material for the Brookfield OU1 closure, the design for Alternative 3 must be completed by 2007 so that it would not affect the schedule for Brookfield Avenue Landfill capping. This timetable is unrealistic so use of the material would be unlikely. The beneficial use of the sediments from Alternative 3 at Fresh Kills presents additional problems as Fresh Kills operations are controlled by NYCDOS, which has its own administrative and financial requirements and contractual agreements concerning the timing, design and construction details for closing the various cells.

4.4.2.7 Cost

A summary of the details of the cost estimate for Alternative 3 is presented in Table 4-2. The estimated net present worth costs of this alternative, calculated at a 3.1 percent discount rate, is approximately $19,201,000 to $29,271,000 depending on the beneficial use or disposal disposition of the dredged material.

Capital Cost

Since the construction would be performed over a two to three-year period, capital costs would vary on an annual basis. The total capital costs for this alternative are estimated to be about $19,700,000 to $30,400,000 depending on end use/disposal location. The estimated present worth of the capital costs for this alternative range between $18,500,000 to $28,600,000, depending on end use/disposal location.

O&M Costs

Due to the varying frequency of different elements of the monitoring program and the O&M program, O&M costs would vary on an annual basis. The estimated annual average O&M costs for this alternative are about $37,700.

Table 4-2
Cost Analysis
Alternative 3: Sediment Removal in Creek and Marsh, Restoration, and Beneficial Use/Disposal (Includes OU1 Remediation and Institutional Controls)

Cost Item	Quantity	Unit Cost	Unit Cost	Unit	Cost	Sources
Capital Costs						
Pre-Construction Studies and Design						
Design Support Testing	1	14,841,805	$516,500	LS	$516,500	1
Design (10% of construction w/o T&D cost)	1	11,007,500	$1,469,207	LS	$1,469,207	1
Pre-Construction Cost Total					**$1,985,707**	
Construction						
Mobilization/Demobilization	1	3,782,821	$286,000	LS	$286,000	4
Creek dredge (dry dredge or suction dredge)	41,000	28.21	$15	CY	$615,000	6
Creek excavation	41,000		$17	CY	$697,000	4
Creek cap sand 5 acres at 6 inches	4,033		$46	CY	$183,985	2
Marsh excavation	206,300		$17	CY	$3,507,100	4
Stream Dewatering aquadam pumps	1		$120,000	Each	$120,000	2
grading, lining drying bed 600x600ft	360,000	22.37	$3	SF	$932,400	4
Geotube 2cy fills 1LF tube	20,500		$25	LF	$512,500	6
Trucking to dewater area 10 yd truck 1mile RT	247,300	26.76	$3	CY	$618,250	2
Temporary bridge for creek crossing	1		$78,000	Each	$78,000	1
Marsh mats for temporary roads in marsh	84,000		$3	SF	$252,000	1
gravel for temp roads	3,111		$34	CY	$106,147	2
Marsh Cap Material	154,725		$35	CY	$5,415,375	2
Habitat & Vegetation Replacement	51	3,668,899	$24,200	AC	$1,234,200	5
Construction Monitoring	1		$134,116	LS	$134,116	3
Subtotal Construction w/o Beneficial Use/Disposal					**$14,692,074**	
T&D to Brookfield (20 yd truck, 2 mile RT)	288,300		$3	CY	$720,750	2
Trucking /Placement/Disposal Fresh Kills	288,300		$16	CY	$4,612,800	2
Trucking/Disposal offsite, regional	288,300	55	$40	CY	$11,532,000	1
Total Construction Brookfield					**$15,412,824**	
Total Construction FreshKills		5,364,654			**$19,304,874**	
Brookfield Permitting (5%) Construction Mgt (10%) (15% of Total construction cost)					**$26,224,074**	
Fresh Kills Permitting (5%) , Construction Mgt (10%) (15% of Total construction cost)	1		$2,311,924	LS	$2,311,924	1
Regional Permitting (5%) , Construction Mgt (10%) (15% of subtotal construction cost)	1		$2,895,731		$2,895,731	1
	1		$2,203,811		$2,203,811	1
Total Capital Costs (Disposal at Brookfield)					**$19,710,455**	
Total Capital Costs (Disposal at FreshKills)					**$24,186,313**	
Total Capital Costs (Disposal Regional)					**$30,413,593**	
O&M Costs						
Review Costs						
Post Construction Monitoring, surface water - two events	2		$43,600	Each	$87,200	1
Post Construction O&M - every year for 25 years after construction is complete	25	34,193	$34,193	Year	$854,825	1, 3
Total O&M Costs					**$942,025**	
Annual Avg O&M (over 25 years O&M period of 2011 through 2036)					$37,681	
Present Worth of Costs						
Construction (Disposal at Brookfield)					$18,542,971	
Construction (Disposal at FreshKills)					$22,753,716	
Construction (Disposal Regional)					$28,612,143	
Post Construction Monitoring					$69,557	
Post Construction O&M - every year for 25 years after construction is complete					$588,827	
Total Present Worth Costs Alternative 3 at Brookfield					**$19,201,356**	
Total Present Worth Costs Alternative 3 Fresh Kills					**$23,412,100**	
Total Present Worth Costs Alternative 3 Regional					**$29,270,528**	
Round To			$19,201,000	to	$29,271,000	

- Cost Estimate date August 2006
- Design Support assume to start in 2006
- Design assumed conducted in 2007
- Construction Estimated to Start 2008
- Monitoring costed for two events

- "Real" discount (interest) rate (after adjustment for inflation) of 3.1% (based on 30-year Treasury maturities), taken from OMB Circular No. A-94 Appendix C (Revised January 2005)
Present worth costs determined using Microsoft Office Excel "PV" formula

Sources:
1 Professional judgement, Vendor supplied data.
2 CDM 90% construction cost estimate
3 Hudson River PCB FS (NYSDOH, 2005)
4 Brookhaven OUV FS (Brookhaven National Library, 1998)
5 NYSDEC Salt Marsh Restoration and Monitoring Guidelines (NYSDEC and NYS DOS, 2000)
6 USACE Vicksburg, Mississippi levee project (Geotec, 1996)

4.5 Alternative 4: Sediment Removal in Creek and Intertidal Marsh, Restoration, and Beneficial Use/Disposal (includes OU1 Remediation and Institutional Controls)

4.5.1 Description

This alternative includes the complete removal/dredging of the first two feet of sediment from Richmond Creek, removal/dredging of one foot of sediment from the intertidal portions of the surrounding marsh, selected engineered capping of the high flow areas of the creek where contaminants would remain in place, placement of marsh substrate material within the intertidal marsh, and wetland species revegetation.

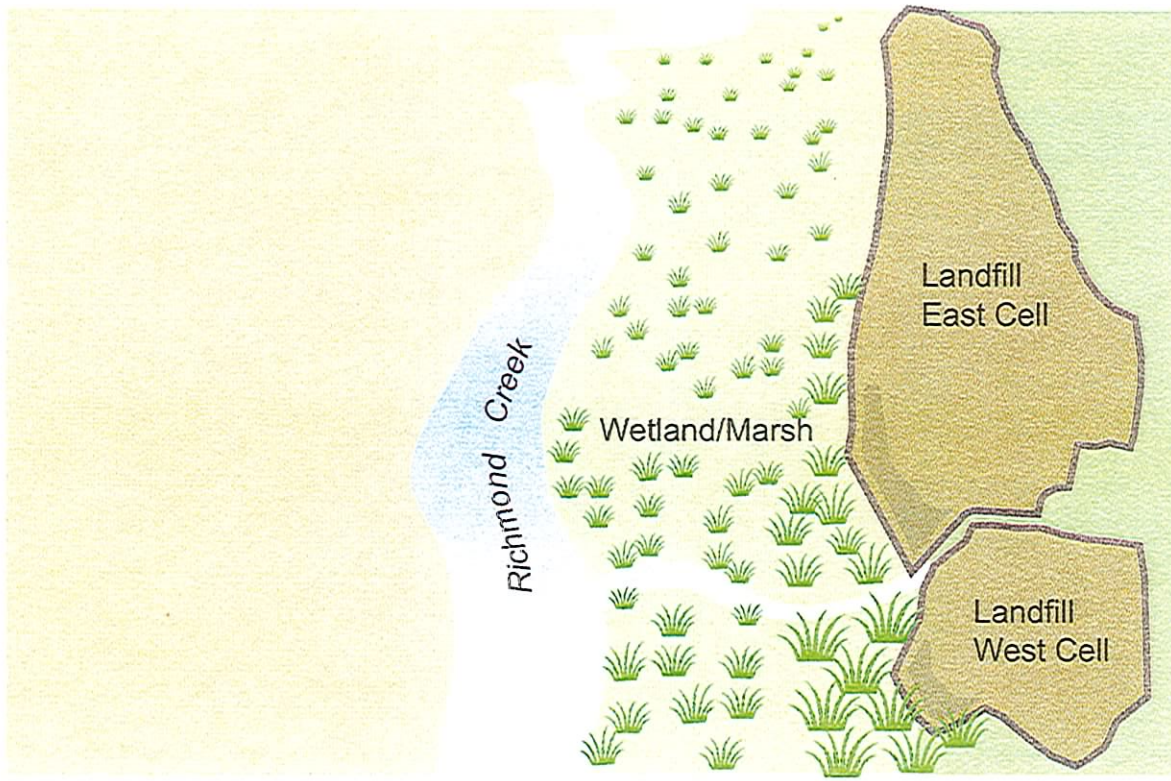
The current conceptual model for OU2 suggests that the majority of the deposition of contaminated sediments within the marsh has occurred within the intertidal marsh areas or locations with approximate elevations of +2 feet msl to +5 feet msl. The high marsh (greater than 5 feet msl) is much less contaminated presumably because it is inundated with creek water only once or twice per year, rather than daily. Figure 4-1 presents a diagram of this conceptual model.

During the OU2 investigation, all marsh sediment samples except one were located in the intertidal marsh (see Figure 4-2). The one sample located at higher elevation (SM-1), on what is likely high marsh, showed lower concentrations of contaminants in the 0- to 6-inch deep sample and almost no contamination below 6 inches. This is not unexpected since the contaminated sediment deposition was performed by overland flow from the landfill, which was controlled by the creek bottom elevations.

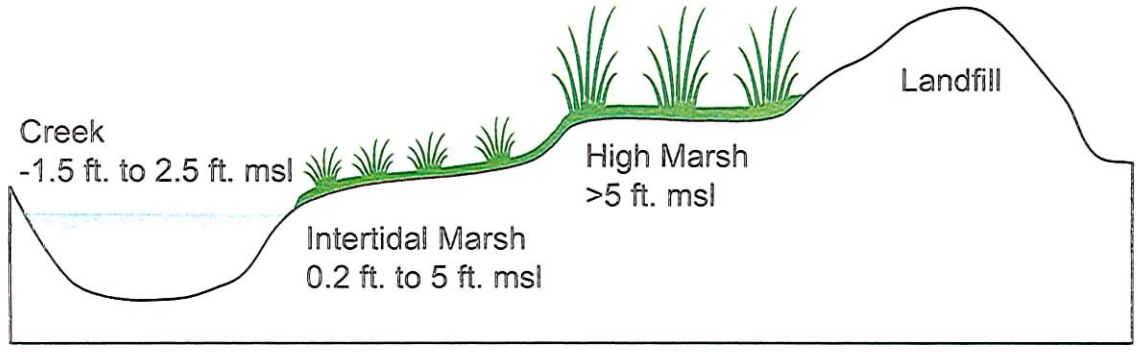
Intertidal marsh is defined by NYSDEC as the vegetated wetland zone lying generally between average high and low tidal elevations (6 NYCRR 661.4). This zone is generally considered the most biologically productive of all tidal wetlands areas. Since it receives twice-daily tidal flushing, it is effective at cleansing ecosystems and absorbing silt and organic material. Plankton flourishes here so it is suitable for fish spawning. For these reasons, it was identified as a subset of the marsh zone where remediation would have the greatest effect.

It is anticipated that during design this conceptual model would be confirmed or disproved by comparing data from high and intertidal marsh in similar areas of OU2. Also during design, vegetation, soil, and elevation differences between the high marsh and intertidal marsh would be determined so that excavation/dredging control during remedial action could be controlled in the field through visual (using vegetation) and topographic means. This should serve to limit the amount of material removed and limit the area of disturbance to this estuary.

The principal components of this alternative are the same as for Alternative 3, described as follows:



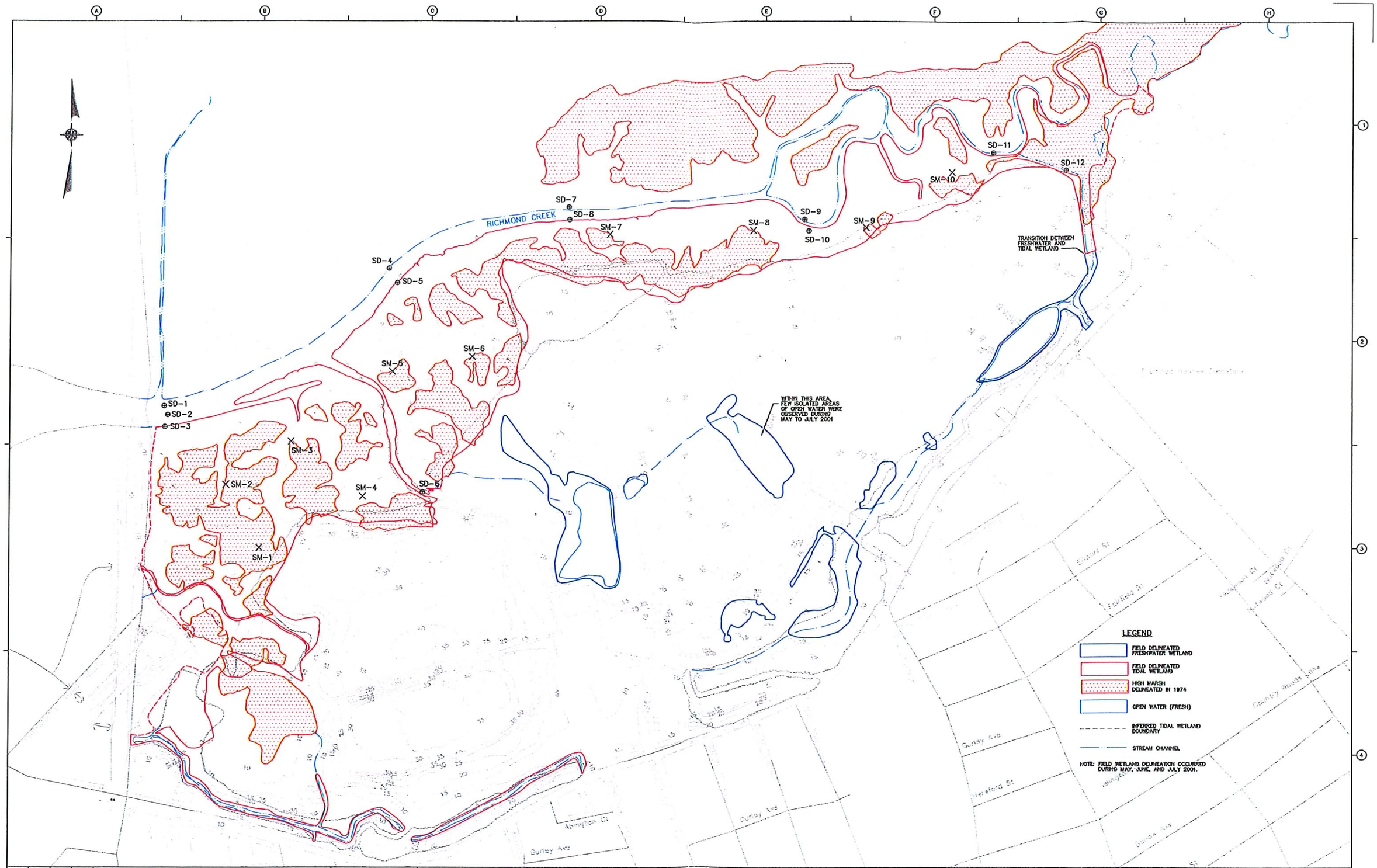
Plan View



Profile View

Not to Scale

Brookfield Avenue Landfill Operable Unit 2
Intertidal and High Marsh
Figure 4-1



REV. NO.	DATE	DRWN	CHKD	REMARKS
				-JOHN BOYER 7/27/01

DESIGNED BY: NZ/JB
DRAWN BY: PD
SHEET CHK'D BY: JB
CROSS CHK'D BY: SG
APPROVED BY: JB
DATE: 8/27/01

CDM Camp Dresser & McKee

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION

BROOKFIELD AVENUE LANDFILL
REMEDIATION PROJECT

OU2 SAMPLING LOCATIONS WITH RESPECT TO HIGH MARSH AND INTERTIDAL MARSH

PROJECT NO. 5215-12928
FILE NAME: WETMAPOU2 FS.dwg

SHEET NO.
Figure 4-2

PLOTTED ON APRIL 30, 2002 BY JOHN BOYER FOR CDM FROM C:\PROJECTS\NYC\5215\12928\WETMAPOU2 FS.DWG AT 17:04 USING 1=1" (1:1)

Source control via OU1 Remediation including Landfill Capping, Leachate Collection, Subsurface Barrier Wall Installation, Landfill Gas Collection, Wetland Enhancements;

- Institutional Controls as for Alternative 2;
- In-stream dewatering and excavation of sediments in Richmond Creek and intertidal marsh using conventional earth moving equipment with the use of suction dredges as needed;
- Dewatering excavated sediments with drying beds (and dewatered dredged sediments with geotubes®), collection of supernatant and testing to ensure water meets NYS discharge criteria (addition of polymers to pumped sediment, if necessary, to accelerate dewatering and reduce amount of contaminants in effluent);
- Capping of creek sediments in selected areas; Placement of marsh substrate material within the intertidal marsh area to original or other appropriate elevations followed by vegetative habitat replacement; and
- Transportation of dewatered sediments to nearby Brookfield or Fresh Kills landfill for beneficial use under the cap or transportation/disposal at a regional facility.

4.5.1.1 Details of the Alternative

The total area of sediments that would be remediated is 66 acres. The estimated volume of sediments to be removed is 147,100 cubic yards. In the creek, approximately 25 acres or 82,000 cubic yards of contaminated sediment would be removed. In the intertidal marsh, approximately 40 acres or 65,100 cubic yards of contaminated sediments would be removed (assuming 1 foot depth). The estimated length of Richmond Creek and its branches that is to be remediated is about 7000 linear feet.

As with Alternative 3, sediment removal would be accomplished by isolating and dewatering sections of the creek and marsh through the placement of temporary upstream and downstream dams. Sediment would be excavated using conventional earth-moving equipment using low ground pressure (LGP) equipment or "swamp buggy" chassis. Also for the creek sediments, removal would be accomplished using a combination of conventional excavation equipment and suction dredge or DryDredge™. Sediments would be trucked or pumped to a dewatering area and staged for eventual beneficial use/disposal. As with Alternative 3, the dewatered material would then be loaded into trucks (20 yd) for beneficial use or disposal.

In the intertidal marsh, about 10% less volume of sediment and vegetation would be replaced than is removed to attempt to restore the creek and marsh to pre-landfill (more "open water") conditions. As with Alternative 3, capping material (up to 12 inches of clean fill consisting of sand and silt) would be placed in an alternating

patchwork of varying amounts of sand/silt and in-marsh plantings of primarily smooth cordgrass (*Spartina alterniflora*).

As with Alternative 3, a number of geomorphic, hydrologic, and biotic factors would be considered during the design phase of the project to ensure that the salt marsh is restored in accordance with NYSDEC requirements.

Also, as with Alternatives 2 and 3, this alternative utilizes naturally occurring attenuation processes to reduce the toxicity, mobility, and volume of the remaining contaminants in Richmond Creek and the marsh after the construction is completed and the wetlands have recovered. Institutional controls (*e.g.*, site use restrictions) are implemented as long term control measures as part of this alternative. These restrictions include continuation or modification of the existing fish consumption advisories and restrictions on disturbing the creek caps and marsh substrate for future construction efforts within the marsh and creek.

4.5.1.2 Implementation Schedule and Sequence of Operations

Assuming design would occur in 2006; remediation for Alternative 4 would commence in 2008 and would be completed in two years.

4.5.1.3 Design Support Investigation (Pre-Construction Studies)

As with Alternative 3, the design support investigation program would be implemented as part of the design required for the sediment removal alternatives. The purpose of the design support investigation program would be to provide current data on sediment conditions prior to initiation of sediment remediation. The design support program would involve the same number of coring locations and sampling as estimated for Alternative 3, about 290 coring locations for the design support sampling program. Cores are nominally estimated at three feet in length.

4.5.1.4 Performance Monitoring Program

The performance monitoring program would consist of two components: monitoring during construction of the alternative and post-construction monitoring.

Construction Monitoring: As with Alternative 3, during construction of this alternative, monitoring would be implemented. This program would include collection of samples from the water column and sediment with bathymetric/topographic surveys.

Post-Construction Monitoring*:* The post-construction performance of this alternative would be monitored through the implementation of the sampling program that would be similar in content to the program conducted for Alternatives 2 and 3. Two surface water sampling events would occur following construction. Annual operations and maintenance (O&M) monitoring would also take place for Alternative 3. This would entail examining OU2 for indications of any cap/marsh substrate disturbance and routine repair and/or replacement of the cap and/or marsh

restoration areas should natural or man-made conditions (e.g., storms or construction activities) cause the cap to become eroded or breached

4.5.2 Analysis

4.5.2.1 Overall Protection of Human Health and the Environment

With respect to sediment contamination, the overall protection of human health achieved by Alternative 4 would be moderate because contaminated material would remain in the high marsh (without any capping) and would be accessible to both humans and biota. Even though the capping concept would be designed to avoid failure, cap damage caused by, for example, natural events like major floods cannot be avoided. Ecologic receptors would initially not be protected due to the wetlands destruction, however upon their recovery should experience moderate protection assuming recontamination were not a consideration.

Since Alternative 4 assumes the separate source control of the OU1 remedy, this alternative will achieve considerable protection of human health and ecologic receptors with respect to surface water contamination in the long run if recontamination were not a consideration. Also, since Alternative 4 will continue the fish consumption advisories and other institutional controls, overall protection of human health will be adequate in the long term, if not the short-term.

Alternative 4 also would address the scour of contaminated sediments associated with one-in-five-year (and greater) flow events, and is therefore effective in reducing the contaminant load to the estuary.

However, much of the currently well vegetated and stable wetland could be potentially lost forever with the implementation of Alternative 4. The overall reduction in long-term ecologic risk achieved by a removal alternative must be balanced against the disturbance to the aquatic community, the estuary and protected wetlands, and the significant habitat of the major nesting colonies of herons and colonial wading birds caused by the removal of sediment and marsh vegetation. Disturbance of the benthic community could cause more adverse impacts to aquatic life than the presence of contaminated sediment. Recent studies highlighting wetlands restoration experience indicates that it is difficult to fully replicate the functionality of established wetlands (National Academy of Sciences, 2001).

4.5.2.2 Compliance with SCGs

Compliance with the chemical-specific SCGs for site-related contaminants in the water-column and sediment are anticipated to improve by Alternative 4. The water and sediment quality would be substantially improved. Through permitting during design, Alternative 4 would comply with action-specific SCGs (*e.g.*, CWA Sections 401 and 404; Section 3004 of RCRA; Section 10 of the Rivers and Harbors Act; New York State ECL Article 3, Title 3, and Article 27, Titles 7 and 9). However, Alternative 4 would not comply with location-specific SCGs (*e.g.*, Endangered Species Act; Fish and

Wildlife Coordination Act; National Historic Preservation Act; and Federal and New York State Coastal Wetlands Laws).

4.5.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

For Alternative 4, residual risk would be reduced through capping any contaminated marsh sediments remaining after dredging and removal of 147,100 cubic yards of contaminated sediments. Alternative 4 does not completely eliminate long-term risks for selected areas in the creek that need to be capped or for marsh sediments that retain contamination after the 1 foot of upper sediments are removed. Also, because sediment removal would only occur in the intertidal marsh, more potentially contaminated sediment would remain within the estuary. Anthropogenic or natural processes (*e.g.*, future construction activities, severe storms, or longer-term changes in the depositional/erosional regime in a given location) may damage or erode and scour the cap and marsh substrate materials and redistribute contaminated capped sediments over wider areas of the estuary. Non-routine repair or replacement of large sections of the cap may need to be undertaken if a breach occurs in a highly contaminated area due to catastrophic events such as a major flood. Depositional buildup of sediments adjacent to the cap could shift currents over the cap creating the potential for erosion in an unexpected area.

As for Alternative 3, with the ongoing Arthur Kill maintenance dredging and the potential dredging required in the Fresh Kills during the closure of cells 1 and 9, the sediment within the creek and marsh will become recontaminated as suspended contaminants are spread throughout the estuary during the flood tide.

Alternative 4 also utilizes the wetland natural attenuation processes such as burial by cleaner sediments, bioturbation, biodegradation, dispersion, dilution through advection and recharge, adsorption, and volatilization to further reduce the concentration of any contaminants that remain after construction is completed and the wetlands have been restored. Since the removal and placement of marsh substrate material would follow existing dendritic pathways already established in the marsh and since a large amount of marsh sediment and vegetation will remain untouched, it is anticipated that the natural attenuation process would occur more quickly for Alternative 4 than for Alternative 3.

Adequacy of Controls

Alternative 4 provides for dredging of contaminated sediments in the creek and marsh and placement of marsh substrate and vegetation over the marsh sediments and engineered cap over selected target areas within Richmond Creek. Dredging is a proven technology to remove contaminants and capping is a control that is anticipated to be effective. This alternative also assumes that the OU1 remedy of landfill capping, barrier wall installation, landfill gas collection and leachate control would proceed and provides for institutional controls such as the fish consumption advisories. Fish advisories are the established procedure for addressing consumption of contaminated fish.

As with Alternative 3, the planned post-construction water column monitoring program in conjunction with the long-term monitoring at WC-12 conducted by IT Corp. and the post-closure monitoring that is part of the OU1 remedy would allow for tracking the natural recovery of the creek after remediation is completed. However, the monitoring program would have no effect on reducing the ecological risks to fish, fish-eating birds, and mammals when they recover.

Reliability of Controls

Sediment capping, sediment removal (dredging and excavation), marsh substrate and habitat replacement, and off-site disposal/treatment of removed sediments are all reliable and proven technologies. However, for Alternative 4, proper design, placement, and maintenance of the cap and marsh substrate in perpetuity are required for its effectiveness, continued performance, and reliability. This presents a challenge within this site. The cap requires a monitoring and maintenance program to insure integrity. The fish consumption advisories would continue to address protection of human health until contaminant concentrations in fish are reduced and the tissue concentrations for protection of human health is attained.

4.5.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

For Alternative 4, the mobility of the contaminants in capped and restored marsh areas would be reduced because they are sequestered under the material. However, since less material would be potentially sequestered, there would be slightly greater mobility of contaminants than for Alternative 3. Again, capping does not satisfy the New York State statutory preference for treatment. In addition, there is little reduction in the toxicity or volume of the contaminants under the cap or marsh substrate material. Under this alternative, the mass of contaminants and the volume of contaminated sediments within the estuary would be initially reduced because over 147,000 cubic yards of contaminated sediment are removed. The sediment remediation would serve to reduce future sediment-to-water transfer of contaminants by removal or isolation of the contaminated sediments. In addition, after construction of the alternative is completed, natural attenuation processes would provide further reductions in the toxicity of contaminants in the remaining sediments and surface water. However, the long–term success of this program will be negatively affected by recontamination.

Since sediments that are removed are not treated (stabilized) prior to beneficial use at the landfill, Alternative 4 does not satisfy the NYSDEC statutory preference for treatment as a principal element of the remedy. Also, as with Alternative 3, there will be recontamination of the remediated creek and marsh upon completion of the remedy due to the continued presence of contamination sources both upstream and downstream within the estuary, the ongoing maintenance dredging of the Arthur Kill and the closure and potential dredging activities that are planned to take place during the closure of Fresh Kills cells 1 and 9.

4.5.2.5 Short-Term Effectiveness

Short-term effectiveness is assessed through review of the four components described previously: protection of the community during remedial actions; protection of the workers during remedial actions; potential adverse environmental impacts resulting from construction and implementation; and time until remedial response objectives are achieved.

Protection of the Community During Remedial Actions

For Alternative 4, fewer disturbances in the marsh and estuary would take place because removal would be limited to the intertidal marsh. Therefore, it is expected that a higher level of community protection would be received by Alternative 4 than for Alternative 3. Exposure levels for fish would not be expected to increase substantively during the dredging so that risks from consuming fish would remain largely the same during the construction period. The fish consumption advisories and restricted access to portions of the creek and marsh undergoing remediation provide protection from risks to human health for the local community and the general public in the short term. Transfer facilities and treatment areas would present potential short-term risks to the community. Therefore, access to these areas would be restricted to authorized personnel. In addition, monitoring and engineering controls would be employed to minimize short-term effects due to material processing activities. Should road transport of the dewatered sediments be necessary, increased truck traffic would also present an incremental risk to the community. The potential for traffic accidents may increase marginally as additional vehicles are on the road.

Protection of Workers During Remedial Actions

For Alternative 4, potential occupational risks would exist to site workers from direct contact, ingestion, and inhalation of contaminants from the surface water and sediments, and routine physical hazards associated with construction work and working on water. For this alternative, site personnel would follow a site-specific health and safety plan, OSHA health and safety procedures, and wear the necessary personal protective equipment.

Potential Adverse Environmental Impacts Resulting from Construction and Implementation

As with Alternative 3, this alternative would cause the release of heavy metals, PCBs and pesticides from the contaminated sediments into the water column during construction (dredging and cap placement) as well as the transport of these sediments throughout the estuary. Resuspension would be controlled to the extent practicable by operational practices (*e.g.*, control of sediment removal rates; use of enclosed dredge buckets; and use of sediment barriers). Although precautions to minimize resuspension would be taken, it is likely that there would be a transient increase of suspended contaminant concentrations in the water column, and possibly in contaminant concentrations in fish. Therefore, in the short term, many RAOs and SCGs are not met for Alternative 4, and this alternative is not protective of human health or the environment during the construction period.

Remedial activities would result in major impacts to aquatic and wildlife habitat of Richmond Creek and marsh. The degree of impact is directly related to the area remediated and volume dredged. Habitat replacement measures would need to be implemented to mitigate these impacts. A monitoring program would be established to verify the attainment of the habitat replacement objectives. While mitigation measures will be utilized, NYSDEC's experience is that the functionality of the system may never be restored. These caveats create uncertainty regarding long-term success. In addition, the damage to the existing ecosystem as a result of the excavation/dredging is not acceptable since this is habitat of high value.

In addition to the ecological effects on the marsh, the truck traffic of approximately 100 truckloads per day depositing sediment at the landfill or other location will increase noise and air pollution within the immediate vicinity of the landfill.

Time until Remedial Response Objectives Are Achieved
For Alternative 4, and similar to Alternatives 1 and 2, compliance with the surface water SCGs is expected to improve following completion of the OU1 remedy. The risk-based concentrations of contaminants in sediment and surface water should improve within a few years after the construction period is complete. The risk based concentrations of contaminants in fish fillet and shellfish for protection of human health are not expected to be met in the short term but could be met long-term if recontamination were not an issue. The risk-based concentrations of contaminants in fish fillet and shellfish for protection of human health will continue to be influenced by contamination sources other than OU2 even after implementation of this alternative.

Wetlands recovery and limited recontamination would be required to achieve additional improvement. These caveats create uncertainty regarding long-term success. In addition, the damage to the existing ecosystem as a result of the excavation/dredging is not acceptable since this is habitat of high value.

4.5.2.6 Implementability

Technical Feasibility
Technical feasibility for Alternative 4 is discussed below in terms of the main components of the alternative. Principal elements of the overall system that must be constructed, operated, and otherwise be available in order to cap and selectively remove targeted sediments, are as follows:

Removal Equipment: Removal work under this alternative would be accomplished by means of conventional excavators and/or suction dredges. In general, the mechanical systems needed to implement this alternative are either available, or can be fabricated.

Transfer Facilities*:* As with Alternative 3, under Alternative 4, transfer facilities would be established at the OU1 site or potentially to the north of the creek to process sediments generated by removal operations. These transfer facilities would require

adequate land area to process incoming sediments and temporary road construction for access to roads offsite, and coordination with OU1 activities.

Transportation and Disposal: Trucking would be the principal transportation mode considered for moving dredged sediments to Brookfield OU1, Fresh Kills or regional landfills. This would increase truck traffic and air pollution in the short term.

Administrative Feasibility
As with Alternative 3, Alternative 4 would be difficult to implement from an administration standpoint. While NYSDEC permits are not required, the remedial activities must meet the substantive technical requirements of several permit programs. Operations under this alternative would have to be performed in conformance with substantive requirements of regulatory programs implemented by USACE (dredge and fill) under Section 10 of the Rivers and Harbors Act and Sections 401 and 404 (wetlands) of the CWA. In addition, discharges during remediation would conform to NYS regulations related to maintenance of Richmond Creek water quality. Habitat replacement would be implemented in accordance with federal and state SCGs.

Contract documents for this alternative would have to contain substantial restrictions on construction activity, including controls on the types of dredging and capping equipment to be used, restrictions on the speed of operations, constraints on barge filling practices, truck traffic, and controls on temporary storage of contaminated dredge spoils. Finally, requirements of other regulatory programs would need to be incorporated as necessary on the basis of information developed during remedial design.

The use of Brookfield or Fresh Kills landfills for the beneficial use of the sediments as landfill subgrade material require NYSDEC approval of the material and issue a beneficial use determination (BUD) for this application at these locations.

Also, to use the material for the Brookfield OU1 closure, the design for Alternative 4 must be completed by 2007 so that it would not affect the schedule for Brookfield Avenue Landfill capping. This timetable is unrealistic so use of the material is unlikely. The beneficial use of the sediments from Alternative 4 at Fresh Kills presents additional problems as Fresh Kills operations are controlled by NYCDOS, which has its own administrative and financial requirements concerning the timing, design and construction details for closing the various cells.

4.5.2.7 Cost

A summary of the details of the cost estimate for the Alternative 4 is given in Table 4-3. The estimated net present worth costs of this alternative, calculated at a 3.1 percent discount rate, are approximately $11,033,000 to $16,171,000, depending on the location for beneficial use/disposal.

Capital Cost
Since the construction would be performed over a two-year period, capital costs would vary on an annual basis. The total capital costs for this alternative are estimated to be about $11,100,000 to $16,561,000 depending on the location for beneficial use/disposal. The estimated present worth of the capital costs for this alternative is $10,442,000 to $15,580,000.

O&M Costs
Due to the varying frequency of different elements of the monitoring program and the five year reviews, O&M costs would vary on an annual basis. The estimated annual average O&M costs for this alternative are about $37,700.

4.6 Alternative 5: Sediment Removal in Creek and Beneficial Use/Disposal (includes OU1 Remediation and Institutional Controls)

4.6.1 Description

This alternative includes the complete removal/dredging of the first two feet of sediment from Richmond Creek, selected capping of the areas of the creek where contaminants would remain in place, some additional excavation of the marsh areas to maintain slopes between intertidal marsh and creek at 5:1 slope, with beneficial use or offsite disposal of the sediments. This alternative would remove the unstable sediment (especially the unconsolidated cohesive sediments called "muck" in the sediment logs) which is the material most likely to be resuspended, causing water column concentrations of contaminants to increase and causing effects on aquatic life. In addition, this alternative would reduce the total amount of material dredged and limits the area of disturbance to this estuary.

The principal components of this alternative are the same as for Alternative 3 and 4, as described below:

- Source control via OU1 Remediation (including Landfill Capping, Leachate Collection, Subsurface Barrier Wall Installation, Landfill Gas Collection, Wetland Enhancements)

- Institutional Controls;

- In-stream dewatering and excavation of sediments in Richmond Creek using conventional earth moving equipment with the use of suction dredges as needed with additional excavation of areas of intertidal marsh bordering the creek so that slopes between the marsh and creek bottom can remain stable;

- Dewatering excavated sediments with drying beds (and dewatered dredged sediments with geotubes®), collection of supernatant and testing to ensure water meets NYS discharge criteria (addition of polymers to pumped sediment, if

Table 4-3
Cost Analysis
Alternative 4: Sediment Removal in Creek and Intertidal Marsh, Restoration, and Beneficial Use/Disposal (Includes OU1 Remediation and Institutional Controls)

Cost Item	Quantity	Unit Cost	Unit Cost	Unit	Cost	Sources
Capital Costs						
Pre-Construction Studies and Design						
Design Support Testing	1	14,841,805	$516,500	LS	$516,500	1
Design (10% of construction w/o T&D cost)	1	11,007,500	$812,866	LS	$812,866	1
Pre-Construction Cost Total					**$1,329,366**	
Construction						
Mobilization/Demobilization	1	3,782,821	$286,000	LS	$286,000	4
Creek dredge (dry dredge or suction dredge)	41,000	28.21	$15	CY	$615,000	6
Creek excavation	41,000		$17	CY	$697,000	4
Creek cap sand 5 acres at 6 inches	4,033		$46	CY	$183,985	2
Marsh excavation	65,100		$17	CY	$1,106,700	4
Stream Dewatering aquadam pumps	1		$120,000	Each	$120,000	2
grading, lining drying bed 600x600ft	360,000	22.37	$3	SF	$932,400	4
Geotube 2cy fills 1LF tube	20,500		$25	LF	$512,500	6
Trucking to dewater area 10 yd truck 1mile RT	106,100	26.76	$3	CY	$265,250	2
Temporary bridge for creek crossing	1		$78,000	Each	$78,000	
Marsh mats for temporary roads in marsh	42,000		$3	SF	$126,000	
gravel for temp roads	1,555		$34	CY	$53,057	
Marsh Cap Material	58,590		$35	CY	$2,050,650	2
Habitat & Vegetation Replacement	40	3,668,899	$24,200	AC	$968,000	5
Construction Monitoring	1		$134,116	LS	$134,116	3
Subtotal Construction w/o Beneficial Use/Disposal					**$8,128,658**	
T&D to Brookfield (20 yd truck, 2 mile RT)	147,100		$3	CY	$367,750	2
Trucking /Placement/Disposal Fresh Kills	147,100		$16	CY	$2,353,600	2
Trucking/Disposal offsite, regional	147,100	55	$40	CY	$5,884,000	1
Total Construction Brookfield					**$8,496,408**	
Total Construction FreshKills		5,364,654			**$10,482,258**	
Brookfield Permitting (5%) , Construction Mgt (10%) (15% of Total construction cost)					**$14,012,658**	
Fresh Kills Permitting (5%) , Construction Mgt (10%) (15% of Total construction cost)	1		$1,274,461	LS	$1,274,461	1
Regional Permitting (5%) , Construction Mgt (10%) (15% of subtotal construction cost)	1		$1,572,339		$1,572,339	1
	1		$1,219,299		$1,219,299	1
Total Capital Costs (Disposal at Brookfield)					**$11,100,236**	
Total Capital Costs (Disposal at FreshKills)					**$13,383,963**	
Total Capital Costs (Disposal Regional)					**$16,561,323**	
O&M Costs						
Review Costs						
Post Construction Monitoring, surface water - two events	2		$43,600	Each	$87,200	1
Post Construction O&M - every year for 25 years after construction is complete	25	34,193	$34,193	Year	$854,825	1, 3
Total O&M Costs					**$942,025**	
Annual Avg O&M (over 25 year O&M period of 2011 through 2036)					$37,681	
Present Worth of Costs						
Construction (Disposal at Brookfield)					$10,442,750	
Construction (Disposal at FreshKills)					$12,591,208	
Construction (Disposal Regional)					$15,580,367	
Post Construction Monitoring					$69,557	
Post Construction O&M - every 5 years for 25 years after construction is complete					$521,139	
Total Present Worth Costs Alternative 4 at Brookfield					**$11,033,445**	
Total Present Worth Costs Alternative 4 Fresh Kills					**$13,181,904**	
Total Present Worth Costs Alternative 4 Regional					**$16,171,063**	
Round To			**$11,033,000**	to	**$16,171,000**	

- Cost Estimate date August 2006
- Design Support assume to start in 2006
- Design assumed conducted in 2007
- Construction Estimated to Start 2008
- Monitoring costed for two events
- "Real" discount (interest) rate (after adjustment for inflation) of 3.1% (based on 30-year Treasury maturities), taken from OMB Circular No. A-94 Appendix C (Revised January 2005)
Present worth costs determined using Microsoft Office Excel "PV" formula

Sources:
1 Professional judgement
2 CDM 90% construction cost estimate
3 Hudson River PCB FS (NYSDOH, 2005)
4 Brookhaven OUV FS (Brookhaven National Library, 1998)
5 NYSDEC Salt Marsh Restoration and Monitoring Guidelines (NYSDEC and NYS DOS, 2000)
6 USACE Vicksburg, Mississippi levee project (Geotec, 1996)

necessary, to accelerate dewatering and reduce amount of contaminants in effluent);

- Capping of creek sediments in selected areas;
- Placement of marsh substrate material in excavated areas of intertidal marsh area to original or other appropriate elevations followed by vegetative habitat replacement;
- Transportation of dewatered sediments to nearby Brookfield or Fresh Kills landfill for beneficial use under the cap or transportation/disposal at a regional facility; and
- A performance monitoring program.

The total area of sediments that would be remediated is 30 acres. The estimated volume of sediments to be removed is 87,200 cubic yards. In the creek, approximately 25 acres or 82,000 cubic yards of contaminated sediment would be removed. An additional 5 acres of intertidal marsh would be excavated alongside the creek to maintain bottoms at 5:1 slope, replaced with marsh substrate to the same bottom elevations and restored with marine wetland vegetation.

About 5 acres of engineered capping would be placed in selected areas of the creek where significant contamination would be left behind after the 2-foot removal (around locations of SD-4 and SD-11).

This alternative also utilizes naturally occurring attenuation processes to reduce the toxicity, mobility, and volume of the remaining contaminants in Richmond Creek and the marsh after the construction is completed in areas of wetland recovery and areas not disturbed. Institutional controls (*e.g.*, site use restrictions) are implemented as long term control measures as part of this alternative. These restrictions include continuation or modification of the existing fish consumption advisories and restrictions on disturbing the creek caps and marsh substrate material for future construction efforts within the marsh and creek. A review of site conditions would be conducted at five-year intervals.

4.6.1.1 Implementation Schedule and Sequence of Operations

The remediation schedule and implementation would be the same as for Alternative 3 and 4. However, the schedule for removal of sediment would be shorter and would be completed in one year.

4.6.1.2 Performance Monitoring Program

The performance monitoring program would consist of two components: monitoring during construction of the alternative and post-construction monitoring. Monitoring during construction would be about half the cost of Alternatives 3 and 4, since the

duration is shorter and less sediment is dredged. Post-construction monitoring would be the same as for Alternatives 3 and 4.

4.6.1.3 Design Support Investigation (Pre-Construction Studies)

The design support program would be similar to Alternatives 3 and 4.

4.6.2 Analysis

4.6.2.1 Overall Protection of Human Health and the Environment

The overall protection of human health and the environment achieved by Alternative 5 would be moderate because all of the contaminated sediments would remain in the marsh areas. As with Alternatives 3 and 4, Alternative 5 assumes the separate source control of the OU1 remedy, and also relies on the fish consumption advisories and other engineering and institutional controls to protect human health. Finally, Alternative 5 also utilizes natural wetland attenuation processes as burial by cleaner sediments, bioturbation, biodegradation, dispersion, dilution through advection and recharge, adsorption, and volatilization to further reduce the concentration of contaminated sediments remaining in Richmond Creek and the marsh after construction is completed.

The long-term risks to human health and ecological receptors would be reduced through excavation/dredging and capping of the creek sediments although there are short-term impacts. Because contaminants remain in the sediment, especially in the intertidal marsh sediment, Alternative 5 may be inherently less protective of human health in the long term because even though the capping concept is designed to avoid failure, cap damage caused by natural events like major floods cannot be avoided. In the short-term the environment is protected to a greater degree due to less wetland destruction.

For Alternative 5, the concentrations of contaminants in wide-ranging fish (relevant to protection of human health) are anticipated to continue to be similar to those found throughout NY Harbor. Cancer risks and non-cancer health hazards due to exposures to sediment possibly may be within the EPA-acceptable risk range by the end of construction activities, since most exposures to humans would be in the Creek. Little exposure would occur within the marsh channels. Site-related contaminants in fish and shellfish should be reduced starting about half way through the monitoring period if cross contamination and recontamination were not issues.

Alternative 5 would address the scour of contaminated sediments associated with one-in-five-year (and greater) flow events, and is therefore effective in reducing the contaminant load to the estuary.

However, some of the currently well vegetated and stable wetland could be potentially lost forever with the implementation of Alternative 5. The overall long-term reduction in ecologic risk achieved by a removal alternative must be balanced against the short-term disturbance to the aquatic community, the estuary and protected wetlands, and the significant habitat of the major nesting colonies of herons

and colonial wading birds caused by the removal of sediment and the marsh vegetation. Disturbance of the benthic community could cause more adverse impacts to aquatic life than the presence of contaminated sediment. Recent studies highlighting wetlands restoration experience indicates that it is difficult to fully replicate the functionality of established wetlands (National Academy of Sciences, 2001)

4.6.2.2 Compliance with SCGs

As with the other alternatives, Alternative 5 is expected to improve compliance with the chemical-specific SCGs for site-related contaminants in the water-column shortly after completion of the OU1 remedy pending recontamination. Alternative 5 is expected to improve compliance with the chemical specific SCGs for biota within the post-construction monitoring period pending cross-contamination and recontamination.

Through permitting during design, Alternative 5 would comply with action-specific SCGs (*e.g.*, CWA Sections 401 and 404; Section 3004 of RCRA; Section 10 of the Rivers and Harbors Act; New York State ECL Article 3, Title 3, and Article 27, Titles 7 and 9). However, Alternative 5 would not comply with location-specific SCGs (*e.g.*, Endangered Species Act; Fish and Wildlife Coordination Act; National Historic Preservation Act; and Federal and New York State Coastal Wetlands Laws).

4.6.2.3 Long-Term Effectiveness and Permanence

Magnitude of Residual Risks

For Alternative 5, residual risk would still remain since the contamination in the marsh sediments remains. Anthropogenic or natural processes (*e.g.*, future construction activities, severe storms, or longer-term changes in the depositional/erosional regime in a given location) may damage or erode and scour the cap in the creek and the existing marsh areas and redistribute contaminated sediments over wider areas of the estuary. Non-routine repair or replacement of large sections of the cap may have to be undertaken if a breach occurs in a highly contaminated area due to catastrophic events such as a major flood. Depositional buildup of sediments adjacent to the cap could shift currents over the cap creating the potential for erosion in an unexpected area.

This alternative also relies on natural attenuation processes to reduce the remaining contaminants left on site, particularly in the intertidal marsh area. Recontamination of the sediment in the creek from offsite sources is probable. There is high likelihood that the restored wetland will not achieve the functionality of the natural wetland.

The Arthur Kill undergoes continual maintenance dredging and potential dredging is required in the Fresh Kills during the closure of cells 1 and 9. The sediment within the creek and marsh will become recontaminated as suspended contaminants are spread throughout the estuary during the flood tides.

Adequacy of Controls
Alternative 5 provides for dredging of contaminated sediments in the creek and placement of cap over the selected target areas of the creek. There would be no controls over the contaminated sediments within the marsh. Excavation/dredging are proven technologies to remove contaminants. This alternative also assumes that the OU1 remedy of landfill capping, barrier wall installation, landfill gas collection and leachate control would proceed and provides for institutional controls such as the fish consumption advisories. Engineering controls include the placement of cap over the selected target areas of the creek.

As with Alternatives 3 and 4, the planned post-construction sampling in conjunction with ongoing IT Corp. sampling at WC-12 location and the OU1 post-closure sampling program would allow for tracking the natural recovery of the creek after remediation is completed.

Reliability of Controls
Sediment removal (dredging and excavation), placement of marsh substrate material, and habitat replacement, and off-site disposal/treatment of removed sediments are all reliable and proven technologies. However, for Alternative 5, proper design, placement, and maintenance of the cap and marsh substrate in perpetuity would be required for its effectiveness, continued performance, and reliability. This presents a challenge within this site. The cap requires a monitoring and maintenance program to insure cap integrity.

The fish consumption advisories would continue to address protection of human health until contaminant concentrations in fish are reduced and the tissue concentrations for protection of human health is attained.

4.6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

For Alternative 5, removal of the creek sediments would reduce the toxicity, mobility, and volume of the contaminants within the creek. Capping would reduce the mobility of contaminants in the creek but does not affect their toxicity or volume. Since sediments that are removed are not treated (stabilized) prior to beneficial use at the landfill, Alternative 5 does not satisfy the NYSDEC statutory preference for treatment. In addition, there would be no reduction in the toxicity or volume of the contaminants under the cap/marsh substrate.

Alternative 5 would result in no reduction of toxicity, mobility or volume of contaminants within the marsh. However, after construction is completed, natural attenuation processes may reduce the toxicity and volume of contaminants in marsh sediments (e.g., through biodegradation) or reduce their mobility (e.g., though burial by cleaner sediments).

4.6.2.5 Short-Term Effectiveness

Short-term effectiveness is assessed through review of the four components described previously: protection of the community during remedial actions; protection of the

workers during remedial actions; potential adverse environmental impacts resulting from construction and implementation; and time until remedial response objectives are achieved.

Protection of the Community During Remedial Actions

Given the lower amount of removal, relative to Alternatives 3 and 4, exposure levels for fish are not expected to increase substantively during the dredging so that risks from consuming fish would remain largely the same during the construction period. The fish consumption advisories and restricted access to portions of the creek and marsh undergoing remediation would provide protection from risks to human health for the local community and the general public in the short term. Transfer facilities and treatment areas would present potential short-term risks to the community. Therefore, access to these areas would be restricted to authorized personnel. In addition, monitoring and engineering controls would be employed to minimize short-term effects due to material processing activities. Should road transport of the dewatered sediments be necessary, increased truck traffic would also present an incremental risk to the community. The potential for traffic accidents would increase marginally as additional vehicles are on the road.

Protection of Workers During Remedial Actions

For Alternative 5, potential occupational risks to site workers from direct contact, ingestion, and inhalation of contaminants from the surface water and sediments, and routine physical hazards associated with construction work and working on water could occur. For all the alternatives, site personnel would follow a site-specific health and safety plan, OSHA health and safety procedures, and wear the necessary personal protective equipment.

Potential Adverse Environmental Impacts Resulting from Construction and Implementation

As with Alternatives 3 and 4, this alternative would cause some release of heavy metals, PCBs and other organics from the contaminated sediments into the water column during construction (dredging and cap placement), as well as the increased transport of these sediments throughout the estuary. This resuspension would be controlled to the extent practicable by operational practices (*e.g.*, control of sediment removal rates; use of enclosed dredge buckets; and use of sediment barriers). Although precautions to minimize resuspension would be taken, it is likely that there would be a transient increase of suspended contaminant concentrations in the water column, and possibly in contaminant concentrations in fish.

Remedial activities would result in impacts to aquatic and wildlife habitat of Richmond Creek. As with Alternatives 3 and 4, the entire benthic community of the creek bed and tidal flats would be destroyed. A monitoring program would need to be established to verify the attainment of the habitat replacement objectives. The degree of impact is directly related to the area remediated and volume dredged. According to NYSDEC, the destruction of onsite wetlands is not acceptable.

Time until Remedial Response Objectives Are Achieved
For Alternative 5, and similar to Alternatives 1 and 2, compliance with the surface water SCGs is expected to improve following completion of the OU1 remedy. The risk based concentrations of contaminants in sediment and surface water should improve within a few years after the construction period is complete. The risk based concentrations of contaminants in fish fillet and shellfish for protection of human health are not expected to be met in the short term but could be met long-term if recontamination were not an issue. The risk-based concentrations of contaminants in fish fillet and shellfish for protection of human health will continue to be influenced by contamination sources other than OU2 even after implementation of this alternative.

Wetlands recovery and limited recontamination would be required to achieve additional improvement. These caveats create uncertainty regarding long-term success. In addition, the damage to the existing ecosystem as a result of the excavation/dredging is not acceptable since this is habitat of high value.

4.6.2.6 Implementability

Technical Feasibility
Technical feasibility for Alternative 5 is discussed below in terms of the main components of the alternative. Principal elements of the overall system that must be constructed, operated, and otherwise be available in order to cap and selectively remove targeted sediments, are as follows:

Removal Equipment: Removal work under this alternative would be accomplished by means of conventional excavators and/or suction dredges. In general, the mechanical systems needed to implement this alternative are either available, or can be fabricated.

Transfer Facilities*:* As with Alternatives 3 and 4, under Alternative 5, transfer facilities would be established at the OU1 site or potentially to the north of the creek to process sediments generated by removal operations. These transfer facilities would require adequate land area to process incoming sediments and temporary road construction for access to roads offsite.

Transportation and Disposal*:* Trucking would be the principal transportation mode considered for moving dredged sediments to Brookfield OU1, Fresh Kills or regional landfills. This would increase truck traffic and air pollution in the short term.

Administrative Feasibility
As with Alternative 3 and 4, Alternative 5 would be difficult to implement from an administration standpoint. While NYSDEC permits are not required, the remedial activities must meet the substantive technical requirements of several permit programs. Operations under this alternative would have to be performed in conformance with substantive requirements of regulatory programs implemented by USACE (dredge and fill) under Section 10 of the Rivers and Harbors Act and Sections

401 and 404 (wetlands) of the CWA. In addition, discharges during remediation would have to conform to NYS regulations related to maintenance of Richmond Creek water quality. Habitat replacement would be implemented in accordance with federal and state SCGs.

Contract documents for this alternative would have to contain substantial restrictions on construction activity, including controls on the types of dredging and capping equipment to be used, restrictions on the speed of operations, constraints on barge filling practices, truck traffic, and controls on temporary storage of contaminated dredge spoils. Finally, requirements of other regulatory programs would have to be incorporated as necessary on the basis of information developed during remedial design.

The use of Brookfield or Fresh Kills landfills for the beneficial use of the sediments as landfill subgrade material requires NYSDEC approval of the material and issue a beneficial use determination (BUD) for this application at these locations.

Also, to use the material for the Brookfield OU1 closure, the design for Alternative 5 must be completed by 2007 so that it would not affect the schedule for Brookfield Avenue Landfill capping. This timetable is unrealistic so use of the material is unlikely. The beneficial use of the sediments from Alternative 5 at Fresh Kills presents additional problems as Fresh Kills operations are controlled by NYCDOS, which has its own administrative and financial requirements concerning the timing, design and construction details for closing the various cells.

4.6.2.7 Cost

A summary of the details of the cost estimate for the Alternative 5 is given in Table 4-4. The estimated net present worth costs of this alternative, calculated at a 3.1 percent discount rate, are approximately $6,051,000 to $9,097,000, depending on the location for beneficial use/disposal.

Capital Cost

The total capital costs for this alternative are estimated to be about $5,800,000 to $9,000,000. The estimated present worth of the capital costs for this alternative is $5,400,000 to $8,500,000, depending on location for beneficial use/disposal.

O&M Costs

Due to the varying frequency of different elements of the monitoring program, O&M costs would vary on an annual basis. The estimated annual average O&M costs for this alternative are about $37,600.

Table 4-4
Cost Analysis
Alternative 5: Sediment Removal in Creek and Beneficial Use/Disposal (Includes OU1 Remediation and Institutional Controls)

Cost Item	Quantity	Unit Cost	Unit	Cost	Sources
Capital Costs					
Pre-Construction Studies and Design					
Design Support Testing	1	$516,500	LS	$516,500	1
Design (10% of construction w/o T&D cost)	1	$401,685	LS	$401,685	1
Pre-Construction Cost Total				**$918,185**	
Construction					
Mobilization/Demobilization	1	$214,500	LS	$214,500	4
Creek dredge (dry dredge or suction dredge)	41,000	$15	CY	$615,000	6
Creek excavation	41,000	$17	CY	$697,000	4
Creek cap sand 5 acres at 6 inches	4,033	$46	CY	$183,985	2
Marsh excavation	5,200	$17	CY	$88,400	4
Stream Dewatering aquadam pumps	1	$120,000	Each	$120,000	2
grading, lining drying bed 600x600ft	360,000	$3	SF	$932,400	4
Geotube 2cy fills 1LF tube	20,500	$25	LF	$512,500	6
Trucking to dewater area 10 yd truck 1mile RT	46,200	$3	CY	$115,500	2
Temporary bridge for creek crossing	1	$78,000	Each	$78,000	
Marsh mats for temporary roads in marsh	21,000	$3	SF	$63,000	
gravel for temp roads	777	$34	CY	$26,511	
Marsh Cap Material	5,200	$35	CY	$182,000	2
Habitat & Vegetation Replacement	5	$24,200	AC	$121,000	5
Construction Monitoring	1	$67,058	LS	$67,058	3
Subtotal Construction w/o Beneficial Use/Disposal				**$4,016,855**	
T&D to Brookfield (20 yd truck, 2 mile RT)	87,200	$3	CY	$218,000	2
Trucking /Placement/Disposal Fresh Kills	87,200	$16	CY	$1,395,200	2
Trucking/Disposal offsite, regional	87,200	$40	CY	$3,488,000	1
Total Construction Brookfield				**$4,234,855**	
Total Construction FreshKills				**$5,412,055**	
Brookfield Permitting (5%) , Construction Mgt (10%) (15% of Total construction cost)				**$7,504,855**	
Fresh Kills Permitting (5%) , Construction Mgt (10%) (15% of Total construction cost)	1	$635,228	LS	$635,228	1
Regional Permitting (5%) , Construction Mgt (10%) (15% of subtotal construction cost)	1	$811,808		$811,808	1
	1	$602,528		$602,528	1
Total Capital Costs (Disposal at Brookfield)				**$5,788,269**	
Total Capital Costs (Disposal at FreshKills)				**$7,142,049**	
Total Capital Costs (Disposal Regional)				**$9,025,569**	
O&M Costs					
Review Costs					
Post Construction Monitoring, surface water - two events	2	$43,600	Each	$87,200	1
Post Construction O&M - every year for 26 years after construction is complete	26	$34,193	Year	$889,018	1, 3
Total O&M Costs				**$976,218**	
Annual Avg O&M (over 26 year O&M period of 2010 through 2036)				$37,547	
Present Worth of Costs					
Construction (Disposal at Brookfield)				$5,445,420	
Construction (Disposal at FreshKills)				$6,719,013	
Construction (Disposal Regional)				$8,490,969	
Post Construction Monitoring				$69,557	
Post Construction O&M - every 5 years for 26 years after construction is complete				$536,857	
Total Present Worth Costs Alternative 5 at Brookfield				**$6,051,833**	
Total Present Worth Costs Alternative 5 Fresh Kills				**$7,325,426**	
Total Present Worth Costs Alternative 5 Regional				**$9,097,382**	
Round To		**$6,052,000**	to	**$9,097,000**	

- Cost Estimate date August 2006
- Design Support assume to start in 2006
- Design assumed conducted in 2007
- Construction Estimated to Start 2008
- Monitoring costed for two events

- "Real" discount (interest) rate (after adjustment for inflation) of 3.1% (based on 30-year Treasury maturities), taken from OMB Circular No. A-94 Appendix C (Revised January 2005)
Present worth costs determined using Microsoft Office Excel "PV" formula

Sources:
1 Professional judgement
2 CDM 90% construction cost estimate
3 Hudson River PCB FS (NYSDOH, 2005)
4 Brookhaven OUV FS (Brookhaven National Library, 1998)
5 NYSDEC Salt Marsh Restoration and Monitoring Guidelines (NYSDEC and NYS DOS, 2000)
6 USACE Vicksburg, Mississippi levee project (Geotec, 1996)

Section 5
Comparative Analysis

This chapter provides an overall comparison of the five remedial alternatives analyzed in detail in Chapter 4, using the seven criteria outlined in NYSDEC regulations (6 NYCRR Subpart 375-1.10). The purpose of the analysis in this chapter is to determine the advantages and disadvantages of each alternative, which would provide the rationale for selecting a remedial alternative. As described in 6 NYCRR Subpart 375-1.10 and Section 4 of this FS, the evaluation criteria are:

- Compliance with standards, criteria and guidance (SCGs);
- Overall protectiveness of public health and the environment;
- Short-term effectiveness;
- Long-term effectiveness;
- Reduction of toxicity, mobility, and volume with treatment;
- Feasibility (i.e. implementability and cost-effectiveness); and
- Cost.

Per NYSDEC's Technical and Administrative Guidance Memorandum (TAGM) # 4030 Selection of Remedial Actions at Inactive Hazardous Waste Sites and DER-10 Technical Guidance for Site Investigation and Remediation (NYSDEC 2002), the first seven criteria are employed in the analysis of alternatives for remediation. An eighth criterion, Community Acceptance, would be addressed after public participation in NYSDEC's ROD for Brookfield Avenue Landfill OU2.

5.1 Compliance with Standards, Criteria and Guidance (SCGs)

This evaluation criterion provides an assessment of whether each alternative complies with applicable SCGs or whether compliance with SCGs is necessary to protect public health and the environment.

Exceedances of SCGs exist in surface water, sediment and biota within OU2. Continuing sources for some of these exceedances have been identified in OU1 (e.g., leachate, groundwater discharge and stormwater runoff) and elsewhere in the Fresh Kills estuary (e.g., Fresh Kills landfill and impacted sediments beyond Brookfield Avenue Landfill OU2). Based on the widespread distribution of environmental impacts, none of the proposed remedial alternatives is expected to achieve full compliance with all SCGs. However, significant source control is expected as a result of the remedial actions planned for OU1 and the pending closure of the Fresh Kills

landfill. These source controls are common to all the remedial alternatives and are expected to result in significant immediate improvement in surface water quality and more gradual improvements in biota contaminant concentrations and sediment quality.

According to 6 NYCRR Subpart 375-1.10(c)(1), a site's program must be designed so as to conform to standards and criteria that are generally applicable, consistently applied, and officially promulgated, that are either directly applicable, or that are not directly applicable but are relevant and appropriate, unless good cause exists why conformity should be dispensed with. Such good cause exists if any of the following is present:

- The proposed action is only part of a complete program that will conform to such standard or criterion upon completion ;
- Conformance to such standard or criterion will result in greater risk to human health or to the environment than alternatives;
- Conformity to such standard or criterion is technically impracticable from an engineering perspective; or
- The program will attain a level of performance that is equivalent to that required by the standard or criterion through the use of another method or approach.

All of the remedial alternatives evaluated in this section are part of a complete program of landfill closure and restoration that is designed to allow the ecosystem to regain its full functionality.

Conformance to all SCGs for sediment would require removal of vast amounts of material from a sensitive ecosystem; large-scale removal would be more harmful to the existing ecosystem than limited removal or natural improvement. As stated in 6 NYCRR Part 375, the goal of the remediation program for a specific site is to restore that site to pre-disposal conditions, to the extent feasible and authorized by law. Non-intrusive alternatives are considered to be more effective at returning OU2 to pre-disposal conditions than the sediment removal alternatives.

Conformance to all SCGs for sediment would be technically impractical due to the volume of material requiring excavation and disposal and because sediments elsewhere in the Fresh Kills estuary and New York Harbor are similarly impacted. With regional contamination documented in past studies, it is clear that recontamination of an excavated area of Richmond Creek would occur over time due to its connections to the regional system.

Through source control, the implementation of appropriate institutional controls, engineering controls and the natural improvement process provided by the existing wetlands, it is expected that human health and the environment can be protected as described below.

5.2 Overall Protection of Human Health and the Environment

5.2.1 Protection of Human Health

Alternative 1 does not actively reduce the levels of contaminants in sediment and does not address human exposure to the contaminants in sediment or biota with the exception of NYS fish consumption advisories. However, under Alternative 1, the OU1 remedy and closure of Fresh Kills Landfill would take place and surface water quality is expected to improve compliance with SCGs due to the control over influx of new contamination and the contaminant removal processes of the wetlands. Existing fish consumption advisories would be maintained but no additional restrictions or advisories would be employed.

Alternative 2, Institutional Controls and Monitoring and the active remedial alternatives address the protection of public health through existing and potential additional institutional controls. Institutional controls, such as access and activity restrictions as well as fish and shellfish consumption advisories, address the major contributors to site risk, which is the potential consumption of fin fish and shellfish. It is probable that estuary wide improvements in water and sediment quality would need to occur before consumption advisories are no longer required in the vicinity of the Brookfield Avenue and Fresh Kills Landfills.

The overall protection of human health achieved by the active alternatives is potentially more than that achieved by the No Action and Institutional Controls and Monitoring alternatives with the exception of individuals involved in the implementation of the active alternatives. For these individuals, protective measures will be employed. For Alternatives 3, 4 and 5, a portion of limited human health risk is reduced immediately upon completion of the action through removal (and selective capping) of contaminated sediments in the creek and marsh. This benefit is muted somewhat due to disturbance of the sediments which would potentially increase exposure to contaminants. The three alternatives would also receive the benefit of the gradual attenuation of residual contaminants as described for No Action and Institutional Controls and Monitoring.

5.2.2 Overall Protection of the Environment

All alternatives will receive the benefit of the OU1 remedy and closure of Fresh Kills Landfill which will greatly reduce the flow of contamination into OU2. The OU1 remedy will reduce the flow of dissolved contaminants from contaminated groundwater and leachate from the Brookfield Avenue Landfill currently migrating to the surface waters of Richmond Creek or sorbing onto the deep sediments beneath the marsh and creek. The OU1 remedy will also prevent any future migration of particle-bound contaminants from the landfill via overland flow. Also, under all the alternatives, exposure of the aquatic community to the contaminated sediments is anticipated to decrease due to the natural redistribution and new deposition

occurring within the estuary. Impacted surface water is also considered to be the primary factor for elevated concentrations in biota. Therefore improvement in biota tissue concentrations would be expected to occur after completion of the landfill capping, barrier wall installation, leachate collection and landfill gas control instituted as the OU1 remedy.

Alternatives 3, 4 and 5 would reduce the amount of contaminants in the marsh and creek that were either released from the landfill during its past operations or from other sources, such as the Fresh Kills Landfill. Once the remedial action is complete, this would reduce the risk to the aquatic community from bioaccumulation in the food chain resulting from concentrations in the removed sediment. In this respect, Alternative 3 is more protective than 4 and 5 because it removes the greatest amount of contamination from the sediments. Alternative 4 offers slightly more protection than Alternative 5. All the protective gains of the active alternatives assume that the wetlands will be restored, because the dredging alternatives will destroy the wetlands to a greater or lesser extent, and therefore the dredging scenarios are initially less protective in regards to protection of the environment.

The overall long-term reduction in ecologic risk presumed by the three active alternatives is not guaranteed. It is possible that the wetland functionality would be lost forever. Also, short-term impacts will include disturbance to the aquatic community, the estuary and wetlands, and the significant habitats of the major nesting colonies of herons and colonial wading birds caused by the removal of sediment and the marsh vegetation. Although Alternatives 1 and 2 do not reduce the exposure of aquatic life to contaminated sediment in the short term, no wetlands or bird habitats are impacted under these alternatives and therefore no ecosystem disruption would take place. Alternative 4 would result in less wetland/vegetative habitat disturbance than Alternative 3 because it leaves unexcavated the higher elevation high marsh sediments. Alternative 5 has even less wetland/vegetative habitat disturbance since only the submerged, unvegetated sediments of Richmond Creek and its tributaries are removed. However, each of the sediment removal remedies would result in some damage to the current wetlands and habitat. Although mitigation measures would be employed and the wetland reconstructed to the extent practicable, wetlands restoration experience indicates that it is difficult to fully replicate the functionality of established wetlands.

5.2.3 Downstream Transport of Site-Related Contaminants

An important aspect to developing remedies for contaminated sediment sites is that the remedy must consider the entire water body. Therefore, in evaluating the degree to which a remedy protects human health and the environment, the potential for redistribution of sediment must be considered.

None of the five alternatives will remove all the sediment in the estuary with concentrations above SCGs and some redistribution of sediment by natural processes would continue to occur.

The three sediment removal remedial alternatives eliminate (long-term) through excavation, or reduce through capping, the potential for resuspension of the contaminated sediments they address. Short-term, the opposite would occur and the disturbance would resuspend contamination that is currently non-mobile. In addition, the existing wetlands serve to limit sediment resuspension and transport. Damaging existing wetlands would result in increased potential for sediment resuspension and transport.

5.3 Short-Term Effectiveness

The short-term effectiveness of each alternative is addressed through evaluation of the following criteria:

- Protection of the community during remedial actions;
- Protection of workers during remedial actions;
- Potential adverse environmental impacts during construction; and
- Time until remedial response objectives are achieved.

5.3.1 Protection of the Community during Remedial Actions

No construction activities are associated with the No Action and Institutional Controls and Monitoring alternatives, so both are more protective of the community during remedial actions than any of the active remedies. Neither alternative increases the potential for the community to come into contact with contaminants from the surface water and sediments of Richmond Creek. Also Alternatives 1 and 2 do not result in heavy equipment operation or increased truck traffic in the vicinity.

For Alternatives 3, 4 and 5, contaminated sediment excavation/dredging, dewatering, transportation and disposal present potential short-term risks to the community. Alternative 3 presents the greatest short-term risks since the largest amount of contaminated sediments (almost 300,000 cubic yards) is removed and handled. For each of the active alternatives, access to the construction areas would be restricted to authorized personnel. In addition, monitoring and engineering controls would be employed to minimize short-term effects due to material processing activities.

Depending on the location for disposal of the sediments, increased traffic would present an incremental risk to the community. The potential for traffic accidents will increase as additional vehicles are on the road. These effects are less likely for Alternatives 4 and 5 which require transporting much lower amounts of material.

5.3.2 Protection of Workers during Remedial Actions

For the No Action alternative, occupational risks are minimal since there will be no site work except for site visits. A slight increase in occupational risk may be associated with the Institutional Controls and Monitoring alternative due to the sampling

involved in the creek and marsh. These activities are typically performed by trained, protected, and medically monitored individuals.

For the three active remediation alternatives, potential occupational risks to site workers from direct contact, ingestion, and inhalation of contaminants from the surface water and sediments and routine physical hazards associated with construction work and working on water are significantly higher than for the No Action and Institutional Controls and Monitoring alternatives.

For these active alternatives, as well as the Institutional Controls and Monitoring alternative, personnel would follow a site-specific health and safety plan and OSHA health and safety procedures, and would wear the necessary personal protective equipment.

5.3.3 Potential Adverse Environmental Impacts during Construction

No construction activities associated with Richmond Creek and marsh are conducted for the No Action and Institutional Controls and Monitoring alternatives. Neither the No Action alternative nor the monitoring program for the Institutional Controls and Monitoring alternative is anticipated to have any adverse effect on the current vegetative habitat and coastal wetlands.

For the three active remediation alternatives, some release of contaminants from the sediments into the surface water during construction (dredging/excavation and capping/placement of marsh substrate), as well as the transport of these resuspended contaminants into the creek beyond Richmond Avenue, would occur. These releases would be controlled to the extent practicable by operational practices (e.g., control of sediment removal rates; use of suction dredging; and use of sediment barriers). Although precautions to minimize resuspension would be taken, it is likely that there would be a temporary increase of suspended contaminant concentrations in the creek, and possibly in fish and shellfish body burdens. Resuspension effects apply only to the areas undergoing or downstream of dredging/excavation. Since Alternative 5 involves the least amount of sediment removal, the negative effects of resuspension are lowest for this alternative of the active remedy alternatives.

More importantly, for Alternatives 3, 4 and 5, remedial activities would result in severe impacts to aquatic and wildlife habitat of the Richmond Creek and marsh. Some or most of the existing wetland vegetation which provide "significant habitat" for endangered and threatened bird species, and some or most of the existing established wetland sediments and benthic communities would be eliminated. The degree of impact would be directly related to the area remediated and volume of sediment excavated or dredged. Habitat restoration measures would be implemented to mitigate these impacts and a monitoring program would be established to verify attainment of the habitat replacement. However, it is typically difficult to fully replicate the functionality of previously established wetlands. Alternatives 1 and 2,

the No Action and the Institutional Controls and Monitoring alternatives are most protective of the wetlands resource and conform to the "Do No Harm" guidance.

5.3.4 Time until Remedial Response Objectives Are Achieved

For all alternatives, due to the separate source control provided by the OU1 remedy, compliance with the surface water SCGs are expected to be improved upon completion of the action.

It is not feasible to accurately predict the timeframe within which the SCGs for biota would be met under the various alternatives due to factors such as recontamination and movement of biota to contaminated areas outside of OU2. However, as surface water is considered to be the primary source of impacts to biota, removal of surface water sources through closure of OU1 and the Fresh Kills Landfill is expected to result in improvement under all alternatives under consideration.

For both Alternative 1 and Alternative 2, the limited identified potential risks to humans and the adverse effects to ecological receptors due to the contaminated sediments would persist throughout the short term. For the Institutional Controls and Monitoring alternative, activity and use limitations and fish consumption advisories would be continued and/or enhanced as a means for protecting human health. The No Action alternative assumes that current advisories are continued, but no new institutional controls are initiated.

Of the active alternatives, remedial response objectives concerning human health risks and ecological effects would be achieved more quickly with Alternatives 3 and 4, in that order. Alternative 5 leaves the contaminated marsh sediment, relying on natural processes to reduce the human health and ecologic risks.

5.4 Long-Term Effectiveness and Permanence

The long-term effectiveness of an alternative is assessed through the following criteria, as evaluated individually in this section:

- Permanence of the remedial alternative;
- Magnitude of the remaining risk;
- Adequacy of controls; and
- Reliability of controls.

5.4.1 Permanence of the Remedial Alternative

All five alternatives will benefit from the source control activities taken at OU1 and the Fresh Kills Landfill. Assuming proper operation and monitoring, these remedial actions can be considered permanent. It can reasonably be assumed that the institutional controls that are incorporated into Alternative 2 and the three active remedies will be maintained as long as periodic monitoring indicates they are

warranted. All alternatives are potentially long-term solutions. However, because sediment above the SCGs will remain in the greater estuary, recontamination of sediment in Richmond Creek and the marsh will occur. Containment (capping) included in Alternatives 3, 4, and 5 can be engineered to be resistant to erosional forces and can be maintained through operation and maintenance programs. However, wetlands and estuaries are dynamic environments subject to occasional strong hydraulic forces (e.g., storm surges, waves, currents), and monitoring and maintenance activities in these areas are also challenging. Therefore, in place containment options are not considered permanent.

5.4.2 Magnitude of the Remaining Risk

Under Alternatives 1 and 2, no actions are taken to immediately reduce the residual risk remaining in Richmond Creek and marsh. As summarized in Section 1, most risks to human health at the Brookfield Avenue Landfill site are through the consumption of finfish and shellfish which are the subject of NYSDOH consumption advisories. Human health risks posed by exposure to surface water and sediment are not considered significant except potentially for a child exposed to upper marsh sediment and the estimated non-cancer hazard index for that exposure was only 2, compared to the EPA non-cancer health threshold of 1 . Ecological risks are predicted based on surface water concentrations of copper and elevated concentrations of constituents in sediment. The Brookfield Avenue Landfill's contribution of contaminants to surface water and sediment will be removed through the completion of the OU1 remedy. Sediments with similar concentrations exist throughout the estuary.

For both alternatives, natural sedimentation provides some degree of protection from residual human health and ecological risks, and the contaminant removal wetland processes continue to provide improvement.

Alternatives 3, 4 and 5 are more effective in reducing residual risks should changes in future site use occur because some on-site contaminated sediment is removed from the estuary. However, none of the active alternatives completely eliminate long-term risks because some contaminated material remains. Alternative 3 removes the most contamination and has the least amount of reliance on the capping and backfilling to protect human health and the environment from future residual risks. However, this alternative is the most disruptive to the existing wetlands. Alternative 4 removes less material than Alternative 3 and, therefore, must rely on the capping and backfilling to address residual risks. Alternative 5 removes the least amount of contaminated sediment and, while it provides institutional controls to limit residual risks from contaminated sediments remaining within Richmond Creek, it does not protect the ecosystem from the contaminated sediments that remain within the marsh.

The Arthur Kill undergoes continual maintenance dredging and potential dredging is required in the Fresh Kills during the closure of cells 1 and 9. The sediment within the creek and marsh will become recontaminated as suspended contaminants are spread throughout the estuary during the flood tides. With regional contamination

documented in past studies, it is clear that recontamination of an excavated area of Richmond Creek would occur over time due to its connections to the regional system.

5.4.3 Adequacy of Controls

While all alternatives assume the separate source control of the OU1 remediation, the No Action and Institutional Controls and Monitoring alternatives do not provide for any additional engineering controls for the contaminated sediments that currently exist in Richmond Creek and marsh. Alternative 1 scores lowest in long term effectiveness because it does not provide any additional controls to reduce human health and ecological risks. Alternative 2 includes additional institutional controls if warranted to limit residual risks from contaminated sediment and surface water in Richmond Creek and marsh. Institutional controls may not be 100 percent effective in reducing human exposure to contaminated fish and shellfish because they rely on voluntary compliance. In addition, institutional controls are not effective for protection of the environment (e.g., ecological receptors).

The three active alternatives provide for dredging/removal of some or most of the contaminated sediments in Richmond Creek and marsh and placement of engineered caps and/or marsh substrate material over the remaining target areas. Removal and capping controls are typically capable of achieving long term protection of public health and the environment assuming appropriate maintenance and recovery of wetlands. Like the Institutional Controls and Monitoring alternative, these alternatives also include institutional controls, such as the fish consumption advisories.

The three active remedial alternatives are not completely adequate to achieve long-term protection of public health and the environment because they cannot prevent the recontamination of the OU2 sediment after the contaminated material is removed from the creek and marsh. Anthropogenic or natural processes (e.g., development upstream, maintenance dredging in Fresh Kills creek, severe storms, or longer-term changes in the depositional/erosional regime in a given location) will result in contaminated material depositing over the remediated sediments. The source of the new contamination could be from upstream (e.g., from the fresh water portions of Richmond Creek), from the marsh and uplands north of OU2, or from further downstream within the estuary (e.g., from the contaminated sediment surrounding the Fresh Kills landfills). While the net flux of sediment within the estuary is out towards the Arthur Kill, downstream sediment can become resuspended during storms or dredging episodes and transported upstream during the flood tide to the more quiescent areas of OU2.

5.4.4 Reliability of Controls

In general, the active removal alternatives are the most reliable long-term if the wetlands recover, as sediment dredging/excavation, capping, habitat replacement, and dewatering/disposal of removed sediments are, individually, all reliable and proven control technologies to various extents. Of the removal alternatives,

Alternative 3 is the most reliable, as it permanently removes the greatest amount of sediment (leaving the least amount of contaminants in the Richmond Creek and marsh sediment). Alternative 4 does not achieve the same degree of reliability due to the potential for defects or damage to the cap and marsh substrate material, thereby reducing its effectiveness. Alternative 5 is the least reliable of the active removal alternatives because it leaves a larger amount of contaminants within the estuary. However, all the active alternatives are not reliable when predicting the full recovery of wetland processes.

All of the alternatives rely on institutional controls (fish consumption advisories and, potentially, access restrictions or recreational prohibitions) to provide protection of human health until contaminant concentrations in sediment, fish and biota are reduced. Because no additional controls are considered, the No Action alternative does not provide as much or as reliable control.

5.5 Reduction of Toxicity, Mobility, or Volume through Treatment

None of the alternatives meet the NYSDEC's statutory preference for treatment as a principal element. However, the wetlands continuously provide treatment functionality in Alternative 1 and Alternative 2, and to the extent they recover or are not impacted in Alternatives 3, 4 and 5. Although Alternatives 3, 4 and 5 provide treatment of the dredged sediments, this purpose of this treatment is to remove excess water, and not destruction of contaminants.

Because all the alternatives assume the separate source control presented by the OU1 remedy, the mass of contaminants within the surface waters (water column loads) at the site would be reduced. Further, as the landfill leachate is prevented from entering the groundwater and surface waters of the marsh and creek, the geochemistry of the estuary would return to a more natural state, potentially reducing the toxicity of the contaminants remaining in the sediment at the site. Monitoring indicates that the groundwaters and surface waters surrounding the landfill are currently being affected by the landfill's release of ammonia, organic carbon, nitrogen, chloride, iron, manganese, phenols and other ions and compounds. The leachate has caused high BOD and COD in these waters and has altered the chemistry, potentially making more soluble the organic and inorganic contaminants that have historically been released from the landfill which are now present in the sediments of Richmond Creek and marsh. Upon completion of the OU1 remedy and closure of the Fresh Kills Landfill, the waters of Richmond Creek estuary may begin to return to their pre-landfill conditions which should make less soluble the organic and inorganic contaminants, thereby reducing their toxicity.

With respect to the sediments in Richmond Creek and marsh, Alternatives 3, 4 and 5 would reduce the volume, mobility and toxicity of the material to which aquatic life could be exposed because the contaminated sediments are permanently removed from the ecosystem. Additional reduction of the water column loads would

potentially result from sediment remediation. The No Action and Institutional Controls and Monitoring alternatives do not involve any artificial containment or removal of contaminants from Richmond Creek and marsh sediments, although the natural wetland processes would continue to provide some treatment of contaminants. These alternatives do rely on natural attenuation processes such as burial by cleaner sediments, biodegradation, bioturbation, and dilution to reduce contaminant concentrations in sediments and surface water (reducing mass). These processes may also result in decreasing the toxicity and mobility of site related contaminants by changing them into less bioavailable forms.

Natural dilution of the contaminated sediments would also reduce the toxicity, but the overall volume of contaminated sediments would increase as contaminants are distributed throughout the estuary. Concentrations of site-related contaminants in fish would respond slowly over time to decreases in concentrations in sediments and surface water.

For the active removal alternatives, the mobility of the contaminants in the capped/backfilled areas is reduced because they are sequestered under the cap. The wetlands also provide similar functionality (i.e., sequestering). However, capping does not satisfy the NYSDEC statutory preference for treatment. In addition, there is no reduction in the toxicity or volume of the contaminants under the cap.

5.6 Implementability

Feasibility is evaluated by considering both technical and administrative implementability as well as the availability of any limiting resources.

Alternative 1 requires the least amount of effort to implement from a technical and administrative standpoint. Institutional Controls and Monitoring (Alternative 2) requires surface water monitoring, which while technically feasible and proven, would require more effort than Alternative 1. In addition, Institutional Controls and Monitoring may require the implementation of additional institutional controls. Fish consumption advisories are currently in place, so institutional controls are considered administratively feasible but again would require more effort to maintain and enforce than Alternative 1.

The active alternatives all use technologies and processes that are technically feasible and have been proven. Excavation and/or hydraulic dredging of the creek sediments is considered technically feasible for all active alternatives. The capability of mechanical equipment to efficiently remove as little as one or two feet of sediment from the marsh has been proven in many marsh restoration projects. Based on available data, it has been calculated that hydraulic dredging operations would resuspend 40 percent less sediment than would mechanical removal operations for the same production rate. Capping of the remaining contaminants in Richmond Creek and placement of marsh substrate to existing grades in the marsh are practices that have all been accomplished before and are expected to be technically feasible for this site. The preparation of a dewatering facility at a location north of Richmond Creek

may be technically feasible since there is available land and access along the existing maintenance road for the sewer interceptor. The use of geotubes for dewatering of the dredged sediment has been proven technically feasible and efficient. Depending on the construction sequence and timing of OU1, an additional dewatering area may be needed at this location for the marsh sediments. Several acres may be needed to house both the geotube and conventional dewatering systems and any associated equipment. Nonetheless, it is expected that such a transfer/processing site can be assembled.

From a technical standpoint, of the active removal alternatives, Alternative 5, which involves the dredging, dewatering and disposal of the unconsolidated sediments from Richmond Creek, is more feasible than Alternatives 3 and 4. The dredging/excavation, dewatering, capping, marsh substrate placement, and wetland restoration required by Alternatives 3 and 4, while commercially available and proven, require more coordination of in-creek construction activities, overall program logistics and a need to be responsive to the unpredictability of weather and nature to successfully complete the wetland restoration activities.

The remedial activities to be completed under Alternatives 3, 4 and 5 would be difficult to implement from an administration standpoint. While permits are not required, the remedial activities must meet the substantive technical requirements of several permit programs. For example, excavation of the marsh sediments would require the destruction of wetlands, which is prohibited under Federal and State regulations unless no other viable alternative is available. NYSDEC has indicated that the wetlands of Richmond Creek and marsh are a significant resource of high value. As indicated in NYSDEC's tidal wetland regulations:

"Intertidal marsh and coastal fresh marsh tidal wetlands are the most biologically productive of all tidal wetlands areas. …Because of these high values and their sensitive location at the land and water interface, **intertidal and coastal fresh marshes must be the most stringently protected and preserved tidal wetlands zones** (emphasis added). Even small portions of these zones are critically important resources. Consequently, only very limited types of land use and development are compatible with the values of these areas."(6 NYCRR Part 661.2(d))

Therefore, destruction of this resource would only be allowed if it could be proven that the current resource is significantly impaired and would be better off being destroyed and reconstructed. This is not the situation in OU2, therefore protection of the wetlands and vegetated habitat is of paramount importance. Endangered and threatened species utilize the wetlands for foraging and nesting. Further, experience has shown that it is typically difficult to fully replicate the functionality of established wetlands. NYSDEC indicates in their Salt Marsh Restoration Guidelines that where restoring historical acreage is not feasible (e.g., the Fresh Kills estuary), habitat restoration is less likely to succeed. In this case the habitat should be given higher priority for protection than for restoration. Therefore, NYSDEC discourages or

refrains from authorizing damage to protected habitats and wetlands by active remediation if the wetlands are functioning, as these are.

The discharge of the supernatant that would be generated under these alternatives during the dewatering process would require a request for discharge criteria to be submitted to NYSDEC. This would require piloting of the geotube filtering capability and sampling and analysis of supernatant prior to receiving NYSDEC approval. A similar permit-type approval would be required for the supernatant emitted from the conventional dewatering of the marsh sediments.

Each active alternative may require that a dewatering facility be established at a location north of Richmond Creek. Several acres may be needed to house these systems and any associated equipment. This land is currently administered by the NYC Department of Parks. Therefore, receipt of permission for a temporary divergence of the land near the creek for the remedial action may be difficult.

Finally, the use of Brookfield or Fresh Kills landfills for the beneficial use of the sediments as landfill subgrade material may be considered administratively problematic. First, it assumes that NYSDEC would approve the material and issue a beneficial use determination (BUDs) for this application at these locations. While NYSDEC has issued a BUD for the dredged sediment from the maintenance dredging of Fresh Kills creek to be placed at Fresh Kills landfill, this material would require a separate administrative action from NYSDEC.

Further, the use of the material for the Brookfield OU1 closure, while making the most sense from a geographic point of view, is problematic from a timing perspective. The existing construction specifications for the Brookfield Avenue Landfill OU1 remedy would need to be modified to incorporate this material as required subgrade material. Since these specifications are nearing 100 percent completion at this time, and the construction contract is scheduled for public bidding during the fall of 2006, these modifications will affect the OU1 schedule. Finally, the use of the material under the cap at OU1 assumes that the Record of Decision (ROD), remedial design, and public bidding for the OU2 remedy can all be completed by 2007 so that the start of the dredging/dewatering for the OU2 remedy would coincide with the schedule for Brookfield capping. Given the typical time requirements for remedial actions, this timetable is optimistic.

The use of the material for Fresh Kills closure, while offering a better situation in terms of timing (Fresh Kills cells 1/9 are not scheduled to be complete until 2012), presents additional problems as far as administrative feasibility. Fresh Kills operations are controlled by NYCDOS, which has its own administrative and financial requirements concerning the timing, design and construction details for closing the various cells within Fresh Kills. NYCDOS has already made commitments to accept material from the NY Harbor deepening program run by the Army Corps of Engineers. It is not certain whether the OU2 material could be accommodated.

5.7 Cost

The present worth for all five alternatives has been calculated for the year 2005 using a 3.1 percent discount rate. The net present worth for all five alternatives, including the range of potential disposal/ beneficial use options, is presented in Table 5-1. The net present worth of the remedial alternatives ranges from zero dollars for No Action to almost $29.3 million for Alternative 3, assuming the offsite regional disposal option. Should the Brookfield Landfill beneficial use option be available, the upper end of the costs would be $19.2 million. The present worth of the Institutional Controls and Monitoring alternative is approximately $749,000.

For the other active remedial alternatives, the net present worth of Alternative 4 is between $11 million and $16.2 million, which is less costly than for Alternative 3, but with a similar amount of environmental protection and less disturbance to the ecosystem. Costs for Alternative 5 are estimated at between $6 million to $9 million. Alternative 5 provides an even lower amount of environmental protection than Alternatives 3 or 4, with the lowest disturbance to the ecosystem of the sediment removal alternatives.

Due to the varying frequency of different elements of the monitoring program, and the five-year period for reviews, O&M costs would vary on an annual basis. The annual average O&M costs range between zero dollars for the No Action alternative and $39,700 for the Institutional Controls and Monitoring alternative.

Table 5-1
Comparative Cost Analysis*
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Remedial Alternative	Estimated Capital Costs	Estimated Annual Average O&M Costs	Estimated Present Worth Costs[1]
Alternative 1: No Action	$0	$0	$0
Alternative 2: Institutional Controls and Monitoring	$0	$39,700	$749,000
Alternative 3: Sediment Removal inCreek and Marsh, Restoration, Beneficial Use/Disposal	$19,700,000 to $30,400,000	$37,700	$19,201,000 to $29,271,000
Alternative 4: Sediment Removal in Creek and Intertidal Marsh, Restoration, Beneficial Use/Disposal	$11,100,000 to $16,600,000	$37,700	$11,033,000 to $16,171,000
Alternative 5: Sediment Removal in Creek and Beneficial Use/Disposal	$5,800,000 to $9,000,000	$37,600	$6,052,000 to $9,097,000

* These costs are planning level costs. Actual costs may be 50% higher to 30 % lower

[1] Using discount rate (after inflation) of 3.1 % per OMB Circular No. A-94 Appendix C, January 2005.

Section 6
Recommended Alternative

As a result of the OU1 RI/FS, NYSDEC selected feasibility study Alternative 2B consisting of capping with active gas collection, wetlands enhancements, leachate collection, a groundwater barrier wall, and a focused end use plan. The remedy provides source control that will meet SCGs, be protective of public health and the environment, and serve to reduce future impacts to OU2 and Richmond Creek.

In the past decade, four other New York City Landfills were also investigated and closure plans were prepared. Three of the landfills, Edgemere, Pennsylvania Avenue, and Fountain Avenue are located along the shoreline of Jamaica Bay. The fourth, the Pelham Bay Landfill, is located in the Bronx, at Pelham Bay Park. The remedial measures selected for these landfills were generally limited to capping and gas collection. At the Fountain Avenue Landfill, a leachate collection trench was deepened. At the Pelham Bay Landfill, a barrier wall was constructed to prevent offsite groundwater from migrating onsite. Although all four landfills are adjacent to the waterways of New York City, sediment management (i.e. dredging or capping) was not performed, except in a small area adjacent to the Pennsylvania Avenue Landfill where PCBs were found to be discharging from the landfill.

The preceding sections presented a detailed and comparative analysis of five different remedial alternatives to address the contamination identified within OU2 of the Brookfield Avenue Landfill. The alternatives were developed to represent the full range of feasible site remediation alternatives, considering proper application of scientific and engineering principles. As per NYSDEC regulations (6 NYCRR 375-1.10), the alternatives evaluated included a "No Action" alternative (Alternative 1) to establish the baseline conditions for comparing the site remedial alternatives and an alternative which returns the site to as close to "pre-disposal conditions" as feasible from the perspective of contamination levels. At many sites, the alternative that results in removal of all impacted material is considered to be the alternative that obtains pre-disposal conditions to the extent feasible and authorized by law. However, due to the distribution of similarly impacted sediments in the vicinity of the Brookfield Avenue Landfill and throughout the region, it is not technically feasible to remove all impacted material. In addition, in the short-term the wetlands would be destroyed and the site would be farther from "pre-disposal conditions" from this perspective. Due to this scenario and location-specific regulatory considerations precluding adverse affects on wetlands unless no other practical alternative exists, the non-intrusive alternatives are considered to be more capable of restoring the area to pre-disposal conditions than the active remedies.

An Institutional Controls and Monitoring alternative (Alternative 2) was developed as well as three partial sediment removal alternatives (Alternatives 3, 4 and 5) involving differing degrees of removal of sediment from Richmond Creek and marsh. Each

alternative evaluated is capable of being integrated into the selected remedy and end use plan for OU1, although minor modifications to the alternative may be required.

Based on the results of the detailed and comparative analyses, Alternative 2, Institutional Controls and Monitoring, in combination with the OU1 active remedy, is selected as the recommended alternative for the Brookfield Avenue Landfill OU2 site. This alternative complements the OU1 remedy of landfill capping, leachate collection, subsurface barrier wall installation, landfill gas collection and wetland enhancements. This alternative provides the best balance between competing needs for the site and region, i.e., the need to implement the OU1 source control remedy of capping the landfill, the need to manage and reduce risk associated with consumption of finfish and shellfish in Richmond Creek and marsh, and the principle to "Do No Harm", given the significant value of the Richmond Creek and Fresh Kills estuary as a natural resource.

The data summarized in Section 1 and that collected for other area landfills and the New York Harbor in general, provide a good basis for decision making. Constituents of concern are widely distributed throughout the area and no localized area or hot spot was identified where isolated removal of sediment would result in a marked reduction in overall human health or ecological risks. Human health risks were determined to be primarily associated with the assumed consumption of finfish and shellfish which have area wide exposure to multiple sources. OU2 sampling has documented improvement of surface water and sediment since the 1996 and 1997 OU1 sampling, indicating that when the OU1 remedy is completed, natural processes will facilitate further improvement of the environment without the need for excavation and the resulting destruction of the wetlands ecosystem.

The Brookfield Avenue landfill is currently leaching contaminants into the creek and marsh and these contaminants include heavy metals and complex organic molecules such as DDT, PCBs and mercury that are persistent in the environment. However, engineering controls applied to OU1 (landfill capping, leachate collection, subsurface barrier wall installation, landfill gas collection and wetland enhancements) represent source control for OU2. Once the landfill is capped and the slurry wall and the leachate collection trench are in place, the flux of heavy metals, pesticides and PCBs that are emanating from the landfill will be stopped. Removal of continuing sources will allow the natural processes of the wetlands to improve surface water, sediment and biota quality. It is expected that this reduction in dissolved contaminants coupled with the geochemical changes that will occur once the leachate flux is eliminated will have a major positive effect on the health of the marsh, allowing the system to further recover. Removal of continuing sources will allow the natural processes of the wetlands to improve surface water, sediment and biota quality.

Factoring into the recommendation is the timing of the OU1 remedy, which is expected to commence in 2007 and finish in 2011. An active remedy involving placement of sediments from OU2 into OU1 would significantly delay the closure of OU1 with its associated source control benefits and creation of a public park. In

addition, removal of sediment would require significant materials handling including dewatering and truck transportation which would have negative short -term impacts on the community and environment.

The Brookfield Avenue Landfill and regional area surrounding the site are at a critical transition period at this time. The ecosystem surrounding the landfill (specifically the salt marsh) is providing valuable benefits. Wetlands such as these at the Brookfield Avenue Landfill OU2 site provide marine food production, provide protection and valuable habitat in the development of many species of aquatic and terrestrial animals and plants, provide flood protection from storm surges, provide stormwater relief of urban runoff, and improve water quality through nutrient absorption and pollutant removal by various physical, chemical, and biological processes. The wetlands are assisting in the reduction of contaminants from the landfill. New York State has classified the marsh north of the Brookfield Avenue Landfill to be a Significant Fish and Wildlife Habitat under their Coastal Management Program and has resolved to protect this resource. The recommended alternative achieves NYSDEC's objective of "Do No Harm" of existing wetlands.

Removing the impacted sediments from the creek and marsh would require that much of the existing wetlands, vegetative habitat, and benthic ecosystem be destroyed. Impacted areas would not only include those where excavation occurs, but would also include access and construction staging areas. While it would be the intent of NYCDEP to attempt to restore the salt marsh after sediment removal, reconstructed wetlands rarely regain full functionality. In addition, such restoration work, always considered a challenge, would be made more difficult by the dense urban setting immediately surrounding the landfill, the changing ecosystem of Fresh Kills landfill further downstream, and the highly industrial sources of contamination located along the Arthur Kill and elsewhere in the NY-NJ Harbor/estuary system. Sediment removal and associated wetland disturbance has not been performed or required as part of closure or remediation of other landfills that abut New York City waterways.

Another critical factor in selecting the Institutional Controls and Monitoring alternative was the realization that given the site's proximity to Fresh Kills landfill, and the ongoing maintenance dredging of the Arthur Kill, and potential maintenance dredging of Fresh Kills during its closure, recontamination of Richmond Creek, should NYCDEP proceed with an active remedy at this time, is a certainty. As previously noted, constituents of concern are widely distributed throughout the area and surface water and sediments are redistributed locally with tides and storms. Contamination would come into the OU2 area from both upstream and downstream as sediment and surface water elsewhere in the Arthur Kill estuary and NY harbor are similarly impacted.

Most importantly, the proposed alternative is protective of human health and the environment. The primary risk posed by the site to human health is through the consumption of contaminated finfish and shellfish. NYSDOH's experience suggests that this exposure pathway is most rapidly and effectively addressed through the

application of consumption advisories. Even if some sediment was removed from OU2, consumption advisories would still be required as the exposure to impacted surface water and sediment is an area -wide issue that extends far beyond OU2. Similarly, except for shellfish most biota are exposed to area -wide conditions and therefore, it is unlikely that surgical removal of sediment from OU2 would markedly reduce concentrations in biota. Regional source reduction to be accomplished with the OU1 remedy and pending closure of Fresh Kills Landfill, and maintenance of the functionality of the existing wetlands environment is considered the most effective alternative to improve environmental conditions area -wide.

In compliance with NYSDEC guidance, Institutional Controls and Monitoring (in combination with the OU1 remedy) meets the requirement that the remedy selected shall eliminate or mitigate all significant threats to the public health and to the environment. The existing fish consumption advisories will remain in place and/or be enhanced and NYCDEP will actively oversee the fencing and signage at the site so that human exposure to the creek and marsh contaminants is minimized. While the Institutional Controls and Monitoring alternative will not immediately result in compliance with existing SCGs, compliance with the surface water SCGs will be improved after the OU1 source control remedy is complete and the natural wetland processes will continue to reduce the contamination within the ecosystem.

As described in Section 4, Institutional Controls and Monitoring is not a No Action approach. In addition to incorporating the OU1 remedy (including landfill cap, barrier wall construction, landfill gas collection, leachate collection and wetlands enhancements), a monitoring effort is included in this alternative. Two consecutive years of surface water quality monitoring will be performed three years after the OU1 remedy is complete to assess changes in surface water quality. Surface water monitoring results will be compared to existing SCGs. Biota monitoring is regularly performed by NYSDEC and the data is used by the NYSDOH in their evaluation of the need for consumption advisories. Therefore, biota monitoring is assumed to occur but is not included in OU2 remedy performance monitoring by NYCDEP. Monitoring may also include review of other available data that pertains to contaminant concentrations of shallow sediment and water column in OU2 (monitoring of a location in Richmond Creek is performed by IT as part of a long-term monitoring program for Fresh Kills Landfill).

Additional monitoring will be performed as part of post-closure monitoring of the OU1 final remedial system (landfill cap, barrier wall, leachate and gas collection systems). This monitoring is to occur for the typical 30-year post closure-monitoring period, and will include: groundwater sampling of 26 wells, surface water sampling at 5 locations, and landfill gas monitoring. This post-closure monitoring will be performed quarterly for the initial 5 years and then annually. This monitoring data will document improvements resulting from the OU1 remedial actions, the reductions in other area sources, and the natural recovery due to the function of the existing wetlands.

Section 7
References

Borrego, J., Morales, J. A., de la Torre, M.L., and J. A. Grande. 2002. *Geochemical characteristics of heavy metal pollution in surface sediments of the Tinto and Odiel estuaries (Southwestern Spain).* Environmental Geology. 41. 785-796.

CDM, 2002. *Brookfield Avenue Landfill Remediation – Operable Unit 1 – Preliminary Design Report December 2002.*

_____. 2002. *Brookfield Avenue Landfill Operable Unit 2 – Historical Data Review and Mapping.*

_____. 2003. *Brookfield Avenue Landfill Operable Unit 2 - RI/FS Workplan.*

_____. 2003. *Brookfield Avenue Landfill Operable Unit 2 - RI/FS Field Operations Plan.*

Christini, A. 1990. *Synthesis of Information on the Distribution of Benthic Invertebrates in the Hudson/Raritan System.* National Estuary Program Grant #12330036-0.

International Technology Corp., 1993. *1993 Annual Surface Water and Sediment Monitoring Report, Fresh Kills Leachate Mitigation System Project.* Prepared for the New York City Department of Sanitation.

International Technology Corp., 1993. *1993 Final Hydrogeological Report, Vol. I, Fresh Kills Leachate Mitigation System Project.* Prepared for the New York City Department of Sanitation.

_____. 1998. *Brookhaven National Laboratory, Operable Unit V, Feasibility Study Report, Draft Final.*

_____, 2000. 1999 *Annual Surface Water and Sediment Monitoring Report, Fresh Kills Landfill.* Prepared for the New York City Department of Sanitation, April 7, 2000.

Chapman, P.M. and F. Wang. 2001. *Assessing sediment contamination in estuaries.* Environmental Toxicology and Chemistry, 20, no. 1, 3-22.

Geotec Associates. 1996. *Proposed Alternative for Raising Mississippi Levees using Geotube Technology Developed Under the Corps of Engineers' Construction Productivity Research Program (CPAR).* Geotec Associates, Vicksburg, MS, November 1, 1996.

Mehrotra, P.E., Sandeep, 2005. Personal communication between C. Ranney and Sandeep Mehrotra, P.E., Hazen and Sawyer, P.C. at (212)539-7011, November 30, 2005.

National Research Council, 2001. A Risk-Management Strategy for PCB-Contaminated Sediments. National Academy Press, Washington, D.C.

Natural Resources Defense Council (NRDC). *Stormwater Strategies, Community Responses to Runoff Pollution.* May 1999.

New York City Department of Environmental Protection (NYCDEP), 1997. *Richmond Creek Drainage Plan - Final Environmental Impact Statement*, prepared with the assistance of: Allee King Rosen & Fleming, Inc, Hazen and Sawyer, Hydroqual, Inc, Environmental Concern, Inc., Historical Perspectives, Inc. and Center for Watershed Protection. July 1997.

_____ 1998a. *Brookfield Avenue Landfill Remediation Project Final – Remedial Investigation Report*. Prepared in association with CDM, Woodbury, NY.

_____. 2001. *Brookfield Avenue Landfill Remediation Project Final – Feasibility Study Report*. Prepared in association with CDM, Woodbury, NY.

_____. 1999. *Wolfe's Pond and Sweet Brook Drainage Plans, Draft Environmental Impact Statement* Prepared with the assistance of Allee King Rosen & Fleming, Inc., Hazen and Sawyer, Hydroqual, Inc, Environmental Concern, Inc., Historical Perspectives, Inc. and Center for Watershed Protection. May 1999.

_____. 2005. *Brookfield Avenue Landfill Operable Unit 2 Final Remedial Investigation Report*. Prepared in association with CDM, Edison, NJ.

Yao, N., 2005. Personal communication between J. Boyer and Naji Yao, NYCDEP Marine Sciences Section, New York Harbor Water Quality Survey annual data, October 20, 2005

New York City Department of Sanitation (NYSDOS), 2004. Draft Solid Waste Management Plan- Attachment X *Fresh Kills Closure Construction and End Use,* October 2004.

_____. 2000. *The DOS Report Closing the Fresh Kills Landfill, New York City Department of Sanitation Report for February 2000*,
http://www.nyc.gov/html/dsny/downloads/pdf/guides/fkclose.pdf

_____2004. Environmental Notice Bulletin Region 2 Completed Applications, dated 5/12/2004. Applicant: NYC Dept of Sanitation
http://www.dec.state.ny.us/website/enb2004/20040512/Reg2.html

New York State Department of Environmental Conservation (NYSDEC), 1994. NYSDEC Division of Fish and Wildlife. *Fish and Wildlife Impact Analysis for Inactive Hazardous Waste Sites (FWIA)*, October 1994.

_____, 1994. NYSDEC Division of Environmental Remediation Technical and Administrative Guidance Memorandum #4046. *Determination of Soil Cleanup Objectives and Cleanup Levels*. January 1994.

_____, 1996. NYSDEC Division of Water Technical and Operational Guidance Series (1.3.1). *Waste Assimilative Capacity Analysis & Allocation for Setting Water Quality Based Effluent Limits*. July 1996.

_____, 1998. NYSDEC Division of Water Technical and Operational Guidance Series (1.1.1). *Guidance Value for the Protection of Fish Propagation, Chronic*. June 1998.

_____, 1999a. NYSDEC, Division of Fish, Wildlife and Marine Resources *Technical Guidance for Screening Contaminated Sediments*. Original publication 1993; updated 1998 and 1999.

_____, 2002. NYSDEC Division of Environmental Remediation. *Draft DER-10, Technical Guidance for Site Investigation and Remediation*. December 2002.

_____, 1999b. NYSDEC Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations NYSDEC 6 NYCRR Part 703, August 1999.

_____, 2002. NYSDEC, Division of Environmental Remediation. *Brookfield Avenue Landfill Site – Record of Decision*. March 2002.

_____, 2005. NYSDEC, Division of Fish, Wildlife & Marine Resources letter to CDM, October 5, 2005.

_____, 1990. *NYSDEC Technical and Administrative Guidance Memorandum (TAGM) #4030 Selection of Remedial Actions at Inactive Hazardous Waste Sites*, Division of Hazardous Waste Remediation, Albany, New York 12233-7010, May 15, 1990.

_____, 1974. NYSDEC, 61st Floor, 2 World Trade Center, NY, NY. *Tidal Wetlands Map, Map 570-490, Index Map Number 1, Scale 1:2400,* 1974.

NYSDEC and New York State Department of State, (2000). *New York State Salt Mash Restoration and Monitoring Guidelines,* December 15, 2000.

New York State Department of Health. 2005. *Eating Sport Fish 2005-2006 Health Advice of the Capital District, Hudson River, New York Harbor, Fresh Waters of Long Island and Marine Waters of New York*. http://www.health.state.ny.us/nysdoh/fish/fishengl.htm

Guastella, J., Public Health Specialist, 2005. Letter from Julia M. Guastella NYSDOH-Bureau of Environmental Exposure Investigation to Dan Walsh NYSDEC, June 20, 2005.

National Academy of Sciences. 2001. *Compensating for Wetland Losses Under the Clean Water Act*. Committee on Mitigating Wetland Losses; Board on Environmental Studies and Toxicology; Water Science and Technology Board; Division on Earth and Life Studies; and National Research Council. National Academy Press, Washington, D.C.

New York State Department of State, Division of Coastal Resources. 2004. *Coastal Atlas.* http://www.nyswaterfronts.com/maps_ny.asp

Office of Management and Budget, OMB Circular No. A-94 Appendix C (Revised January 2005)

Ontario Centre for Environmental Technology Advancement (OCETA). 1999. The Eriksson System Contaminated Sediment Removal and Dewatering. Downloaded from http://www.oceta.on.ca/profiles/eriksson/eriksson.html November 8, 2005.

Pritchard D.W. 1967. What is an Estuary: Physical viewpoint. In Lauff G.H., ed. Of *Estuaries. American Association for the Advancement of Science*.

Rossi, James. 2005. Personal communication between C. Ranney, CDM and James Rossi, NYCDEP Bluebelt Field Office at (718)317-3235,November 30, 2005.

Soren, J. 1988. *Geologic and Geohydraulic Reconnaissance of Staten Island, NY. U.S. Geological Survey, Water Resources Investigation, Report 87-40-18*, prepared for New York State Department of Environmental Conservation.

TAMS Consultants, Inc. 2000. *Hudson River PCBs Reassessment RI/FS Phase 3 Report: Feasibility Study* Prepared for U.S. Environmental Protection Agency Region 2 and U.S. Army Corps of Engineers, Kansas City District.

Turner, A.; Millward, G.E. and S. M. Le Roux. 2001. Sediment-water partitioning of inorganic mercury in estuaries. *Environmental Science and Technology*. 35, 4848-4854.

U.S. Army Corps of Engineers (USACE). 2003. ERED Database. Accessed Online April 2004. URL www.wes.army.mil/el/ered

U.S. Army Corps of Engineers (USACE). 1994. *Technical Guidelines For Hazardous and Toxic Waste Treatment and Cleanup Activities, EM 1110-1-502.* Department of the Army, U.S. Army Corps of Engineers, Washington, DC 20314-1000, 30 April 1994.

U.S. Department of Commerce, National Oceanic & Atmospheric Administration, 1999. Screening Quick Reference Tables (SQuiRTS), September 1999. HAZMAT Report 99-1.

_____, 2005. National Oceanic and Atmospheric Administration (NOAA), Center for Operational Oceanographic Products and Services (CO-OPS). March 22, 2005. P*ublished Bench Mark Sheet for 8531142 Port Reading, Arthur Kill, New Jersey.*

U.S. Environmental Protection Agency (USEPA), 1982. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants, Parts I, II*. Prepared by Tetra Tech., Inc. in cooperation with the USEPA Center for Water Quality Modeling. Athens, GA.

_____. 1994. "*ARCS Remediation Guidance Document.*" EPA 905-B94-003. Great Lakes National Program Office, Chicago, IL.

_____. 1996. *Assessment and Remediation of Contaminated Sediment Program (ARCs)*. Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod *Hyalella azteca* and the Midge *Chironomus riparius*. EPA 905-R96-008. Great Lakes National Program Office. Chicago, IL.

_____. 2002. *National Recommended Water Quality Criteria: 2002*. Office of Water. Office of Science and Technology. EPA-822-R-02-047.

_____. 2003. *Ecological Screening Levels*. U.S. EPA Region 5, RCRA Corrective Action. URL - http://www.epa.gov/reg5oopa/rcraca/edql.htm.

_____,2005a. PEER REVIEW *DRAFT Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, Peer Review Document, January 2005.*

_____2005b. Region 2 Superfund Site Summary, ALUMINUM COMPANY OF AMERICA, NEW YORK EPA ID# NYD980506232. http://www.epa.gov/region02/superfund/npl/0201690c.pdf

_____2005c. Region 3 Technical Support Section *Updated Risk Based Concentration (RBC) Tables*, *updated October 2005*,

U.S. Fish and Wildlife Service, 1997. Significant Habitats and Habitat Complexes of the New York Bight Watershed. Southern New England-New York Bight Coastal Ecosystems Program, Charlestown, Rhode Island, November 1997. http://training.fws.gov/library/pubs5/web_link/text/akc_form.htm.

U.S Food & Drug Administration, 2001, Center for Food Safety & Applied Nutrition. Third Edition June 2001. *Fish and Fisheries Products Hazards and Controls Guidance: Chapter 9 Environmental Chemical Contaminants & Pesticides (A Chemical Hazard).*

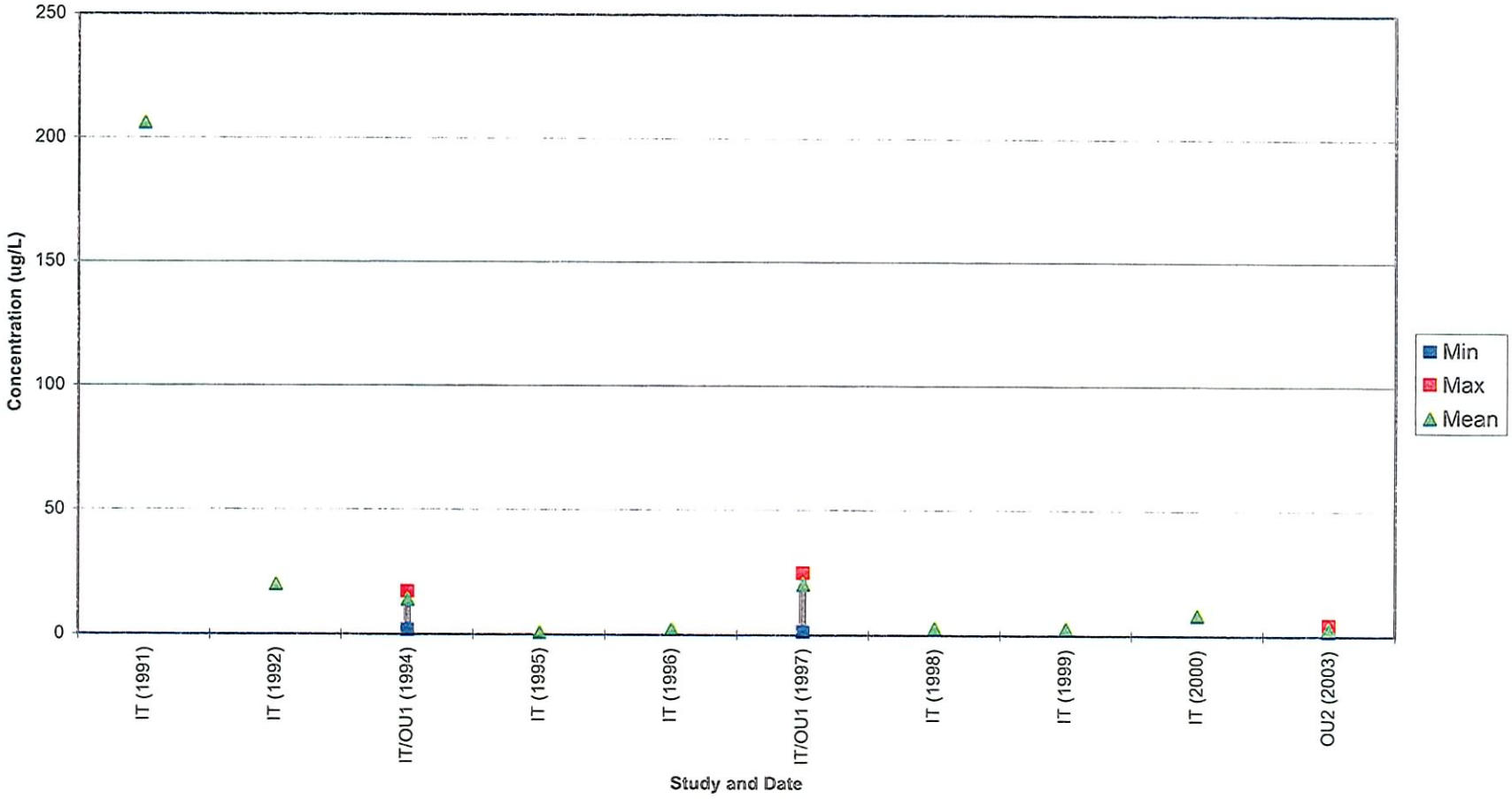
Vokral, J. , Gumb, D. , Smith, R., and Mehrotra, S. 2001. *Staten Island Bluebelt Program, A Natural Solution to Environmental Problems.* in Stormwater, The Journal for Surface Water Quality Professionals. 2001.

Walsh, D., PhD. 2005. Personal communication with Dr. Dan Walsh, NYSDEC, January 26, 2005.

Whiting, K.S. 1992. T*he Thermodynamics and Geochemistry of Arsenic, with Application to Subsurface Water at the Sharon Steel Superfund Site at Midvale, Utah*. M.S. Thesis T-4128, Colorado School of Mines, Golden, Colorado.

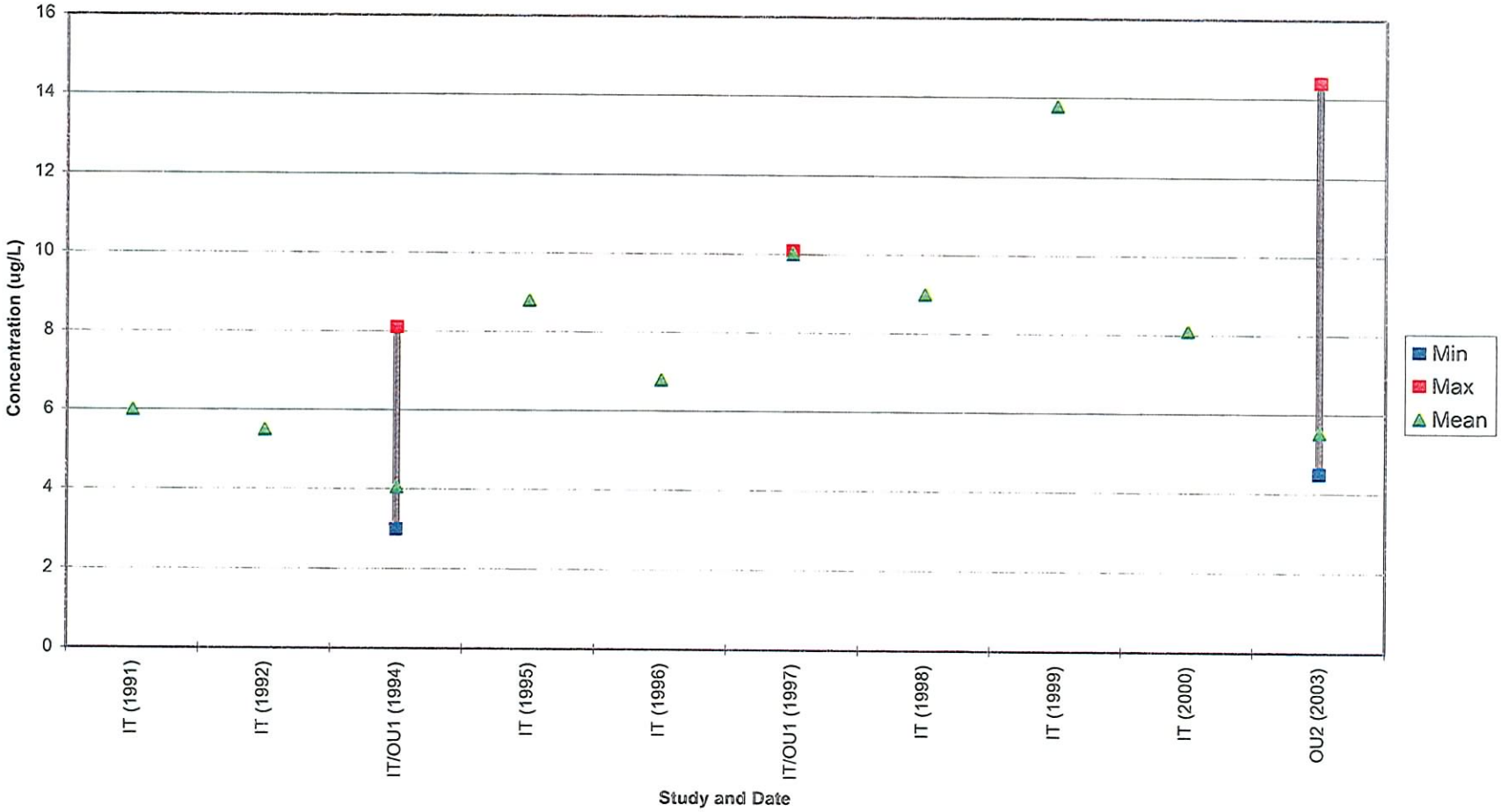
Appendix A.1

Antimony Concentrations in Surface Water



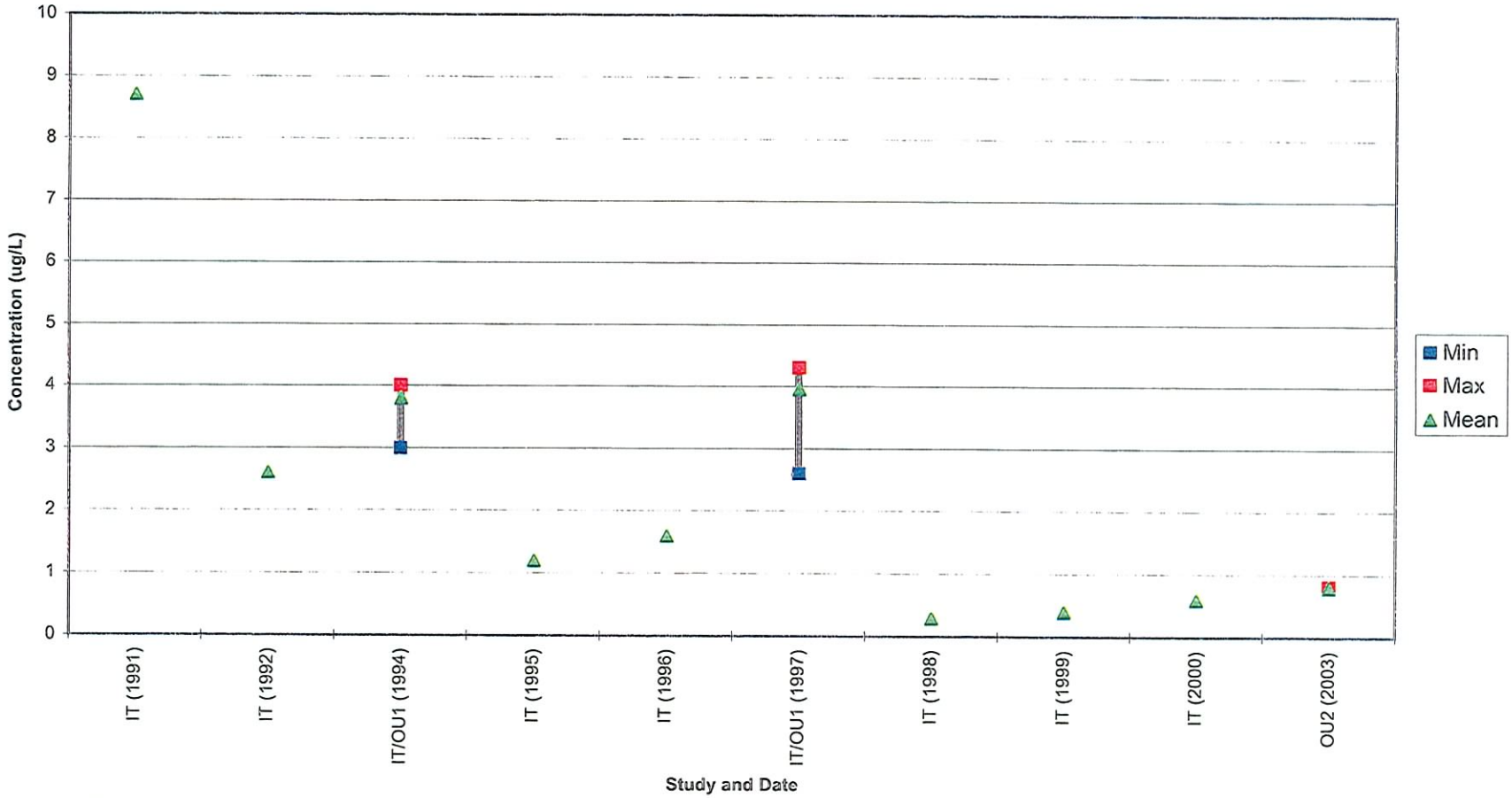
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Arsenic Concentrations in Surface Water



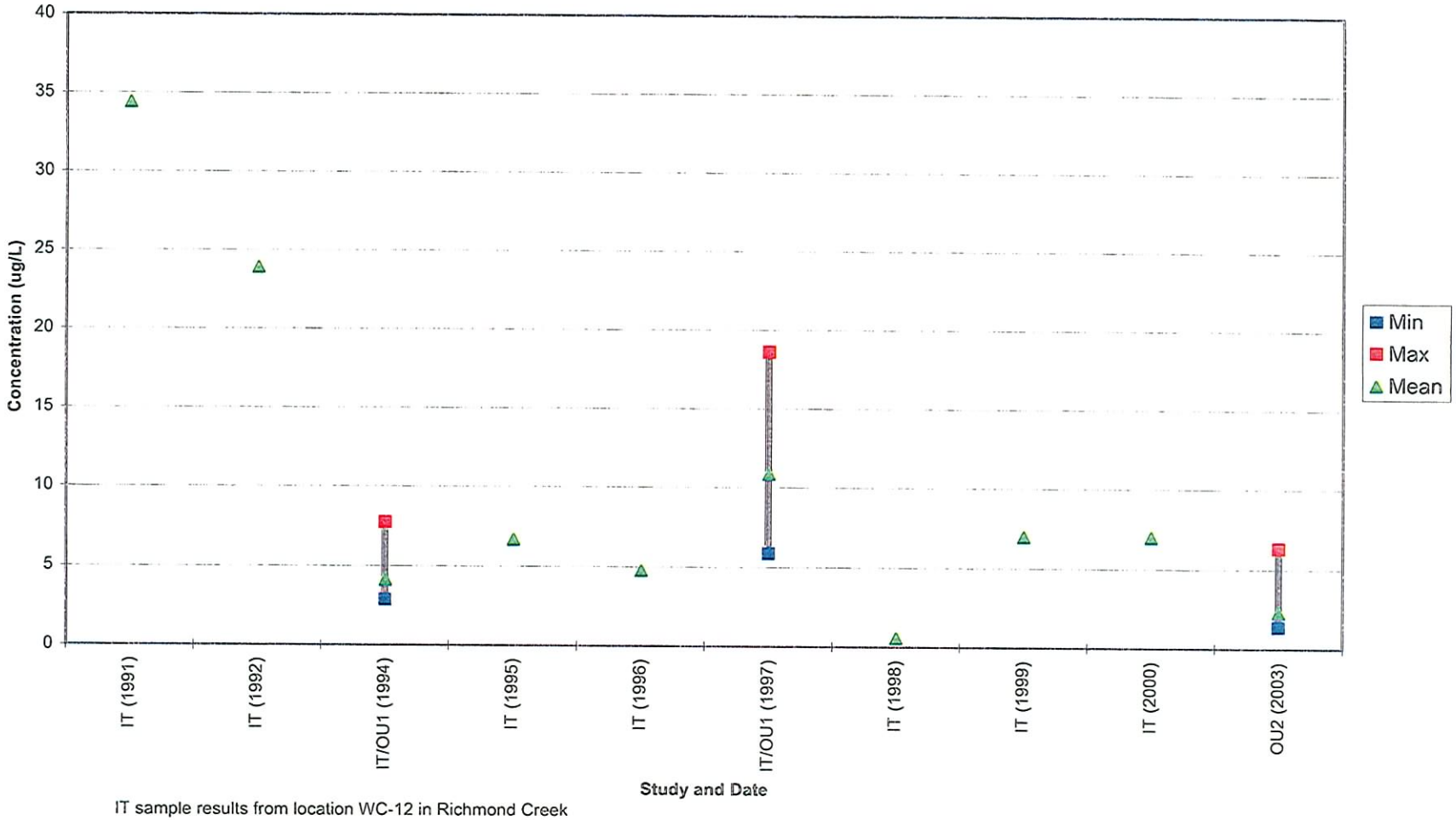
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Cadmium Concentrations in Surface Water



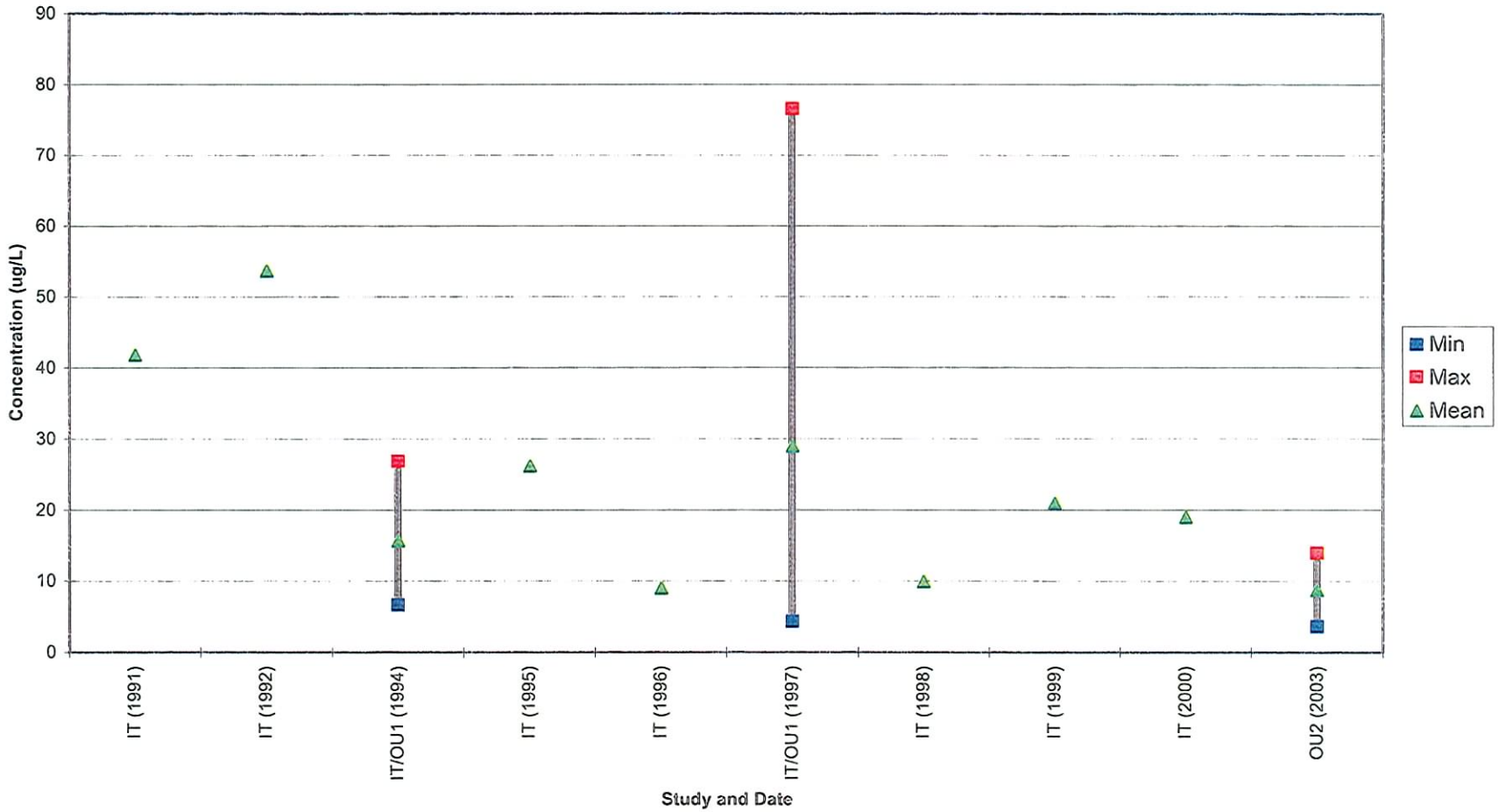
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Chromium Concentrations in Surface Water



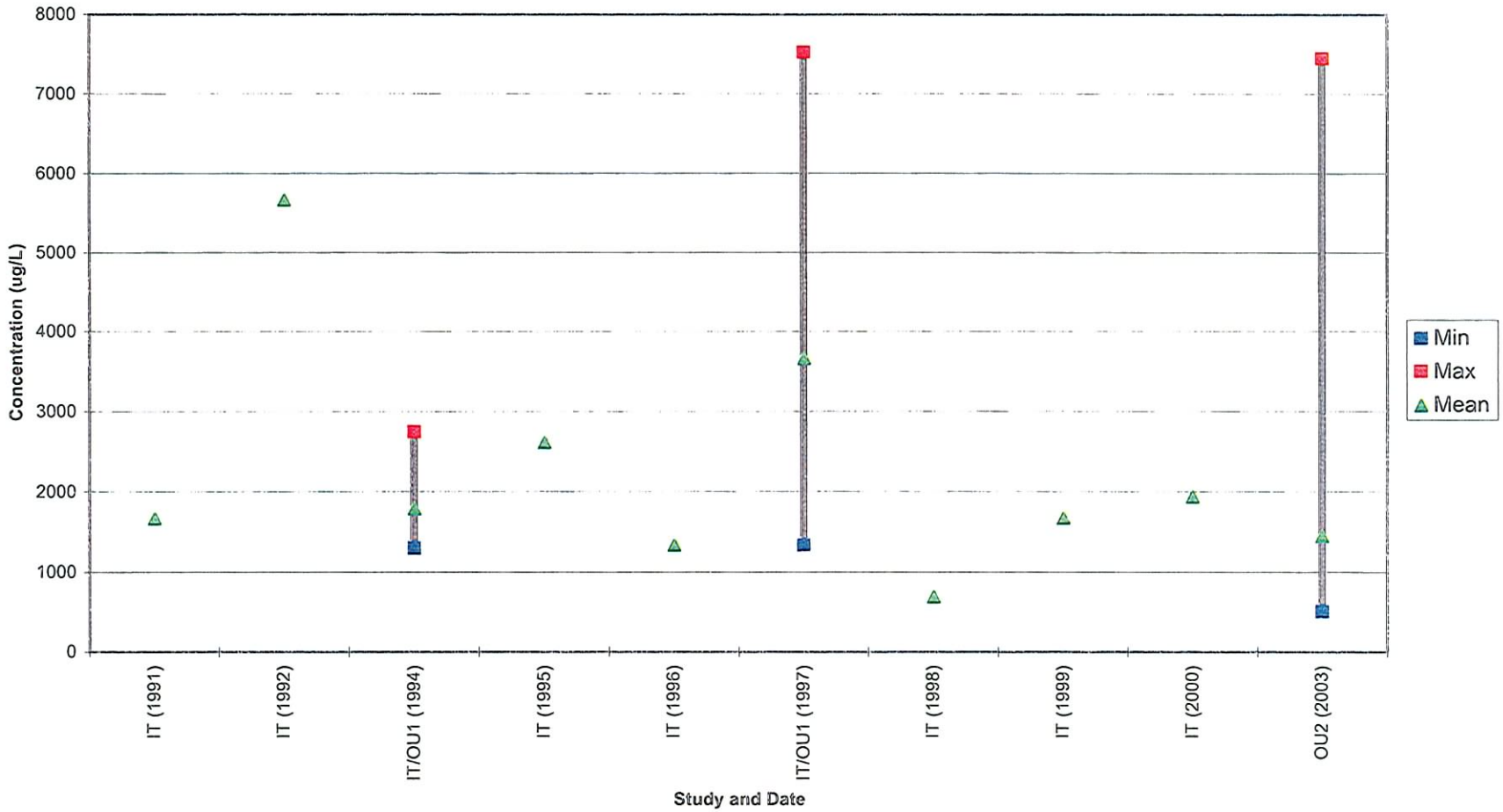
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
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Copper Concentrations in Surface Water



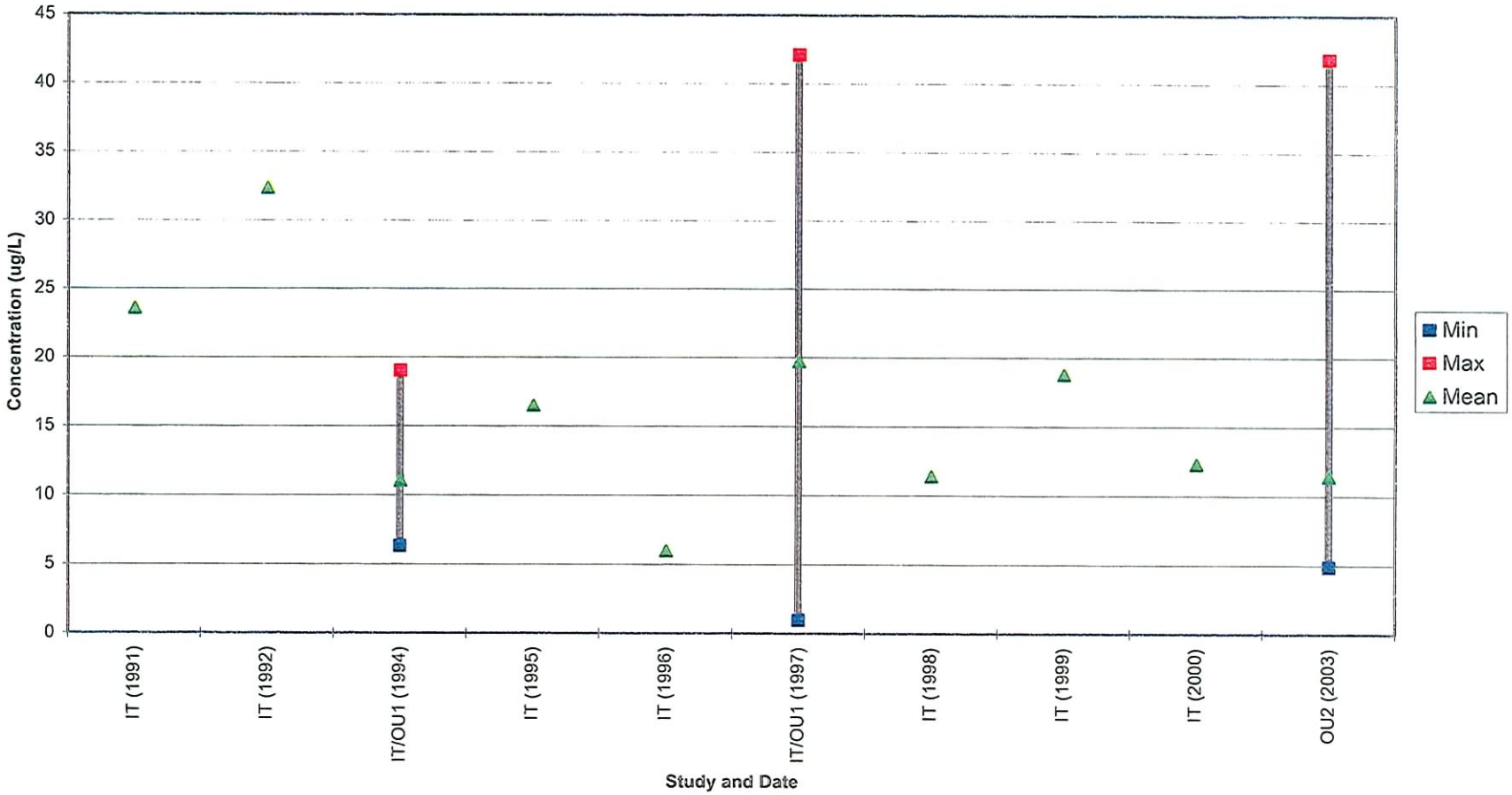
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Iron Concentrations in Surface Water



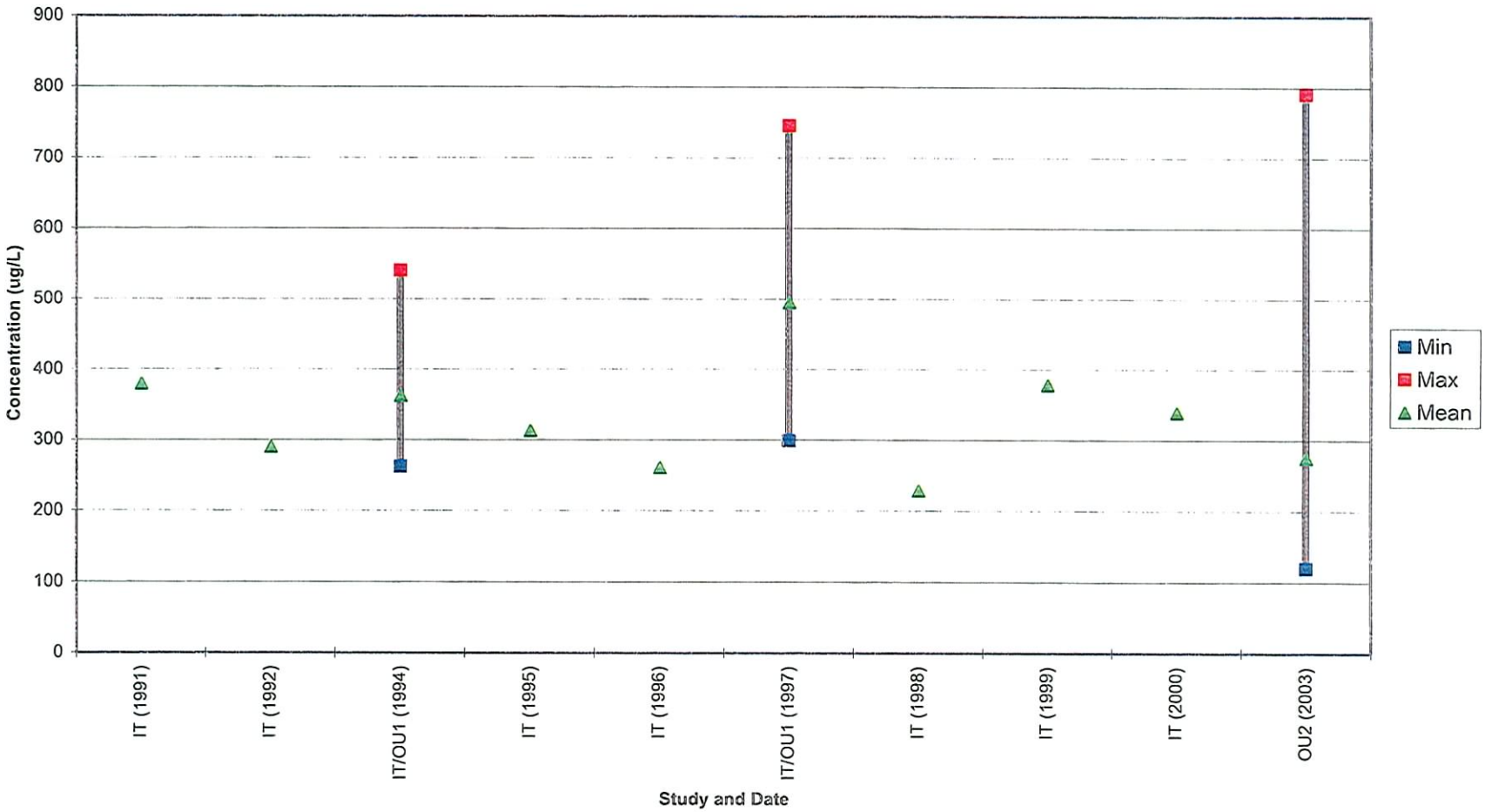
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Lead Concentrations in Surface Water



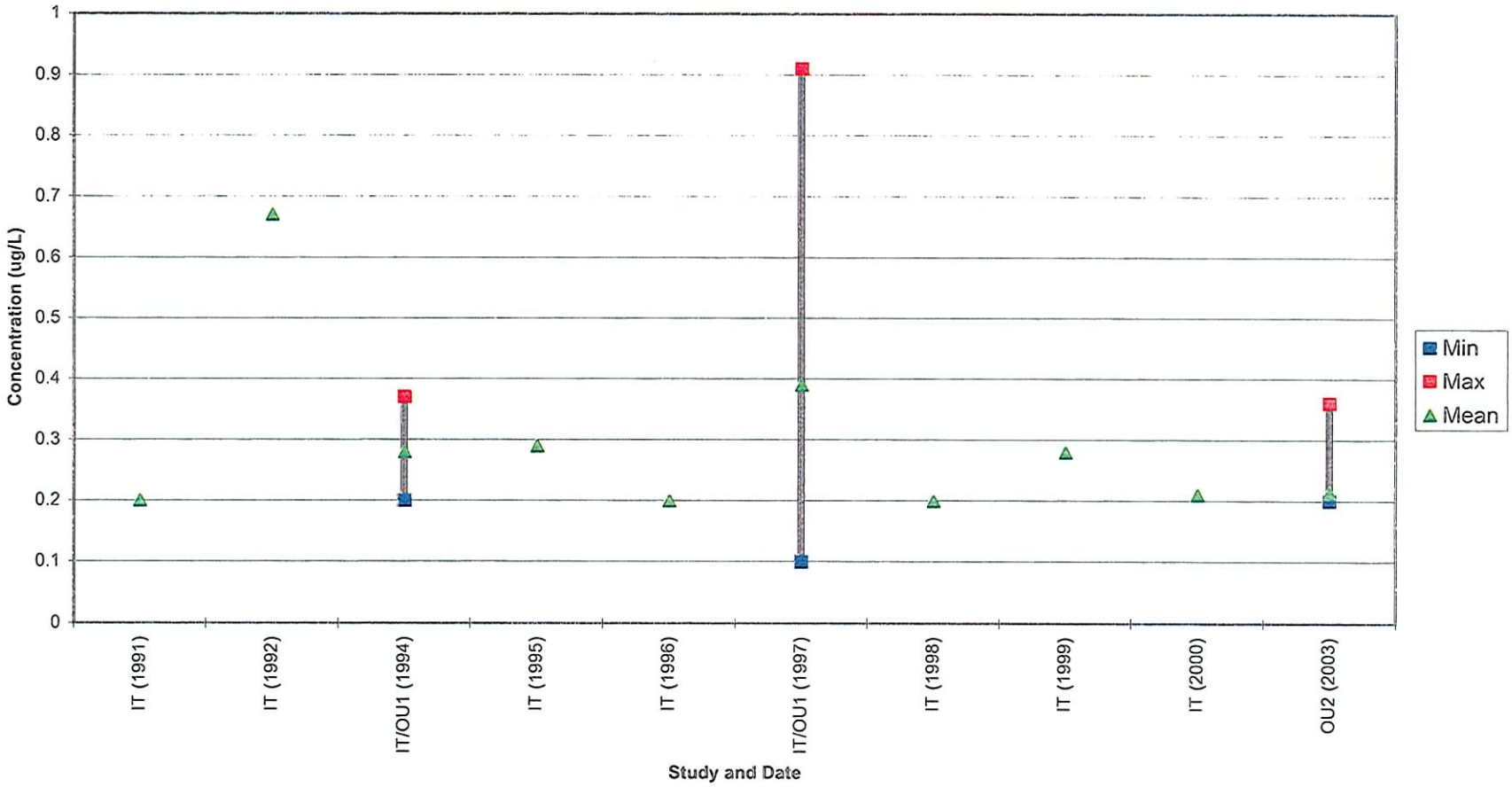
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Manganese Concentrations in Surface Water



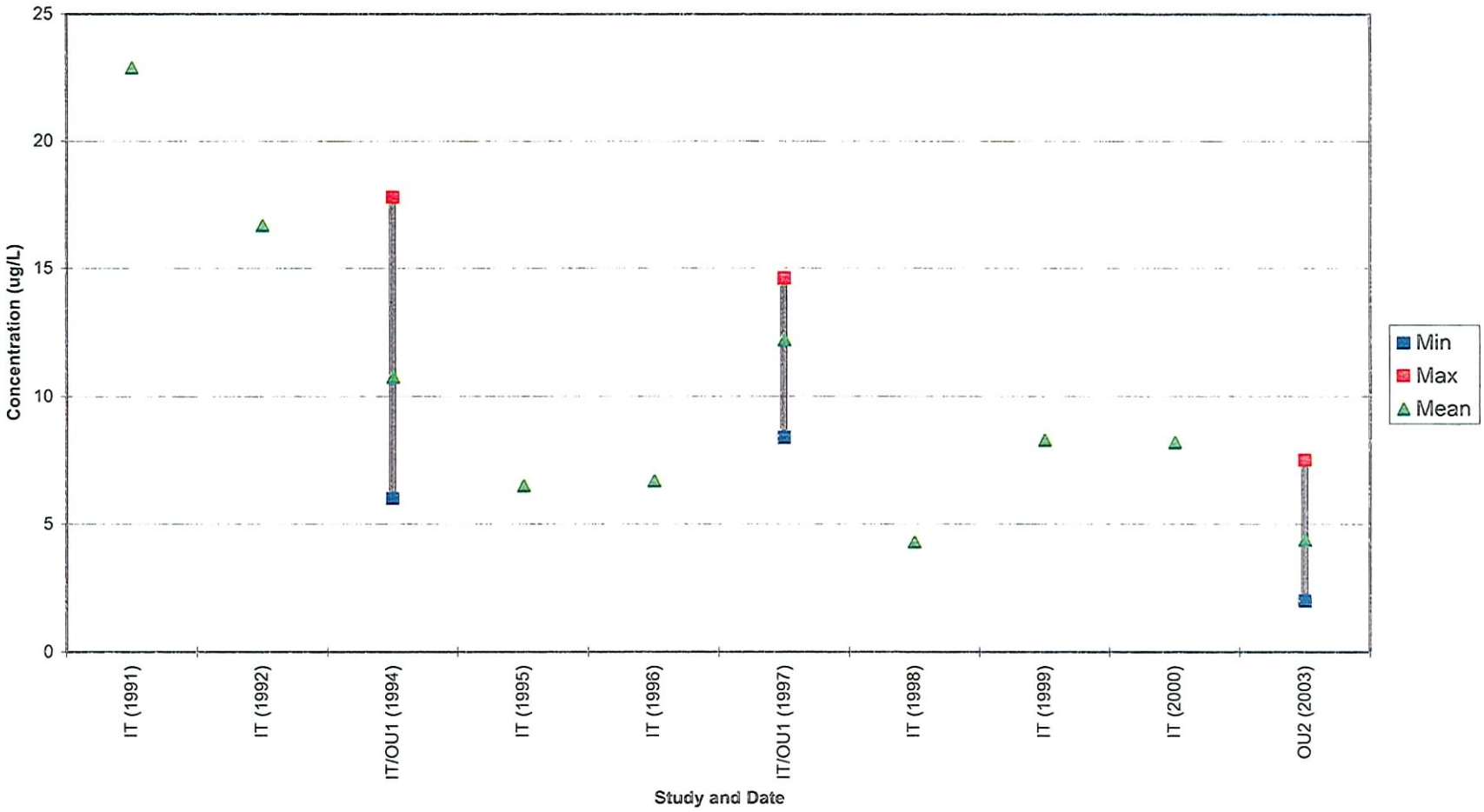
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Mercury Concentrations in Surface Water



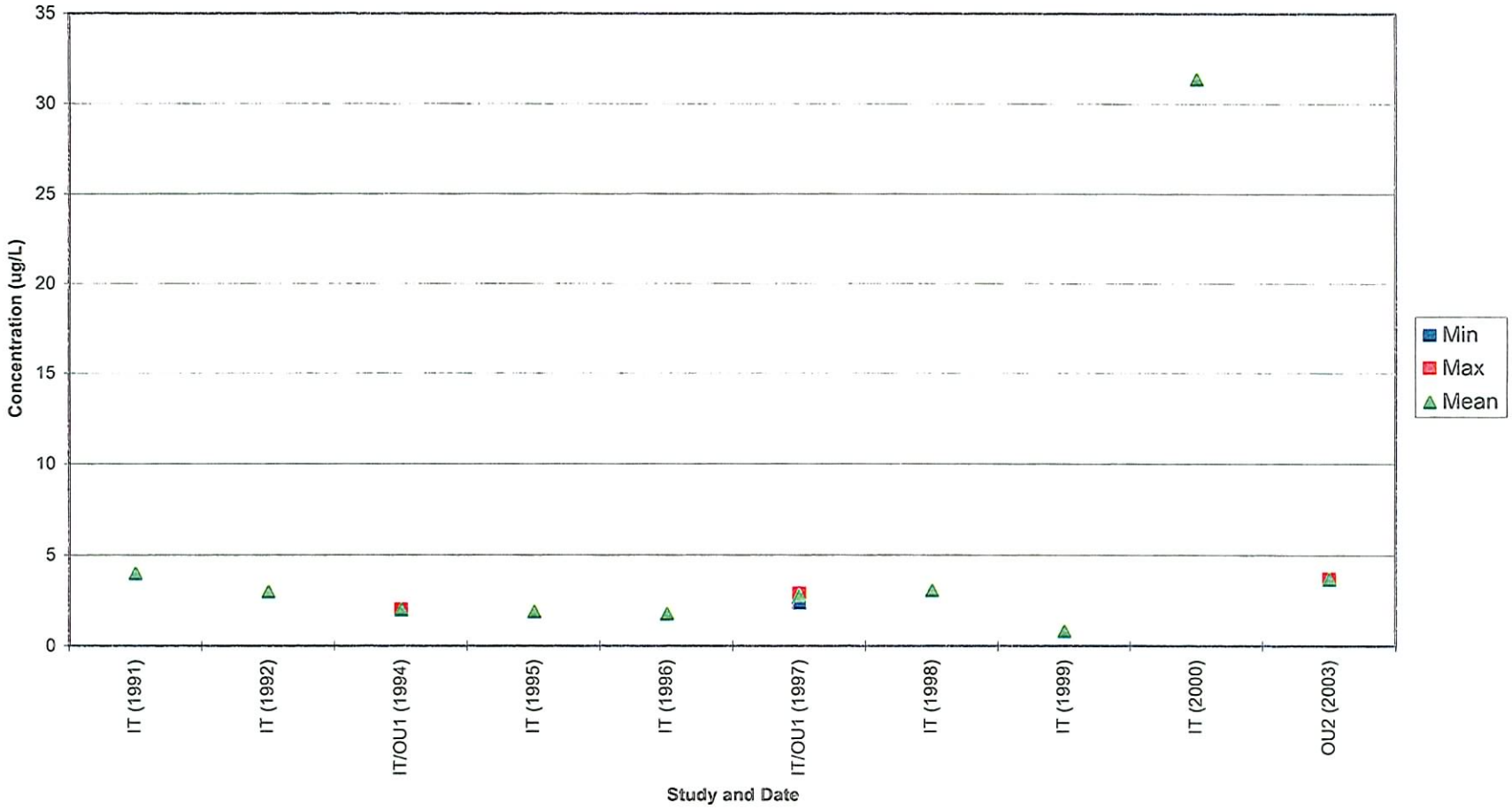
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Nickel Concentrations in Surface Water



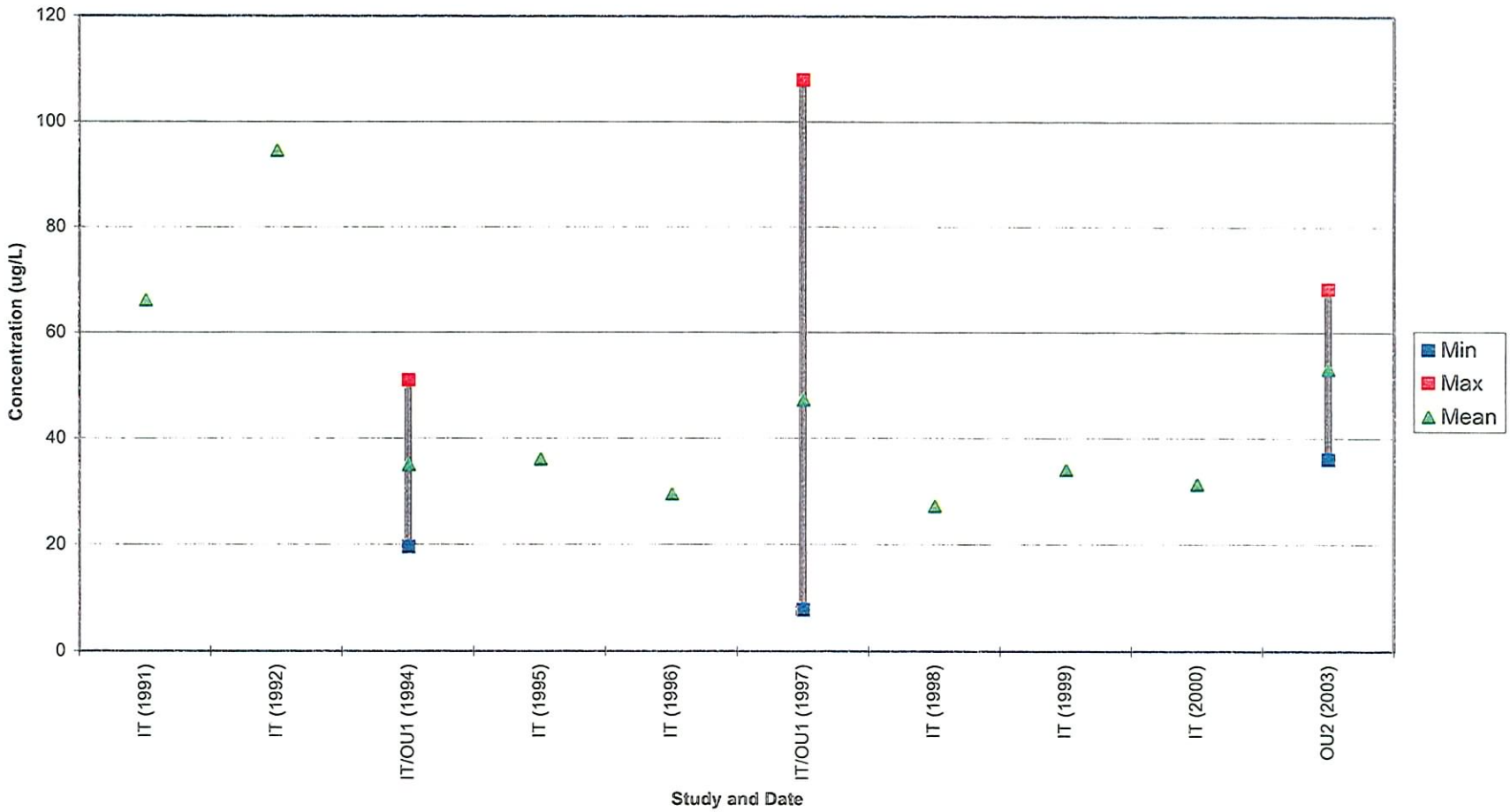
IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

Silver Concentrations in Surface Water



IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

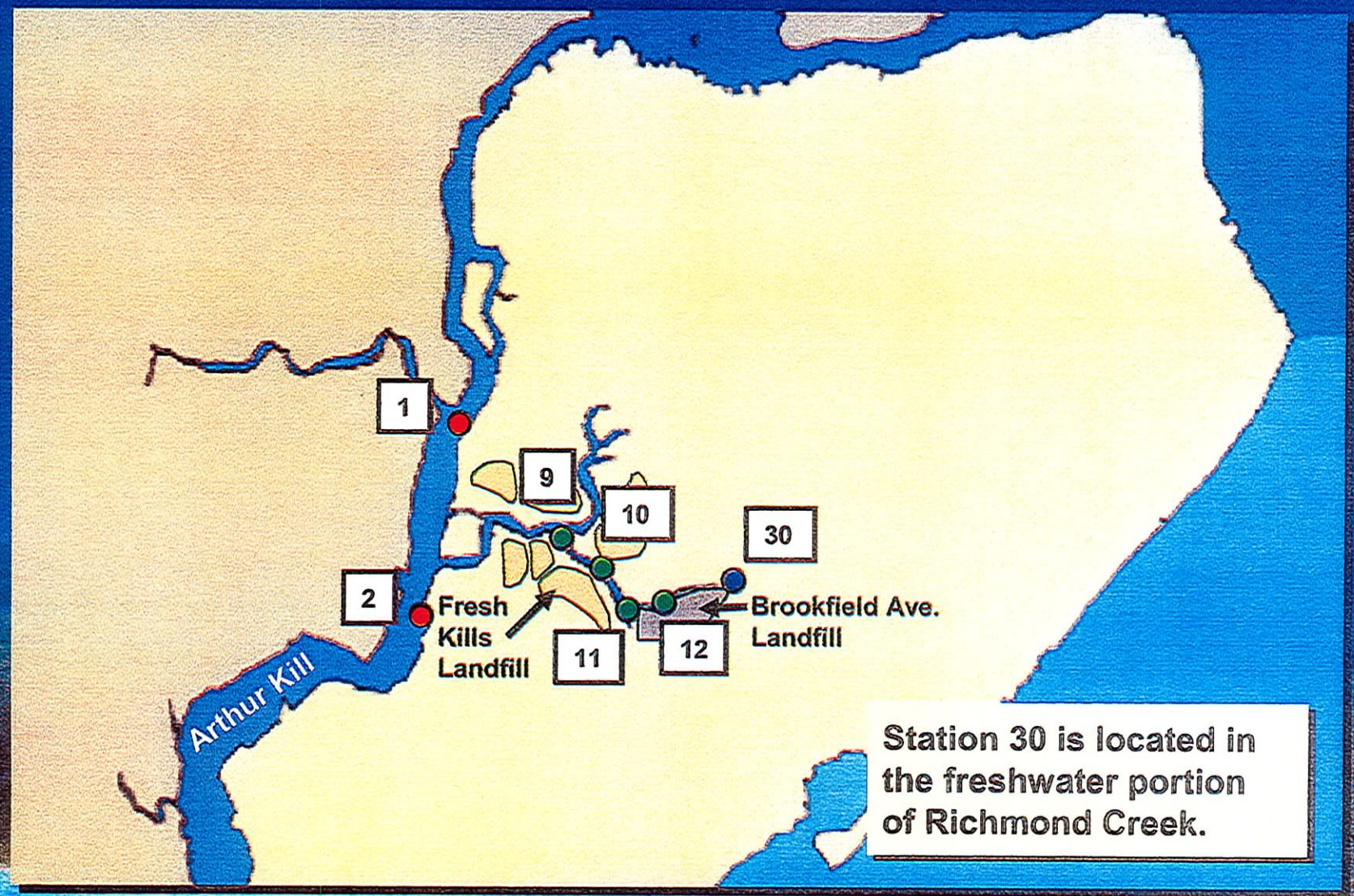
Zinc Concentrations in Surface Water



IT sample results from location WC-12 in Richmond Creek
OU1 sample results from locations SW-1 through SW-4 (low tide)
OU2 sample results from locations SW-1, SW-2, SW-3, SW-5, SW-6, and SW-7 (low tide); and SW-B1 through SW-B6

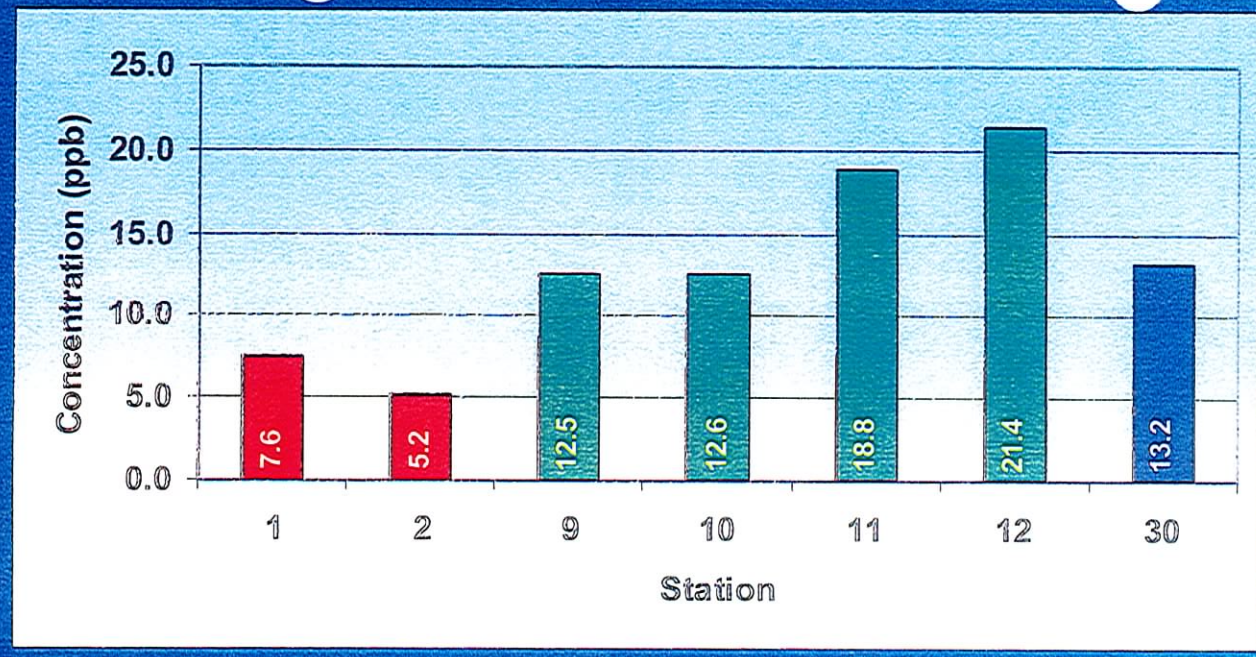
Appendix A.2

Fresh Kills LTMP sampling locations in Arthur Kill and Richmond Creek

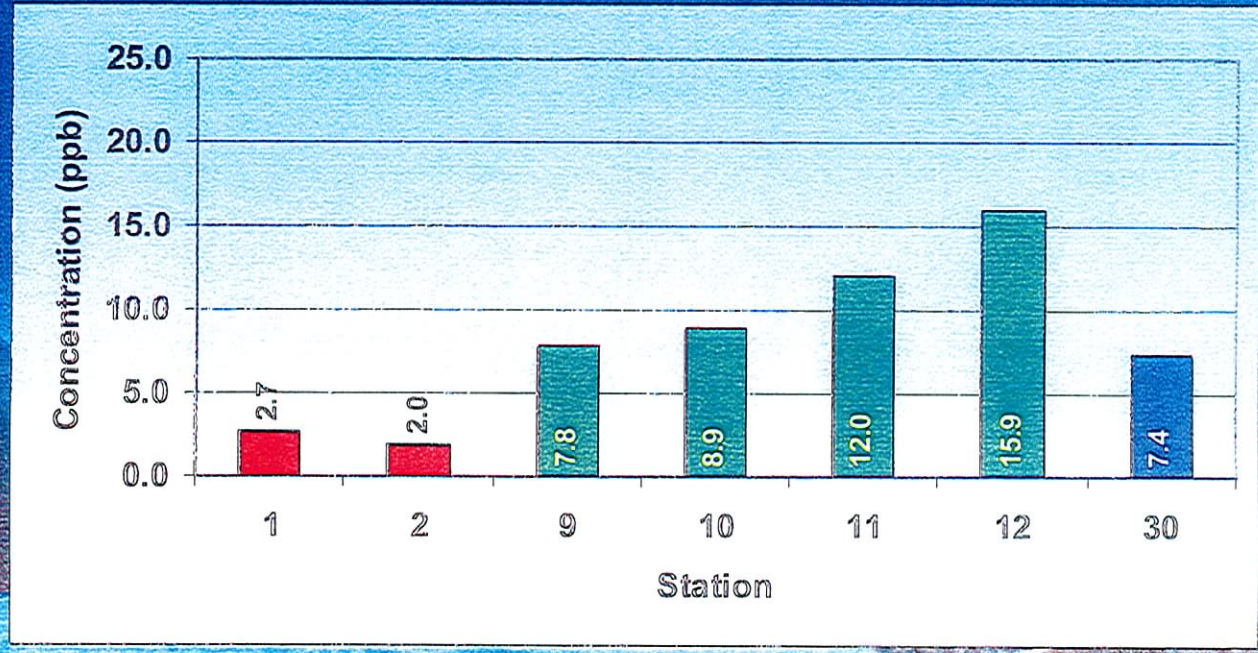


Water Quality

Copper 1991-1998



Copper 2000

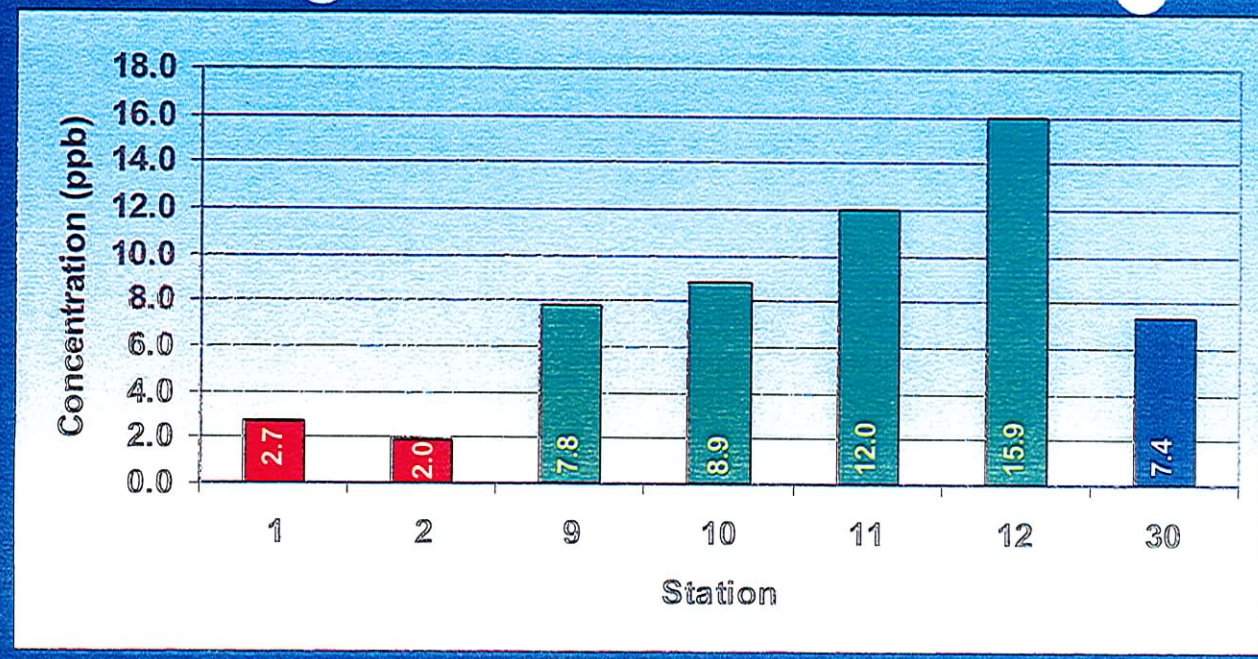


Source: IT Corp, LTMP

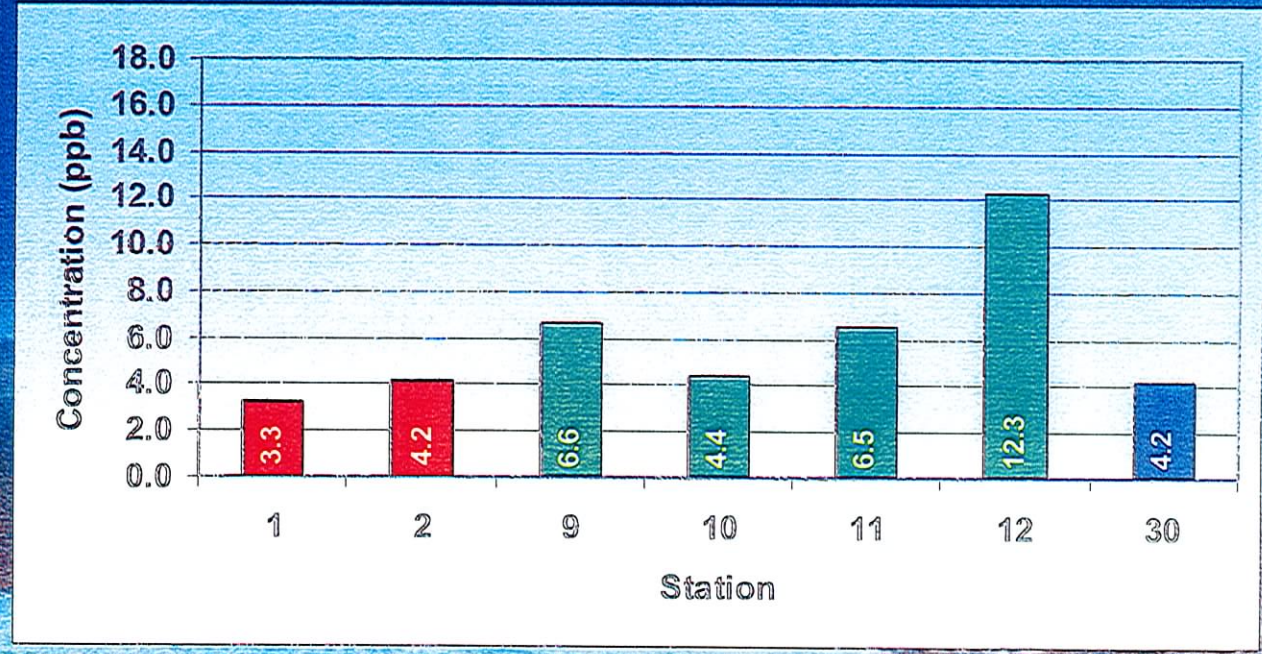
Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Water Quality

Lead 1991-1998



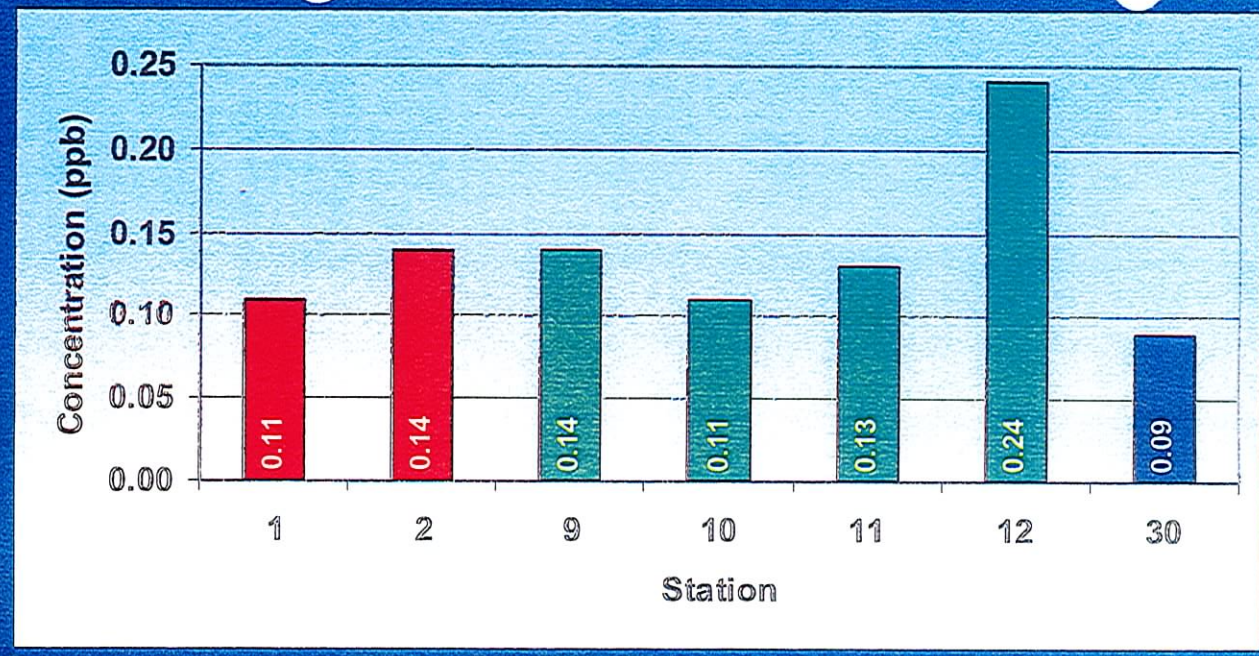
Lead 2000



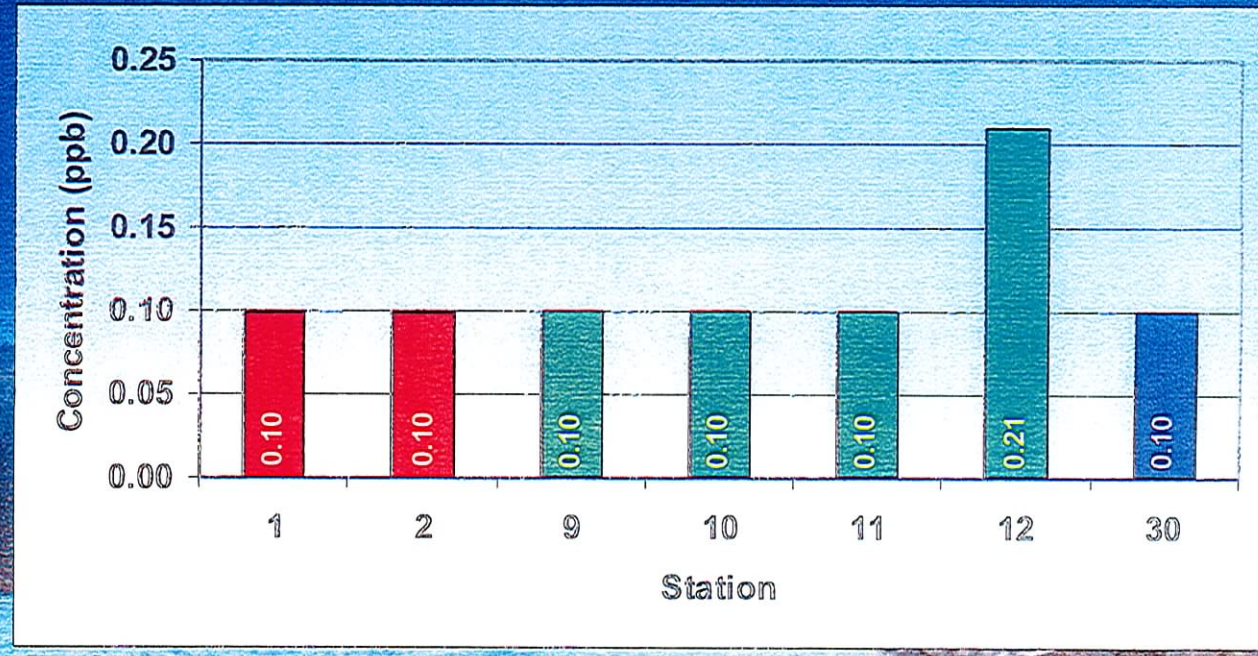
Source: IT Corp, LTMP

Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Mercury 1991-1998



Mercury 2000

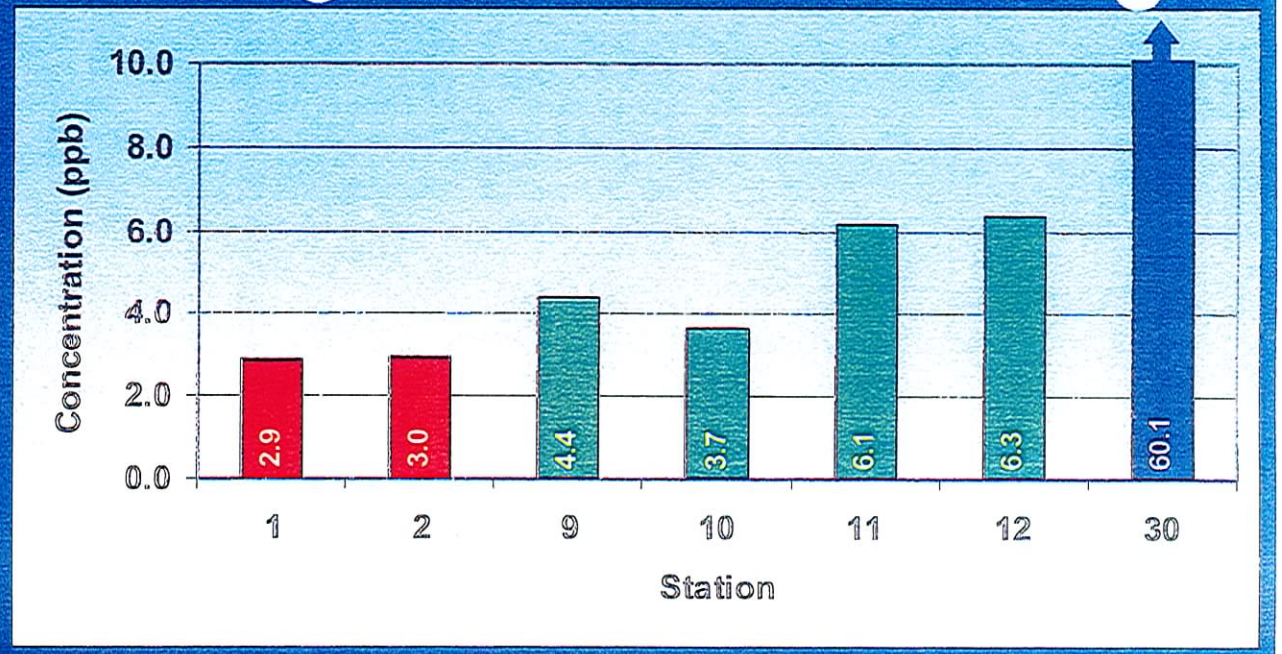


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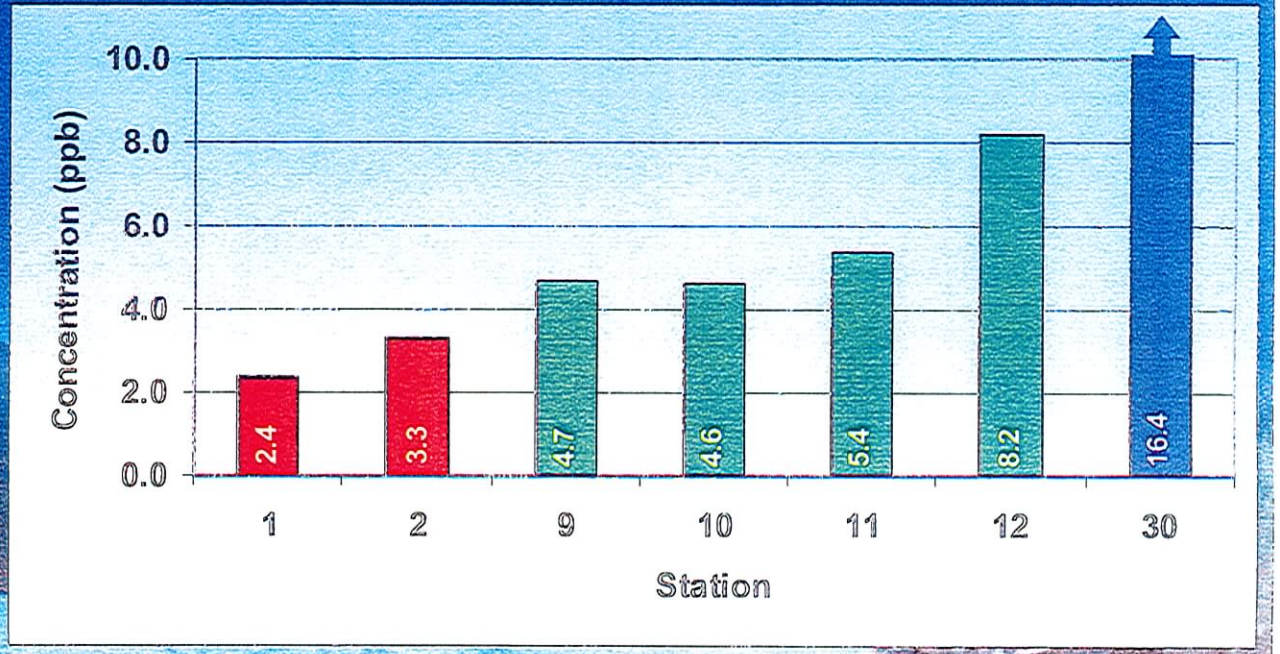
Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Water Quality

Nickel 1991-1998



Nickel 2000

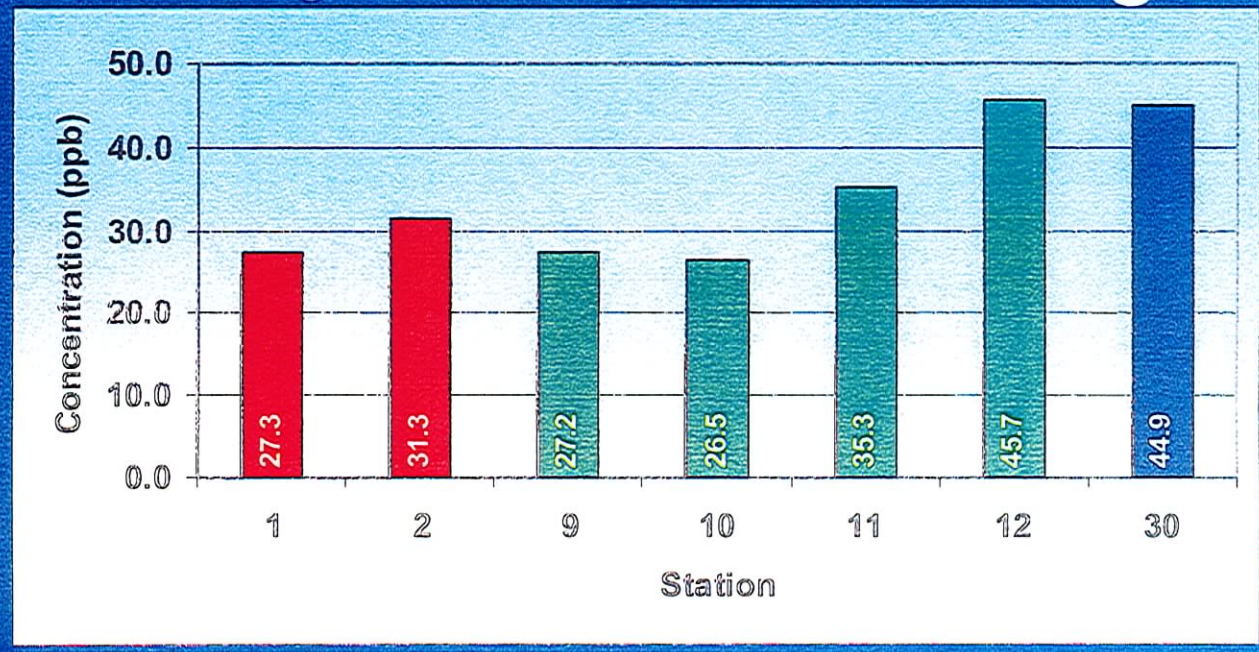


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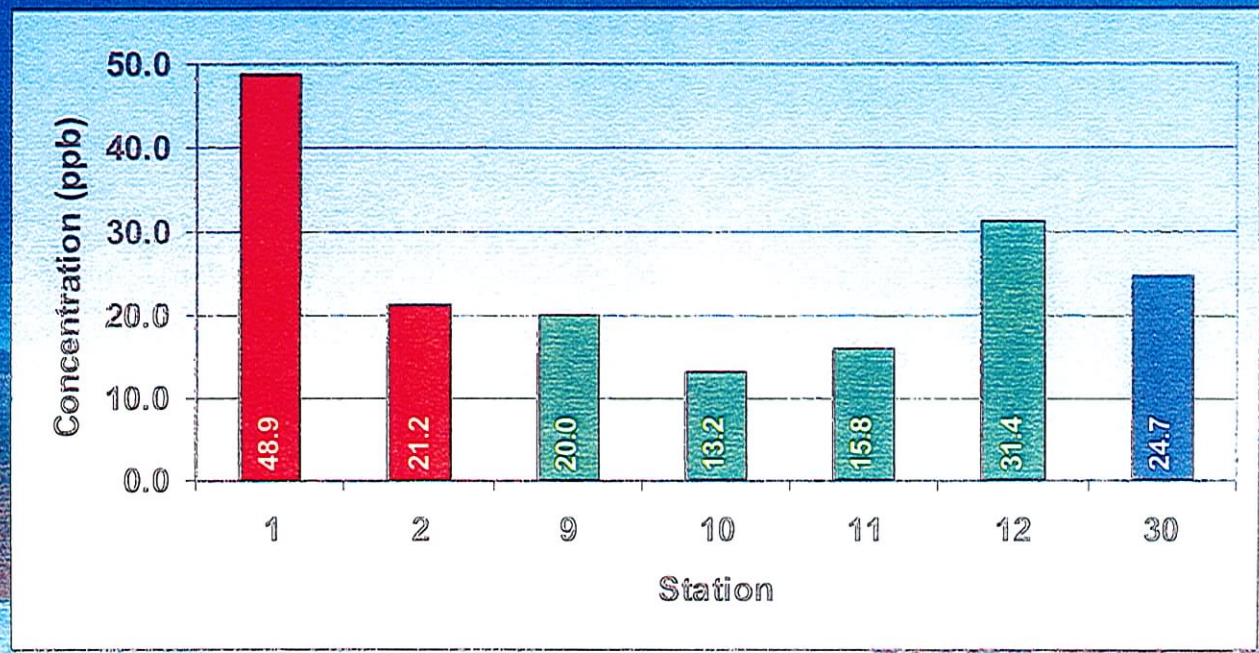
Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Water Quality

Zinc 1991-1998



Zinc 2000

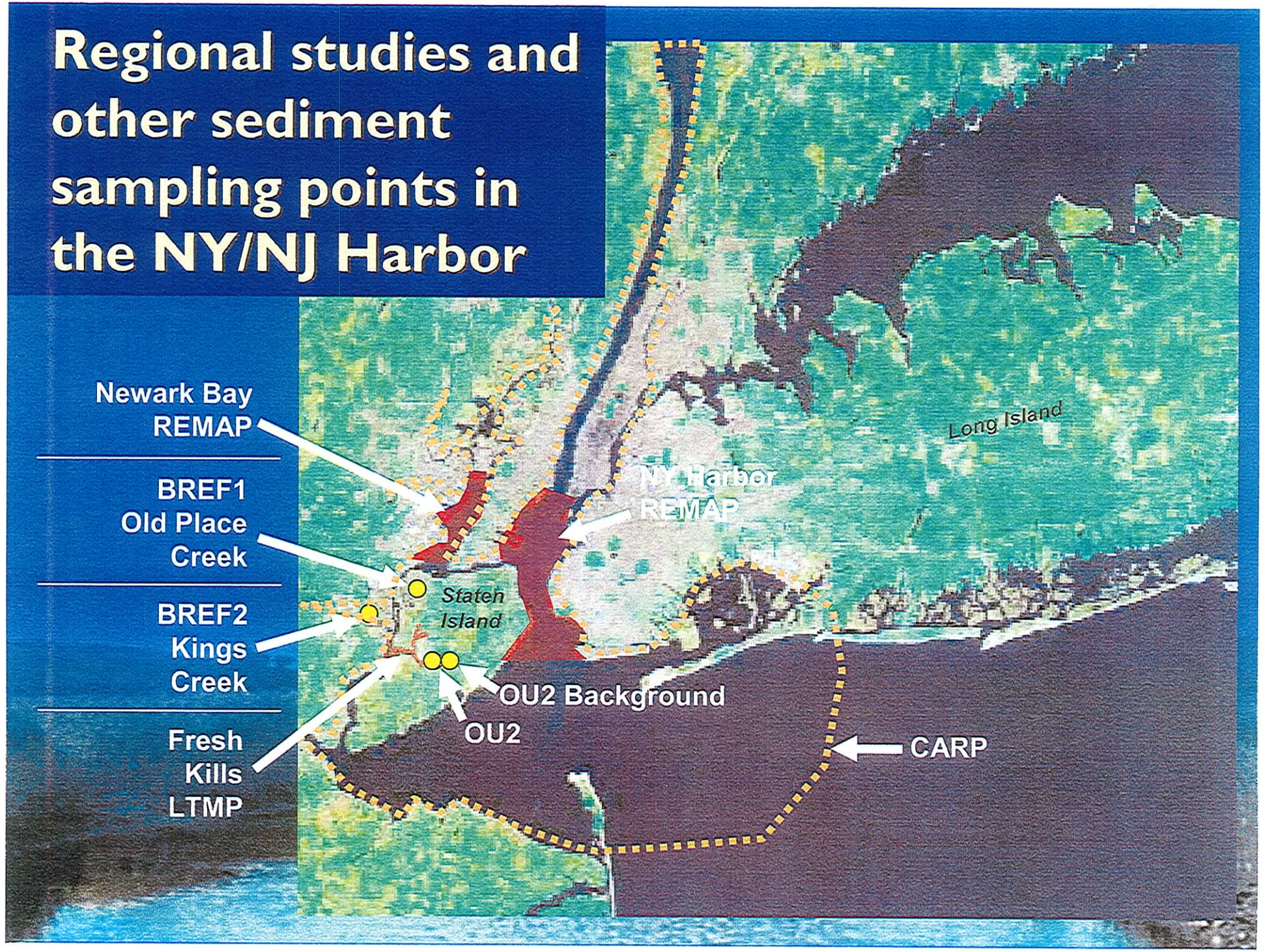


Source: IT Corp, LTMP

Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

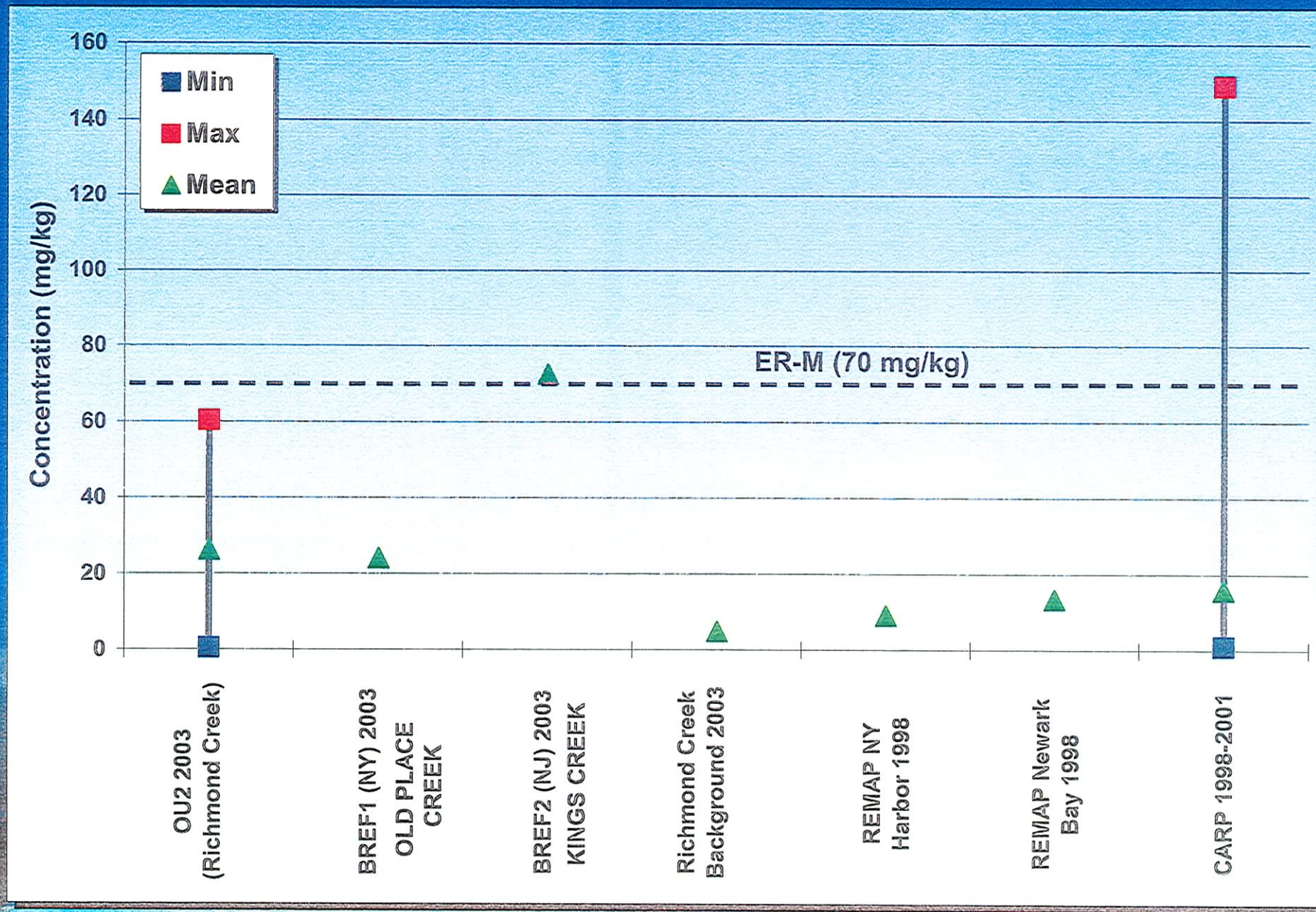
Appendix A.3

Regional studies and other sediment sampling points in the NY/NJ Harbor

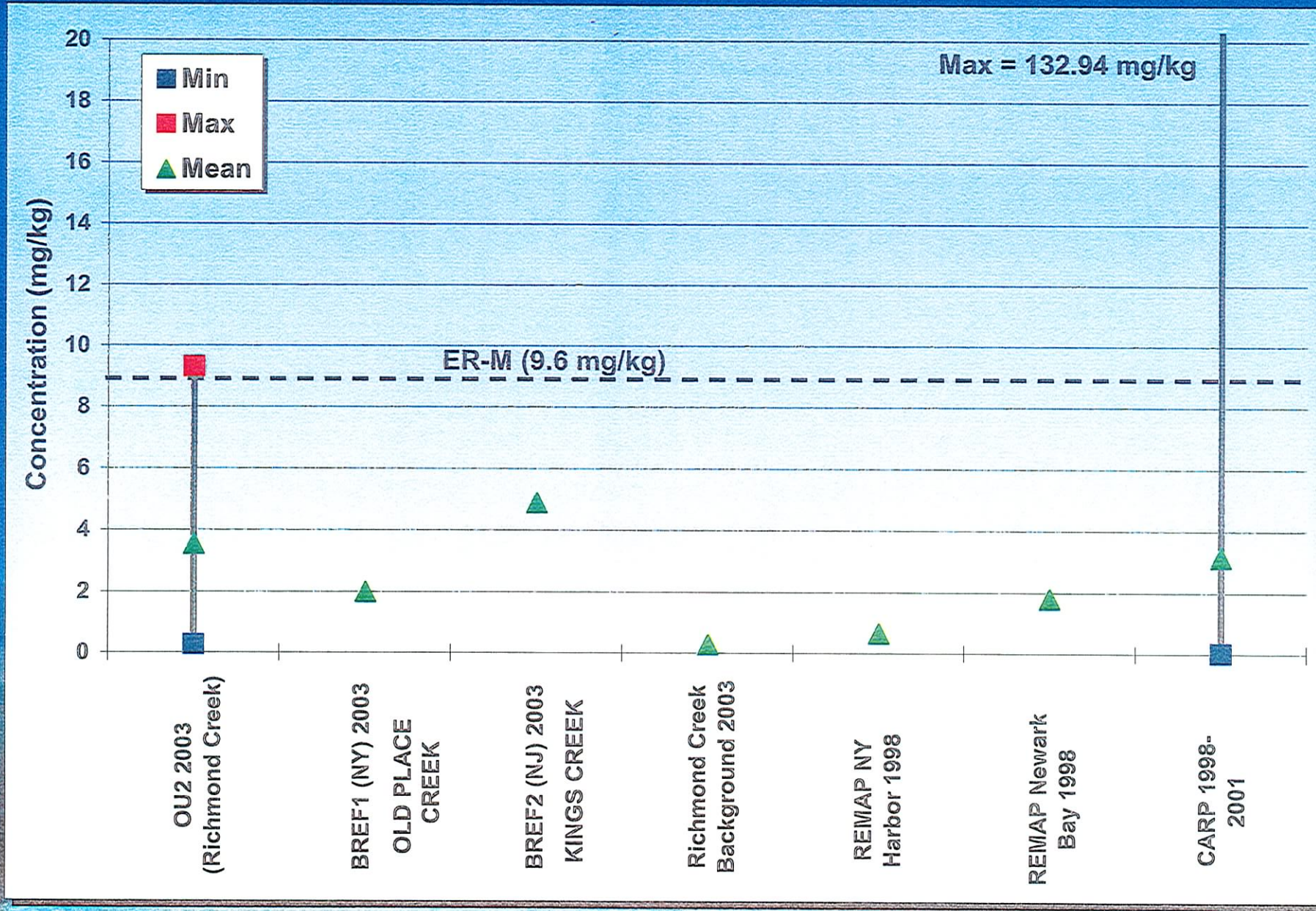


Sediment Quality

Arsenic

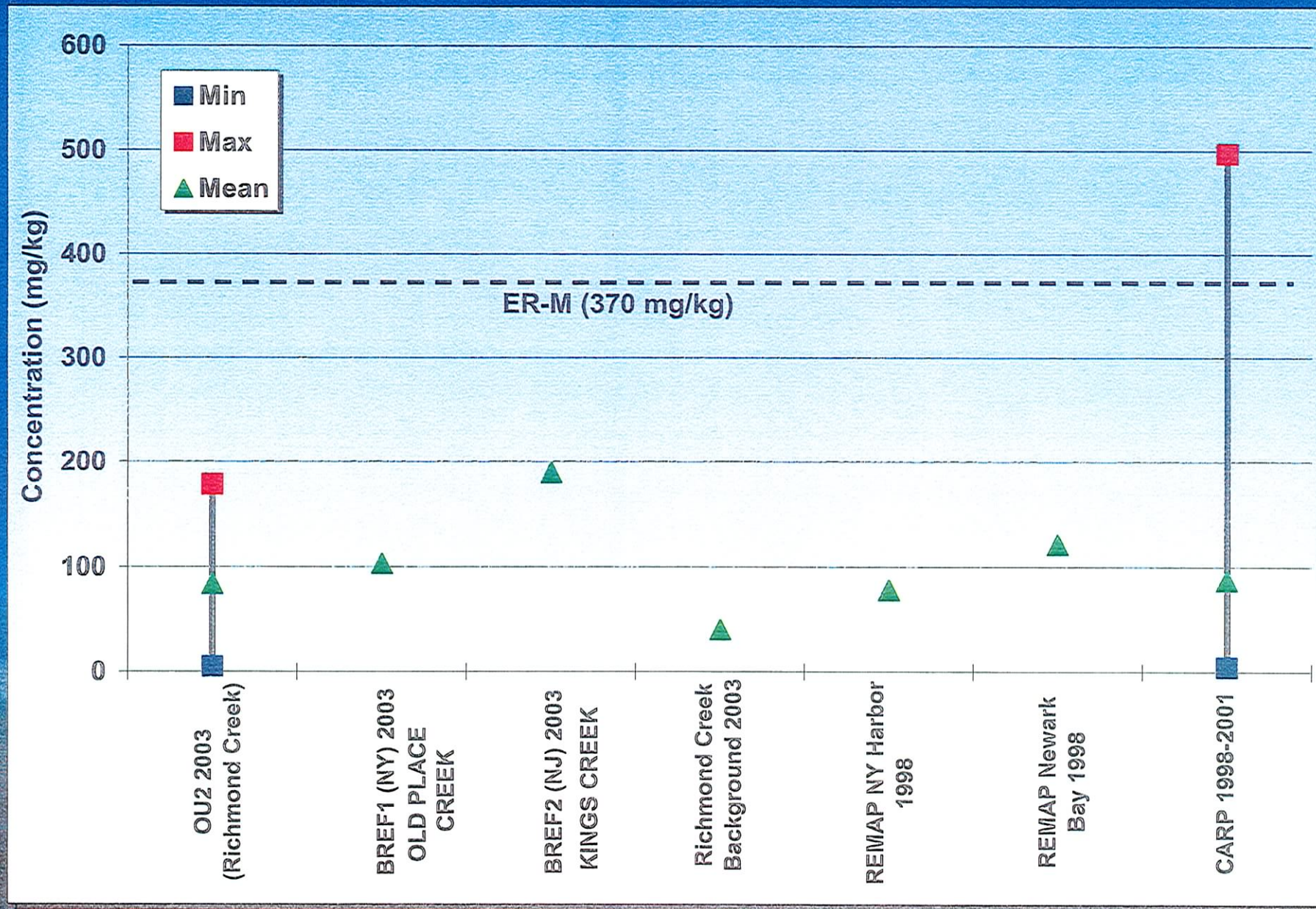


Cadmium

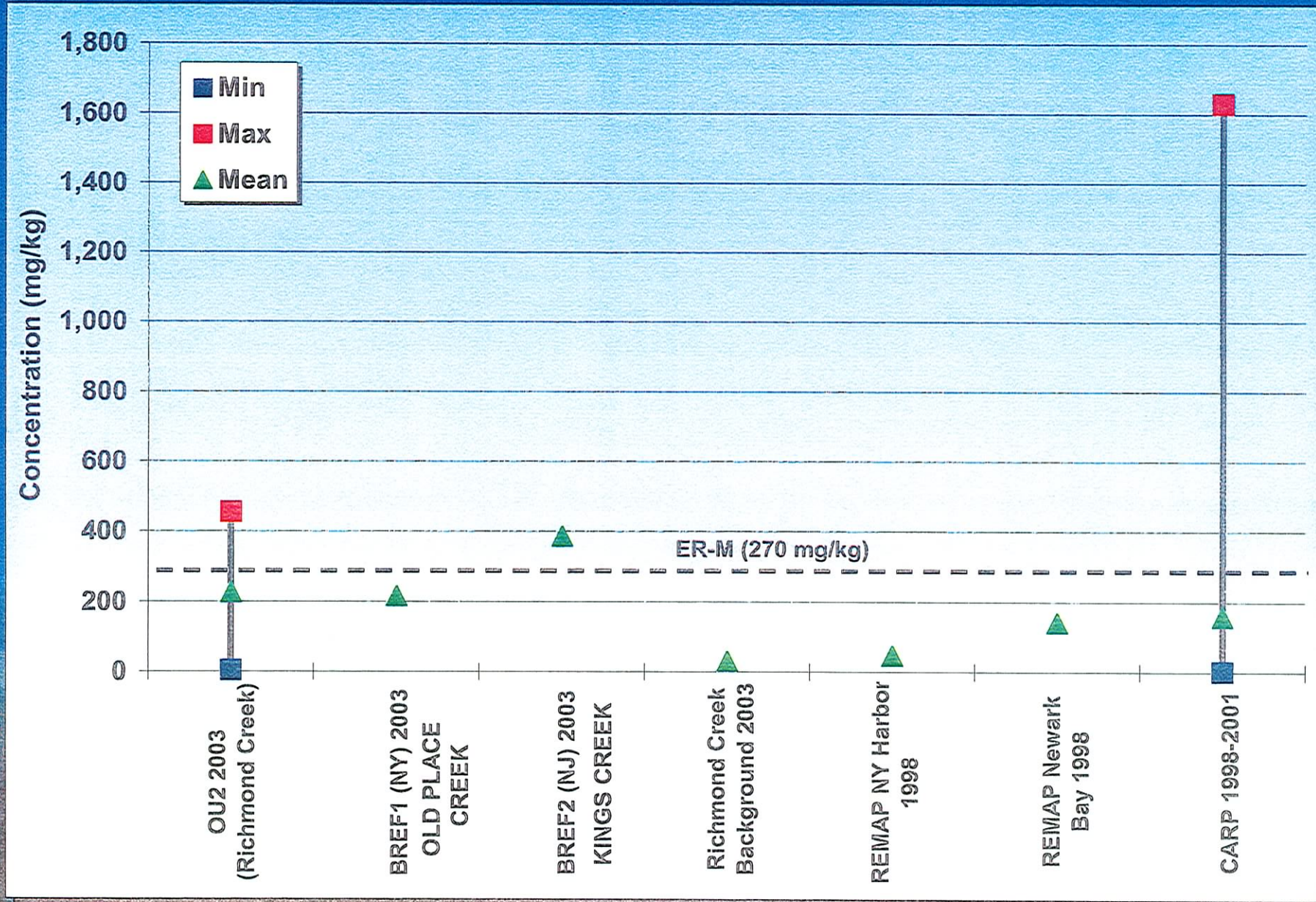

Min
Max
Mean
Max = 132.94 mg/kg
ER-M (9.6 mg/kg)
Concentration (mg/kg)
0
2
4
6
8
10
12
14
16
18
20
OU2 2003 (Richmond Creek)
BREF1 (NY) 2003 OLD PLACE CREEK
BREF2 (NJ) 2003 KINGS CREEK
Richmond Creek Background 2003
REMAP NY Harbor 1998
REMAP Newark Bay 1998
CARP 1998-2001

Sediment Quality

Chromium

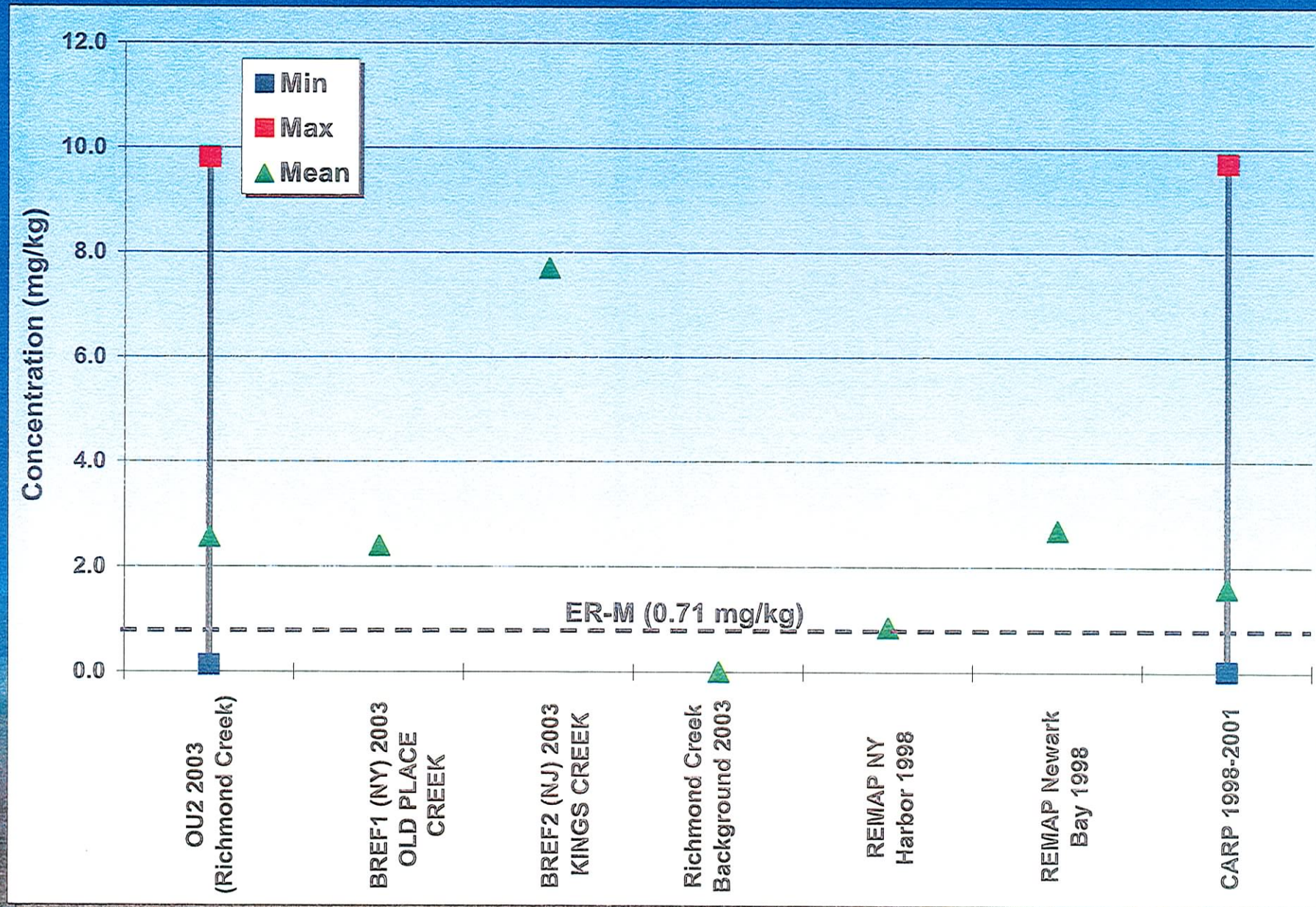


Copper


Concentration (mg/kg)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Min
Max
Mean
ER-M (270 mg/kg)
OU2 2003 (Richmond Creek)
BREF1 (NY) 2003 OLD PLACE CREEK
BREF2 (NJ) 2003 KINGS CREEK
Richmond Creek Background 2003
REMAP NY Harbor 1998
REMAP Newark Bay 1998
CARP 1998-2001

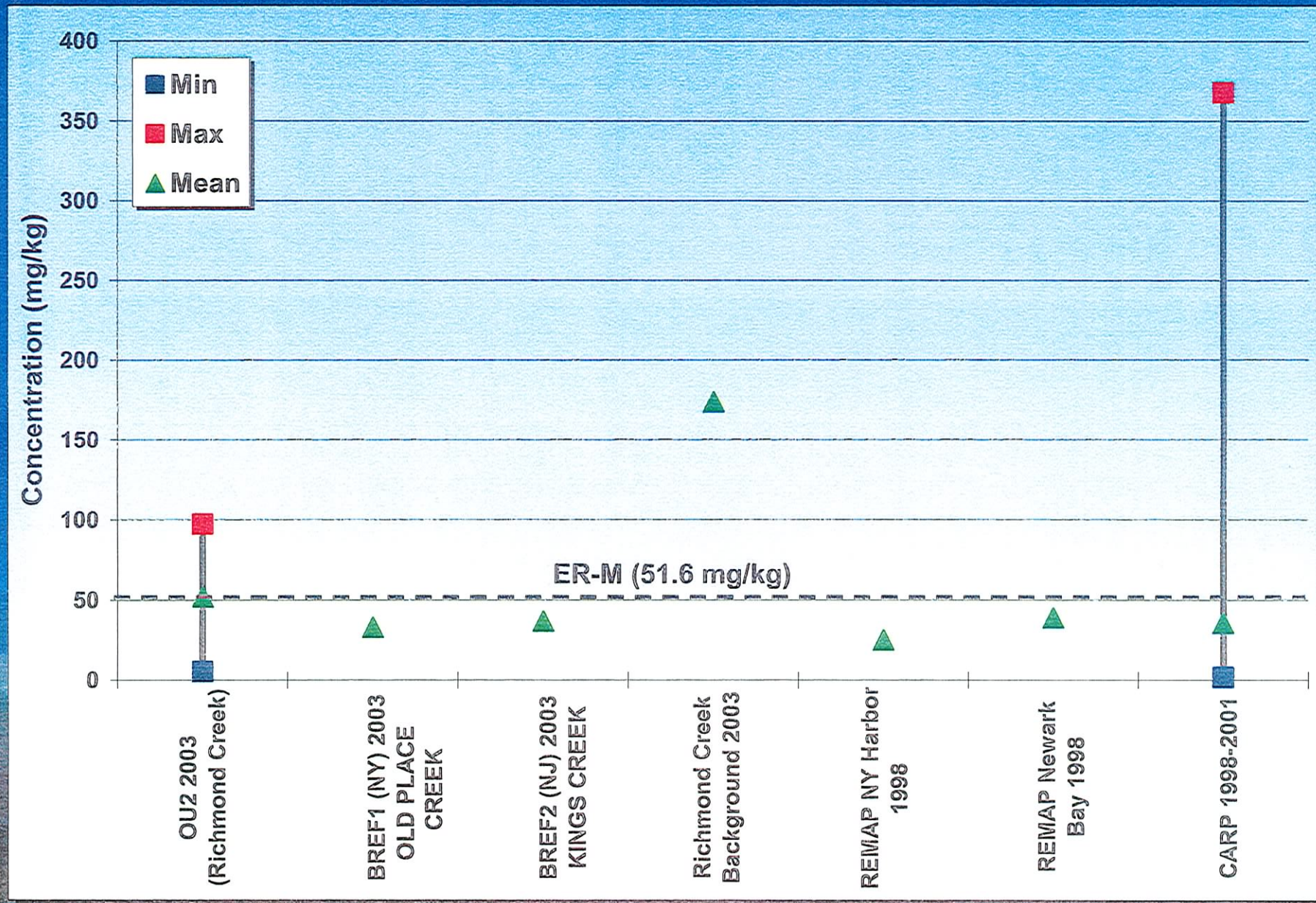
Sediment Quality

Mercury



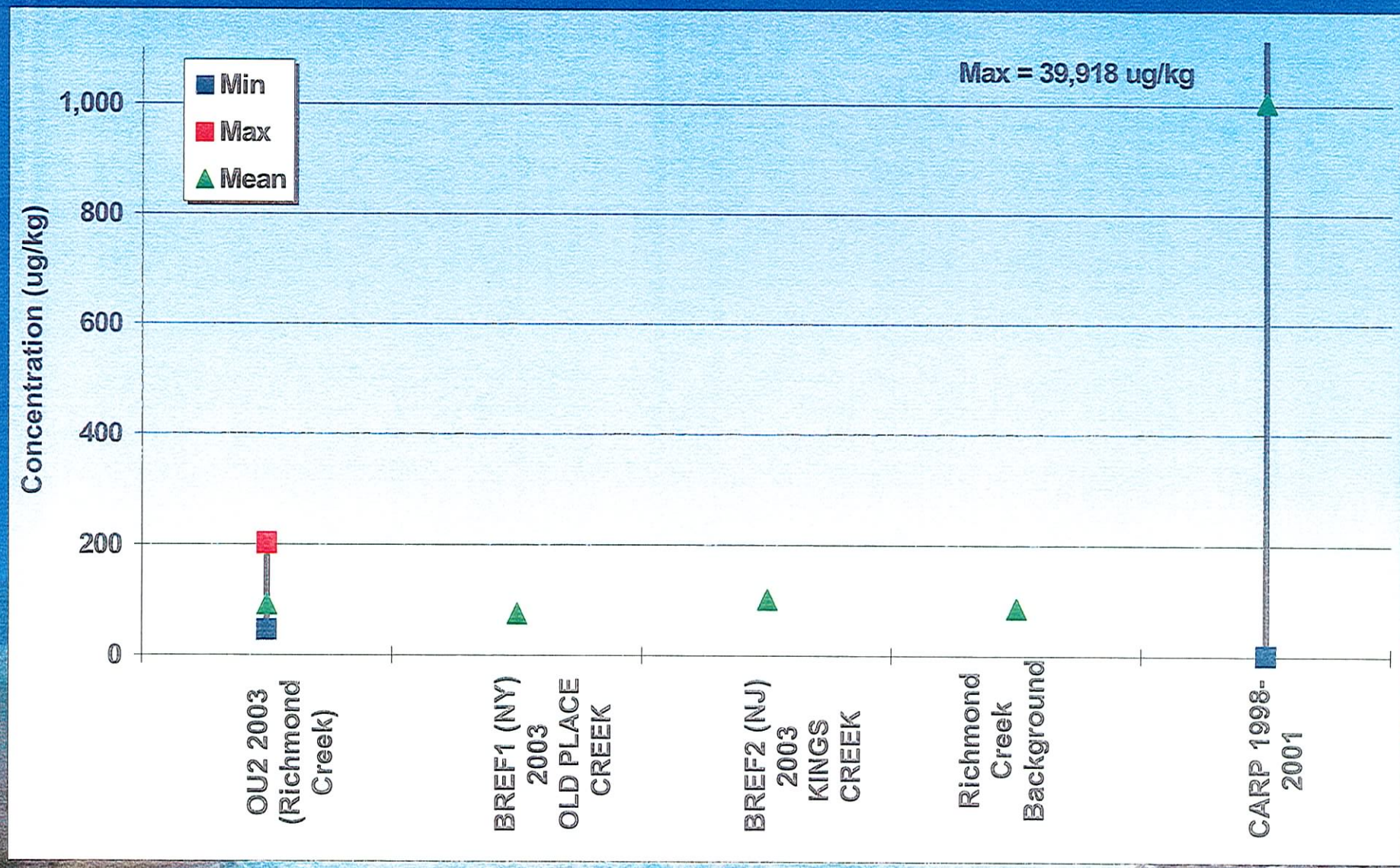
Sediment Quality

Nickel



Sediment Quality

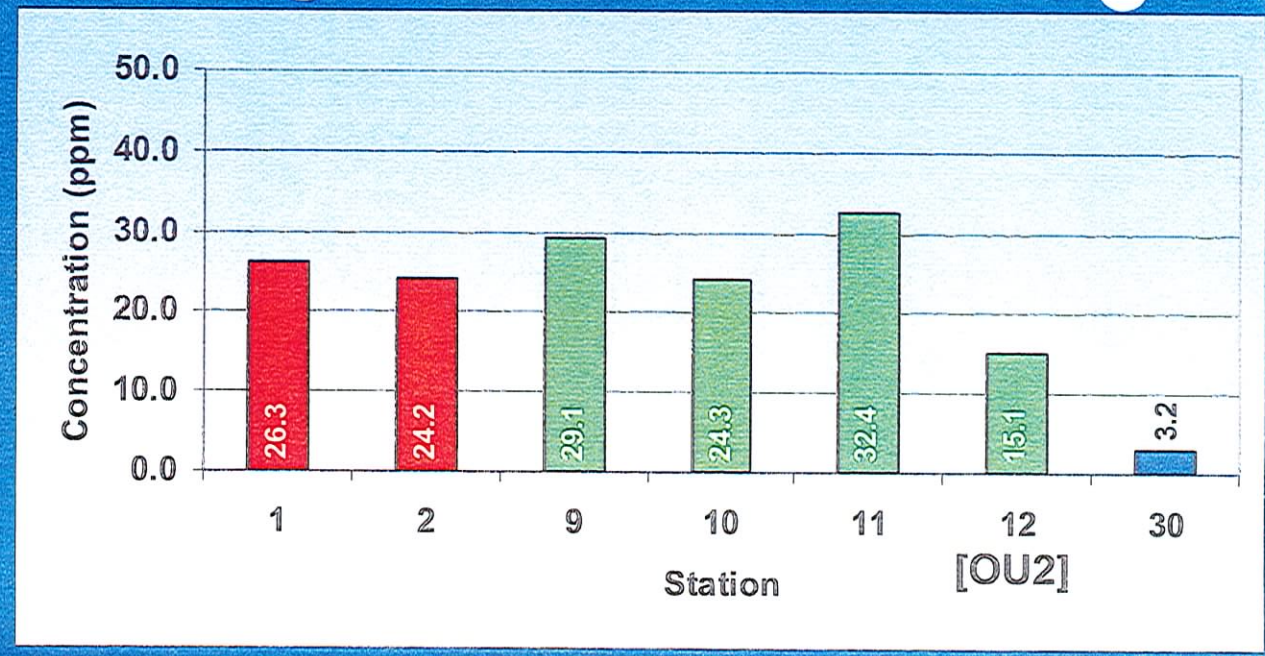
PCBs



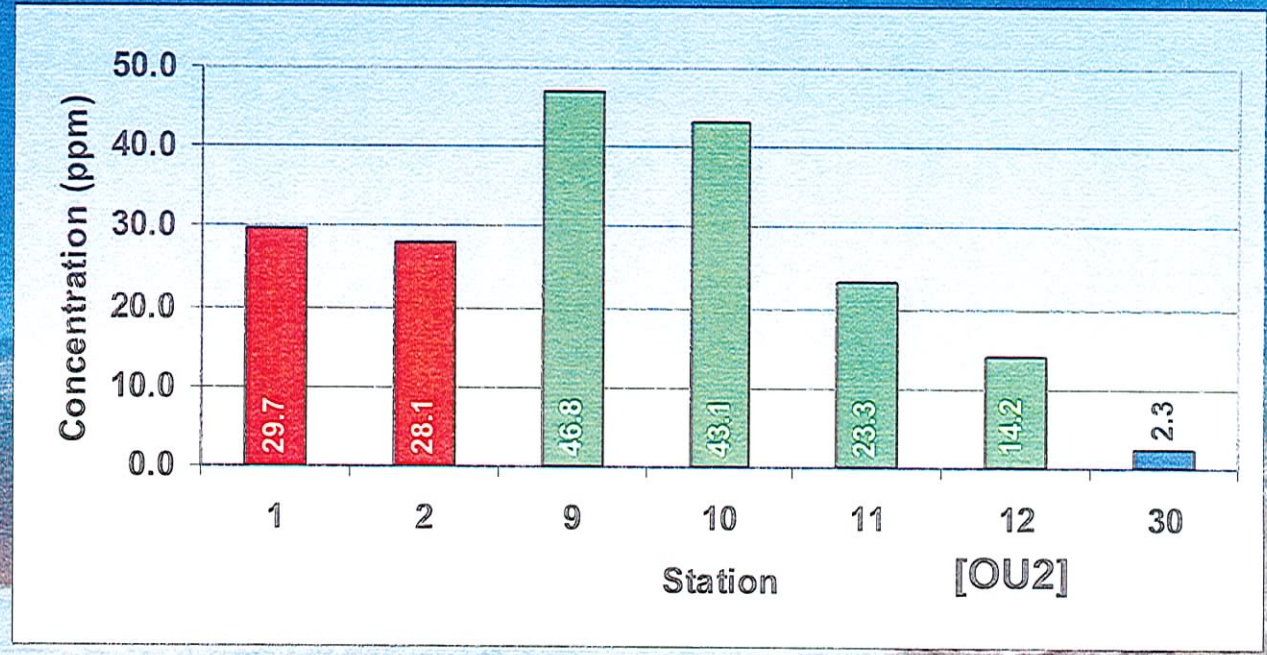
Appendix A.4

Sediment Quality

Arsenic 1991-1998



Arsenic 2000

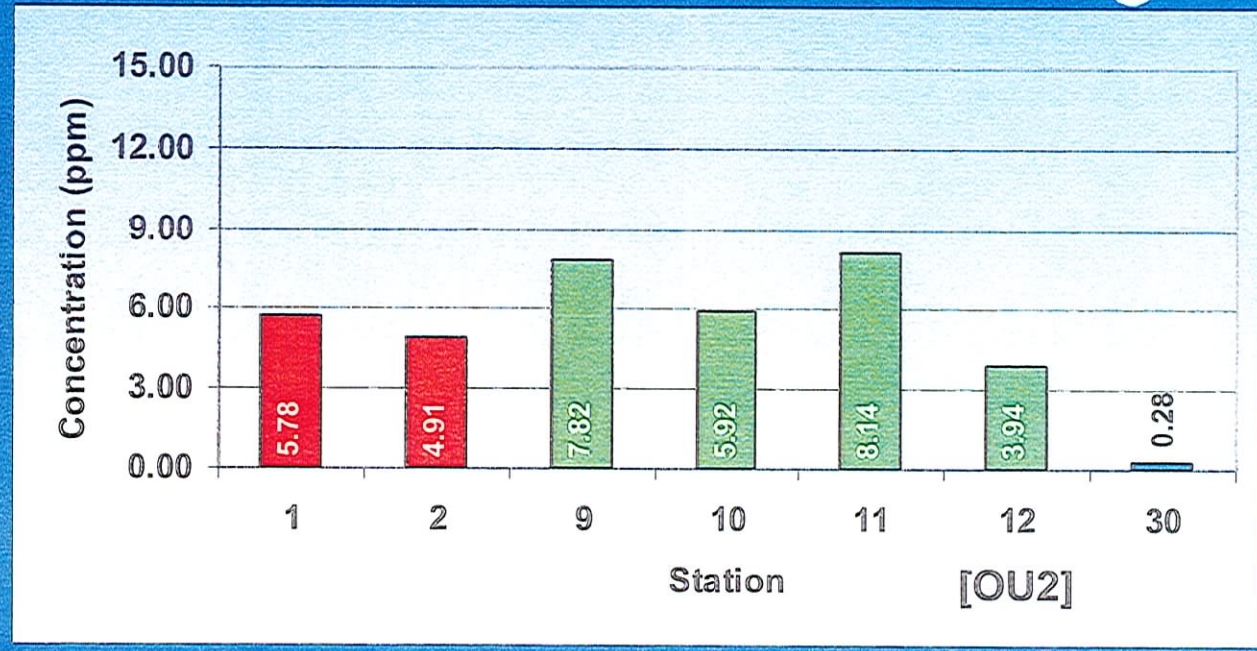


Source: IT Corp, LTMP

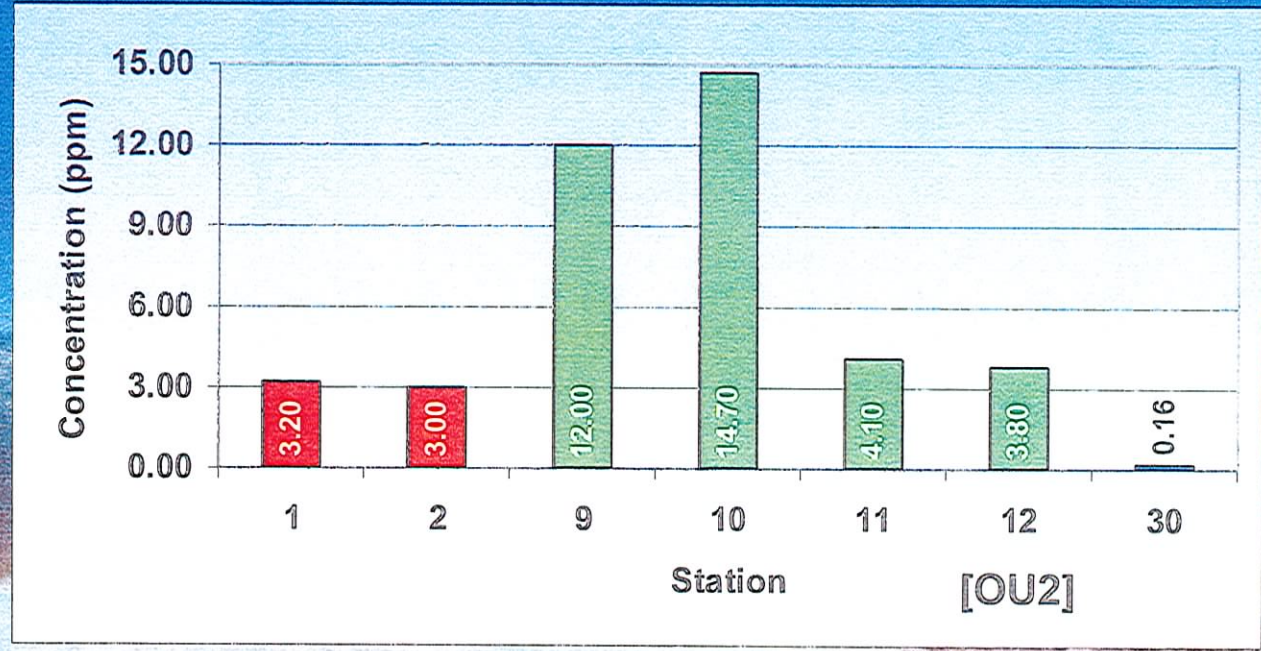
Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Sediment Quality

Cadmium 1991-1998



Cadmium 2000

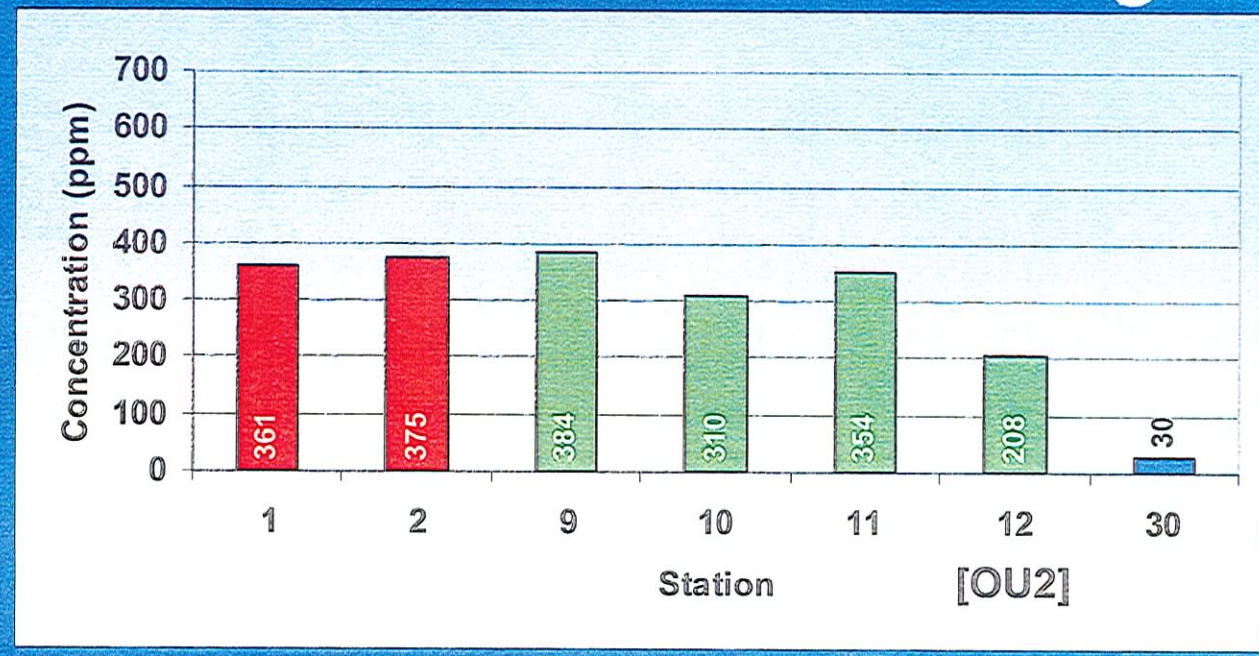


Source: IT Corp, LTMP

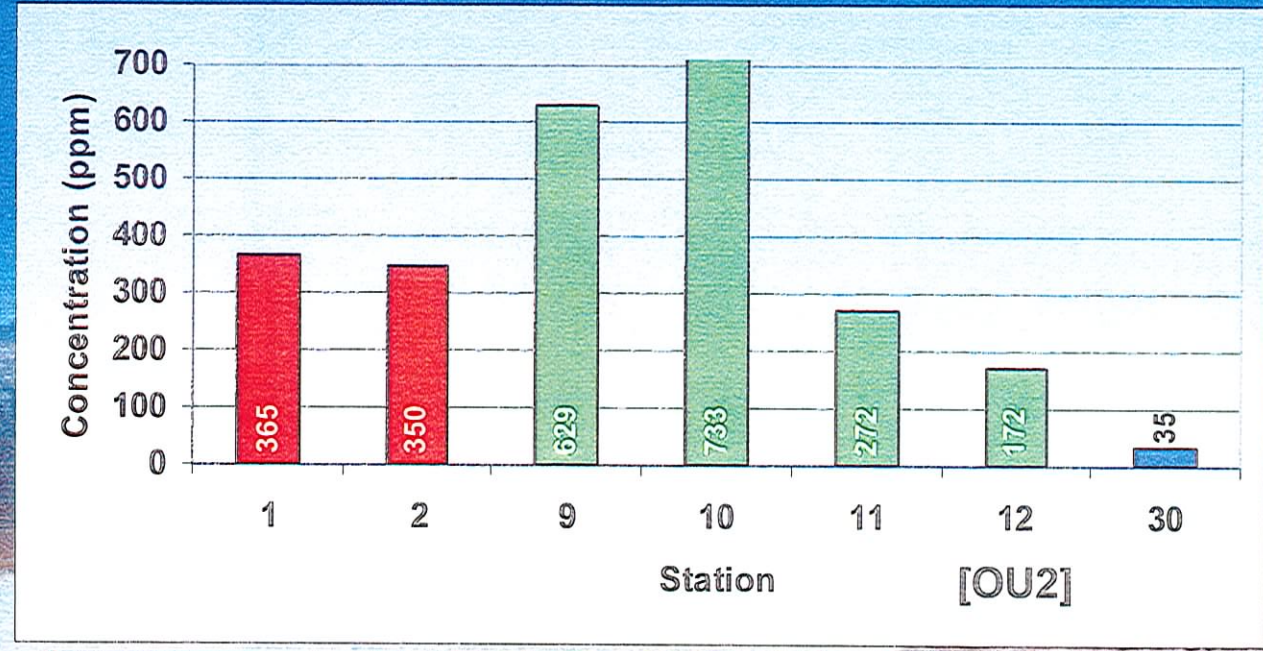
Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Sediment Quality

Copper 1991-1998



Copper 2000

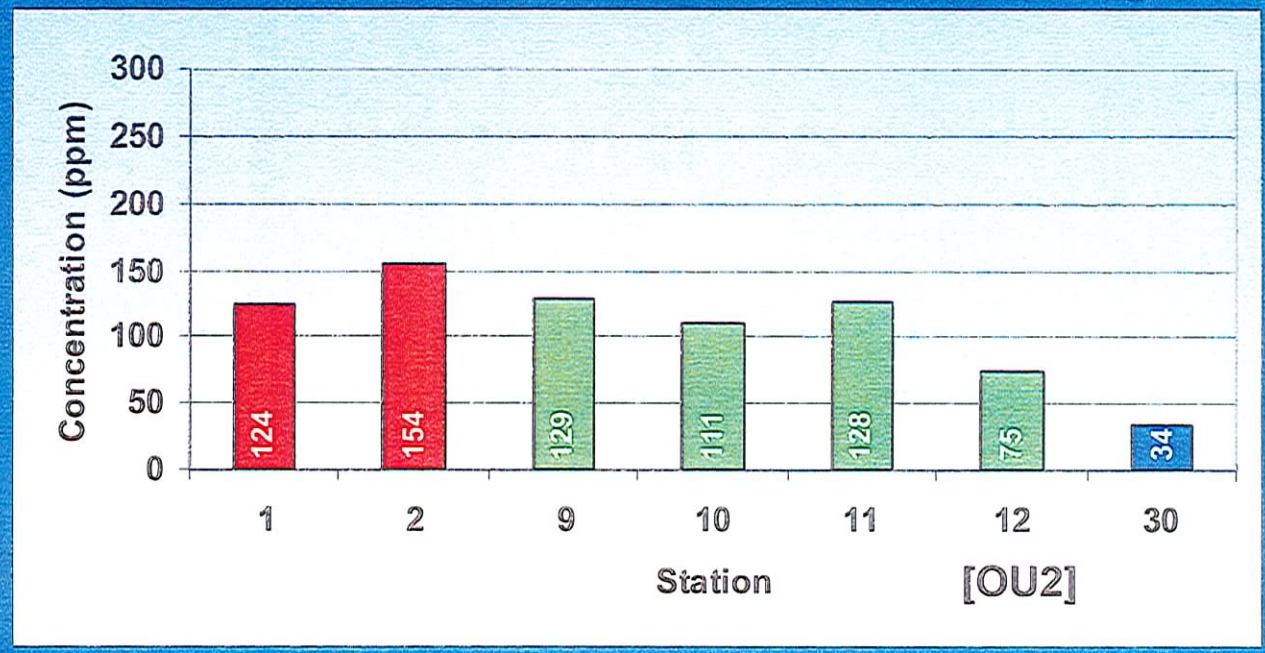


Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

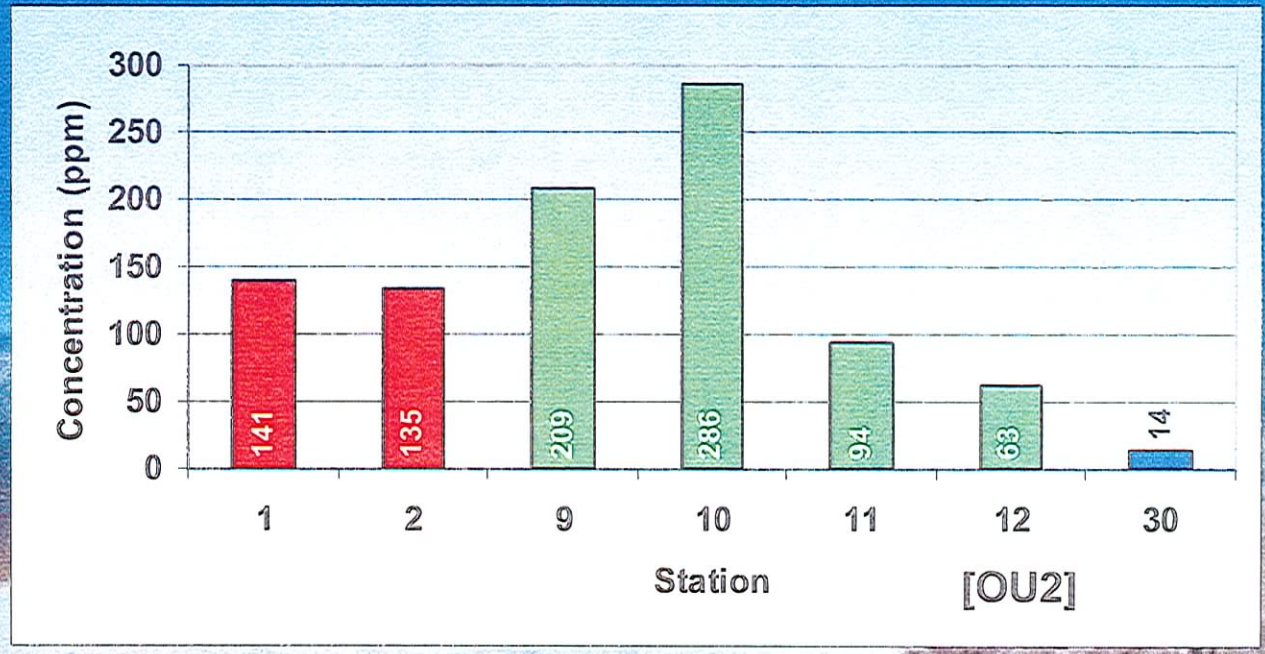
Source: IT Corp, LTMP

Sediment Quality

Chromium 1991-1998



Chromium 2000

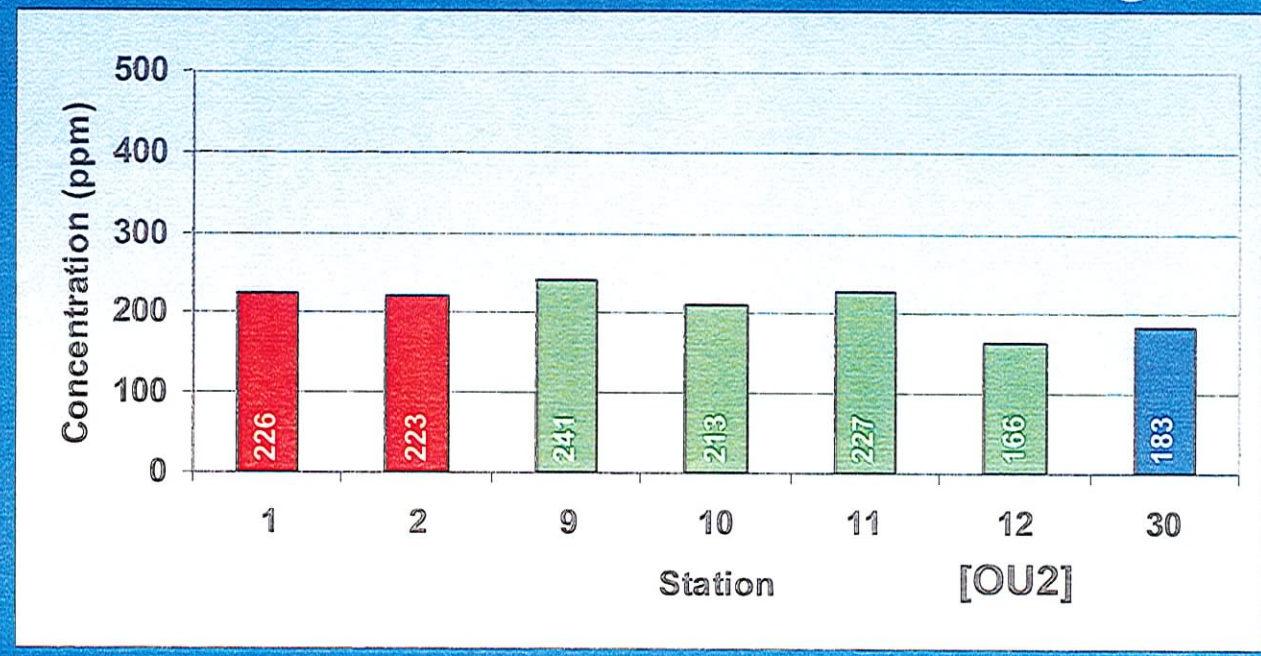


Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

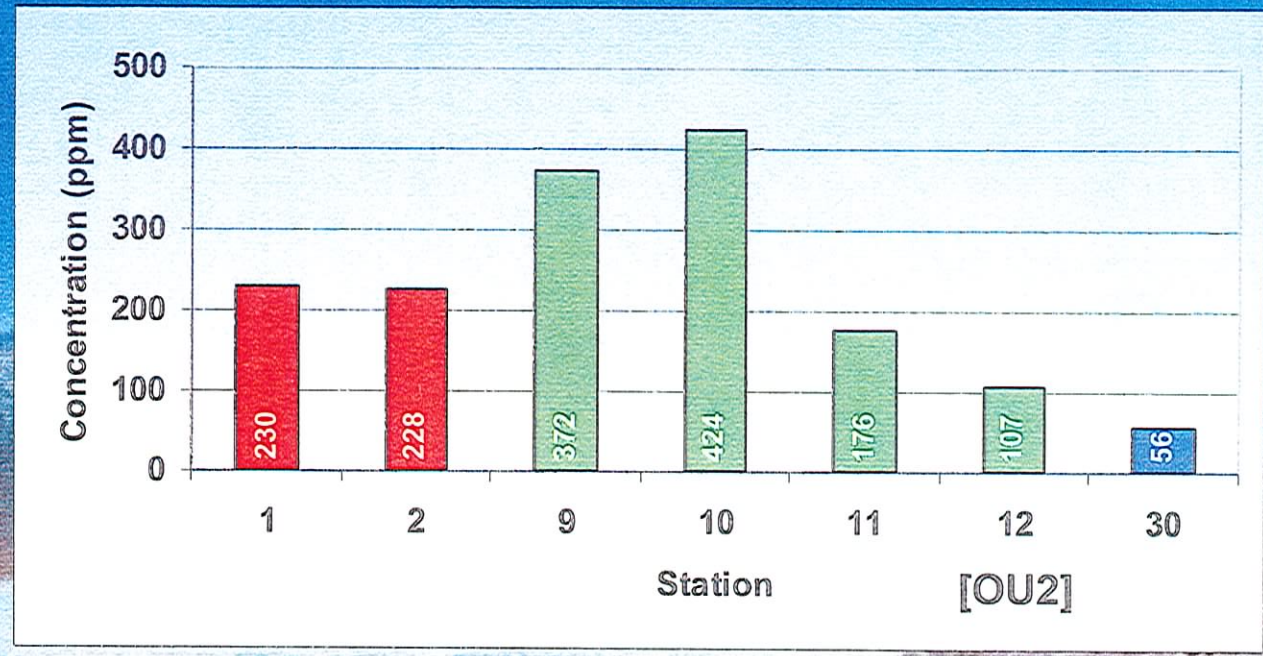
Source: IT Corp, LTMP

Sediment Quality

Lead 1991-1998



Lead 2000

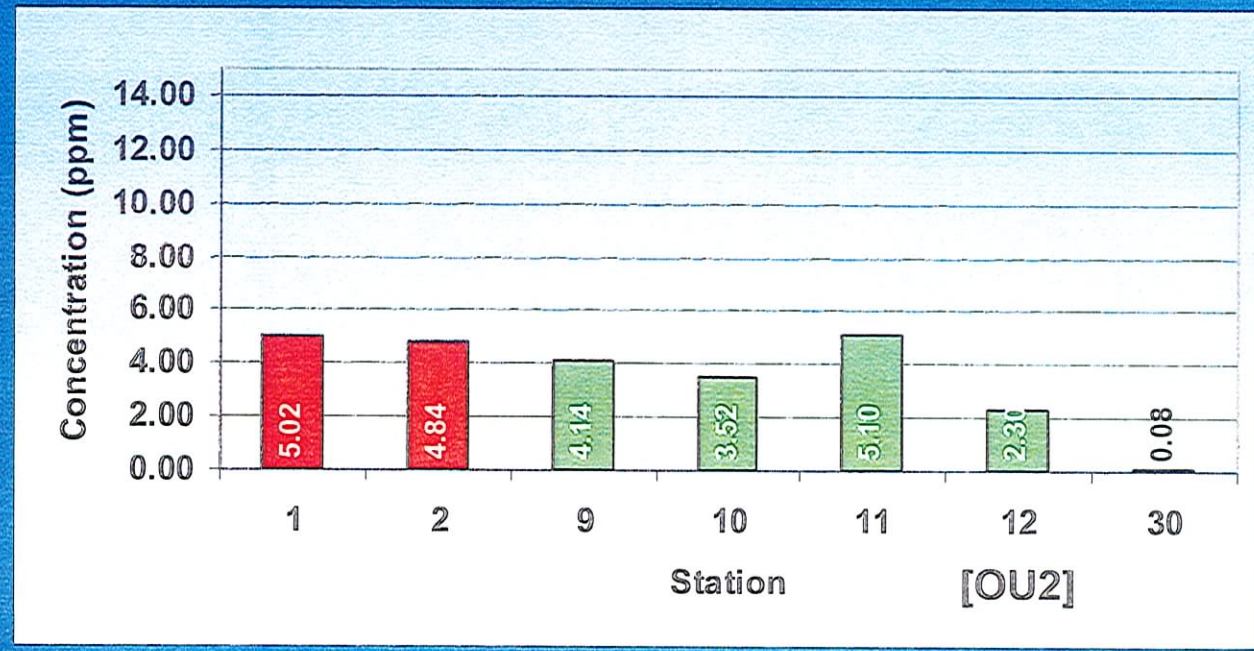


Source: IT Corp, LTMP

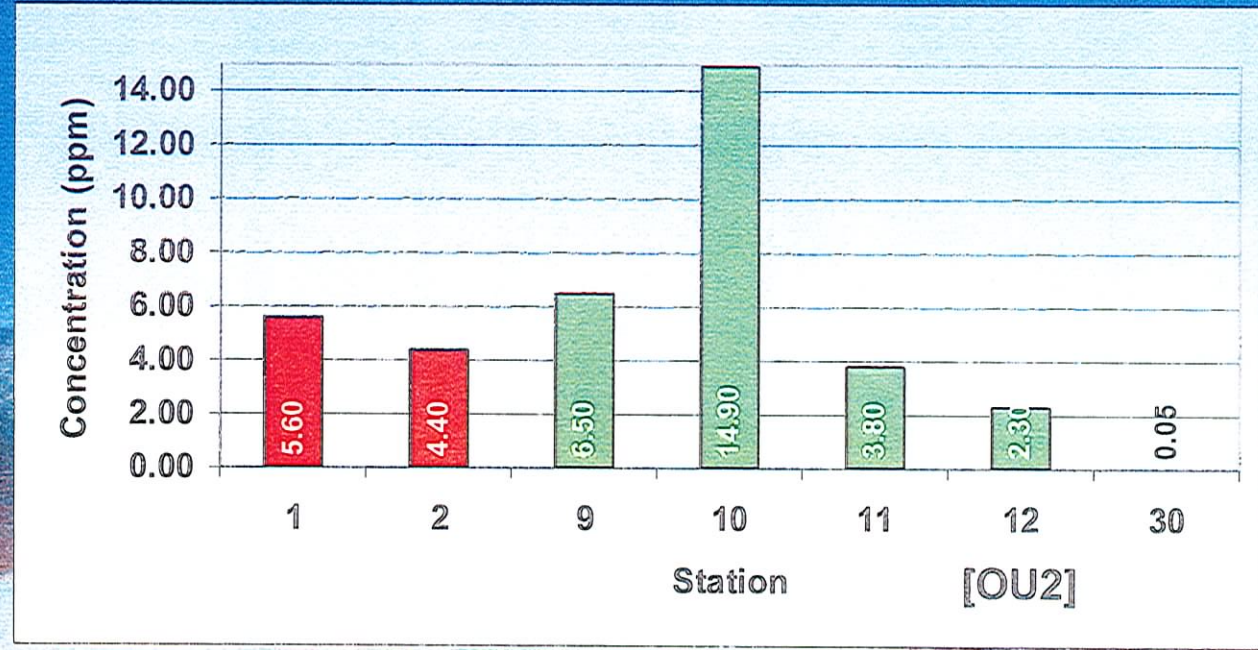
Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Sediment Quality

Mercury 1991-1998



Mercury 2000

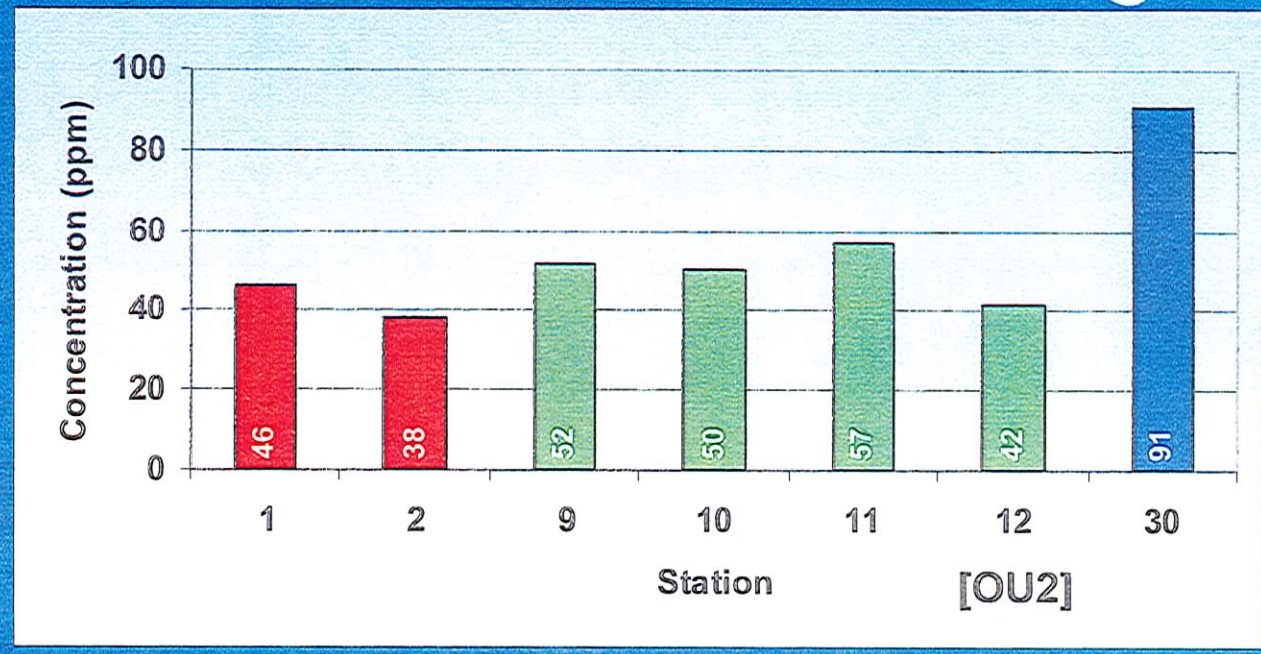


Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

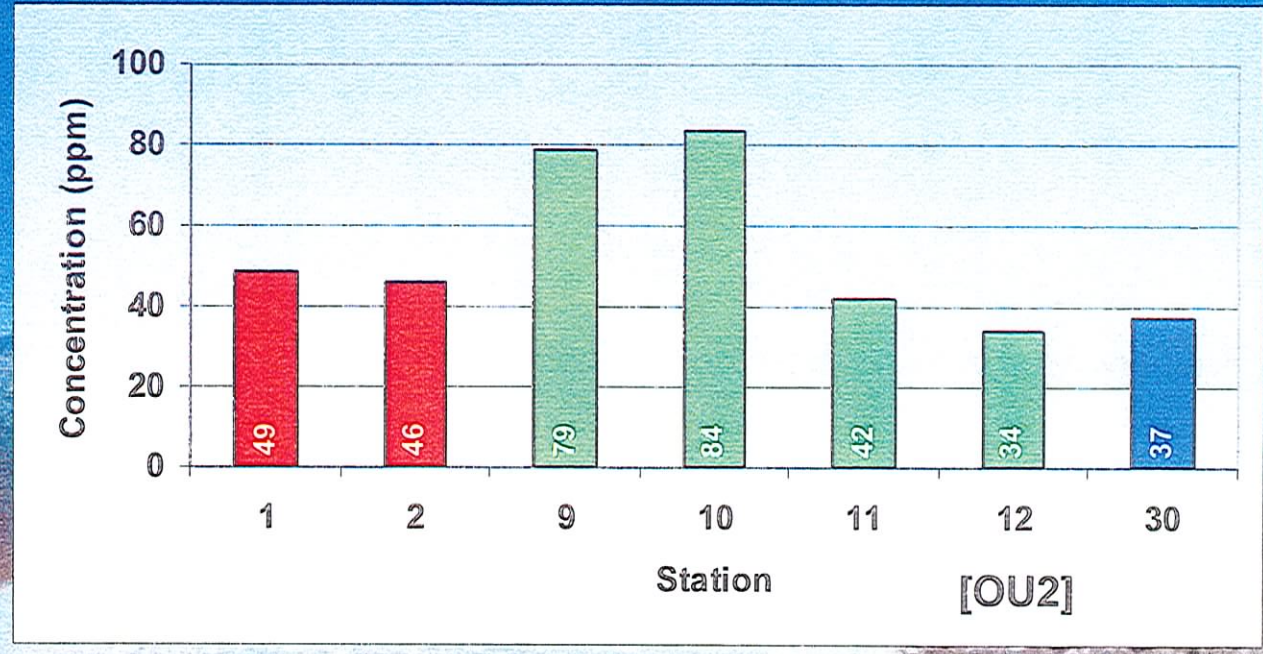
Source: IT Corp, LTMP

Sediment Quality

Nickel 1991-1998



Nickel 2000

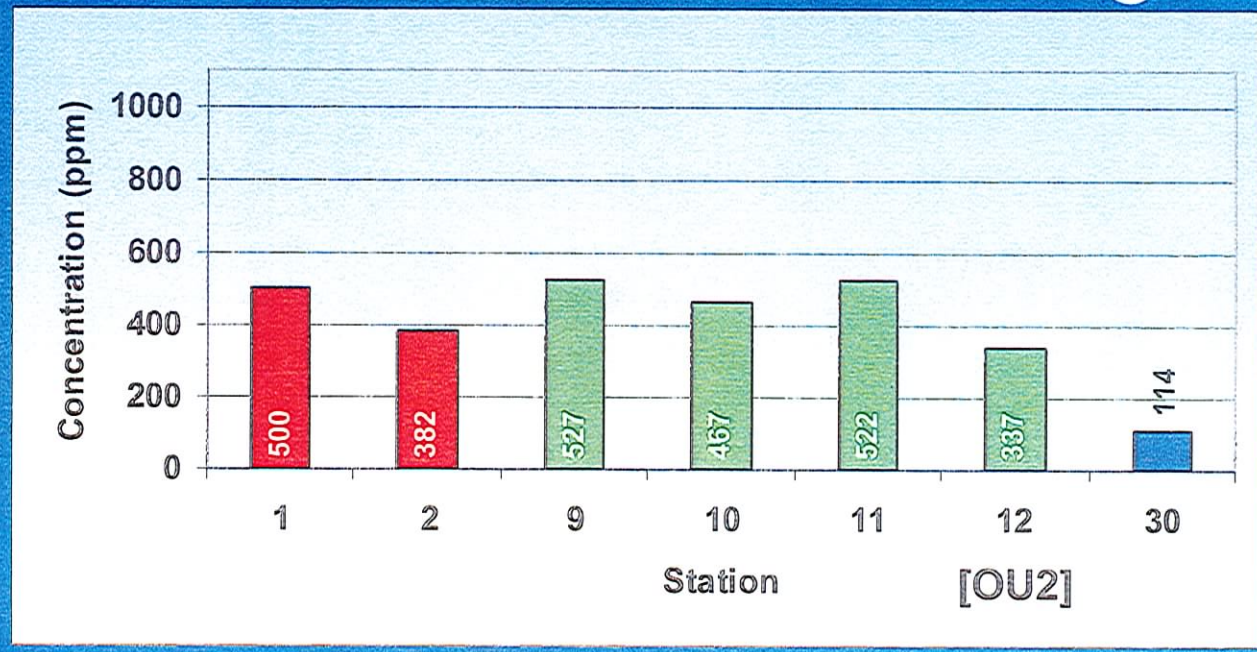


Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

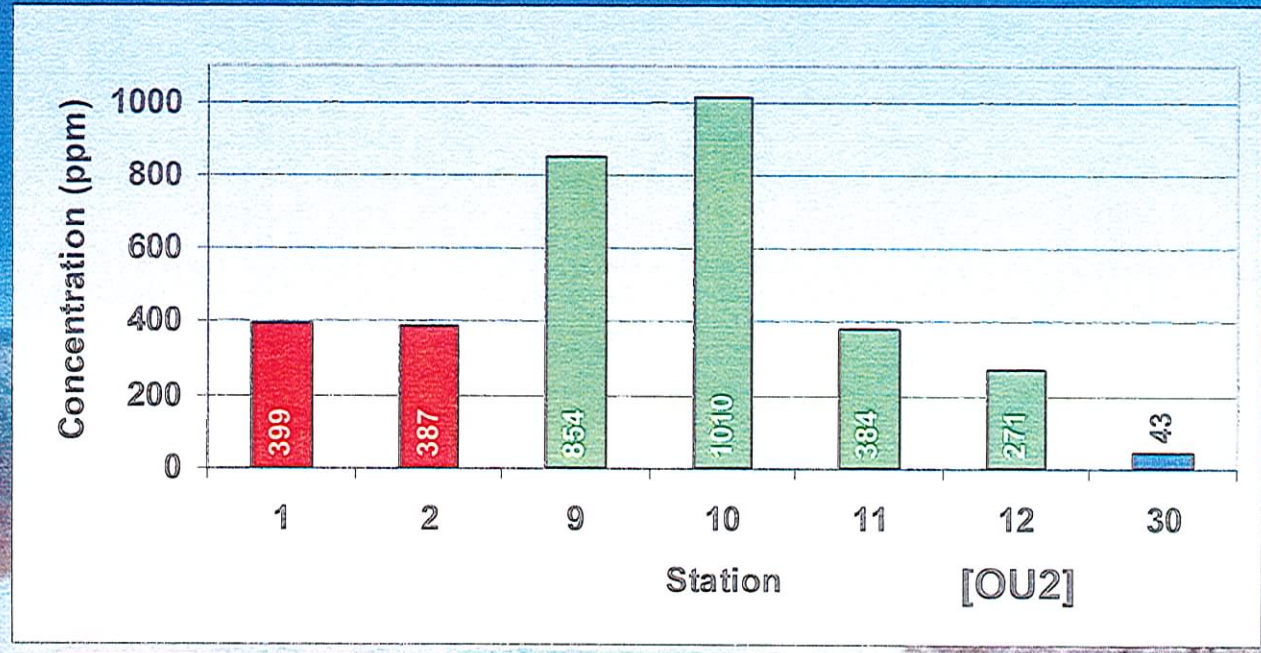
Source: IT Corp, LTMP

Sediment Quality

Zinc 1991-1998



Zinc 2000

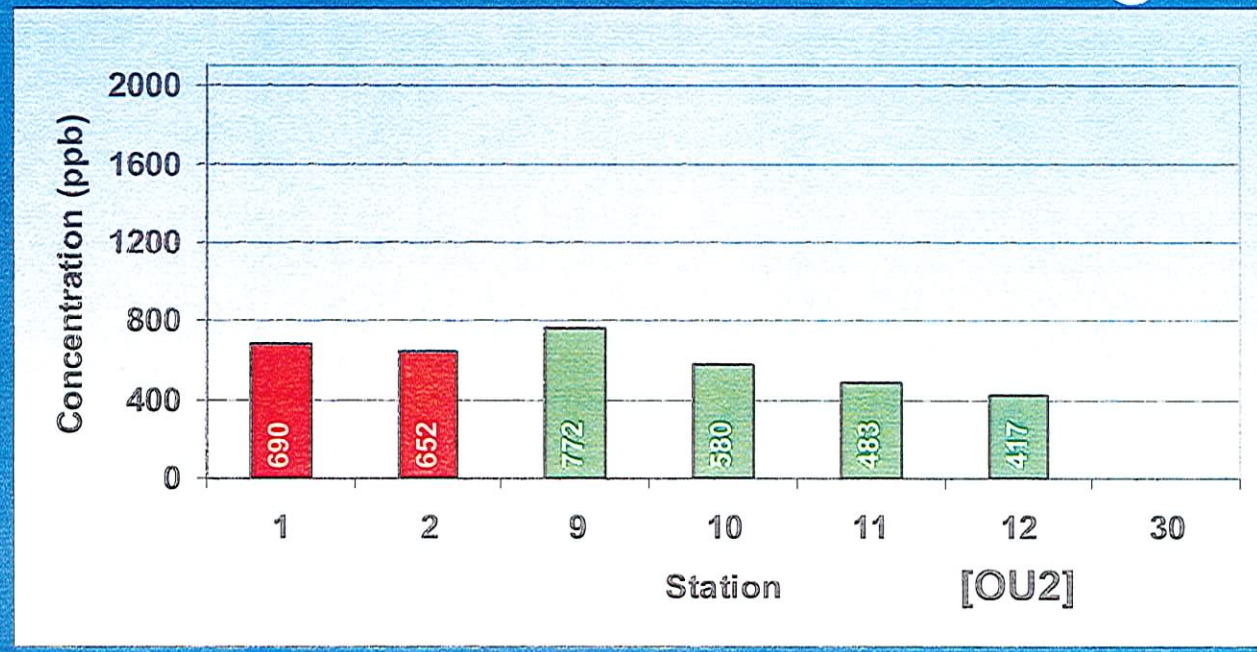


Source: IT Corp, LTMP

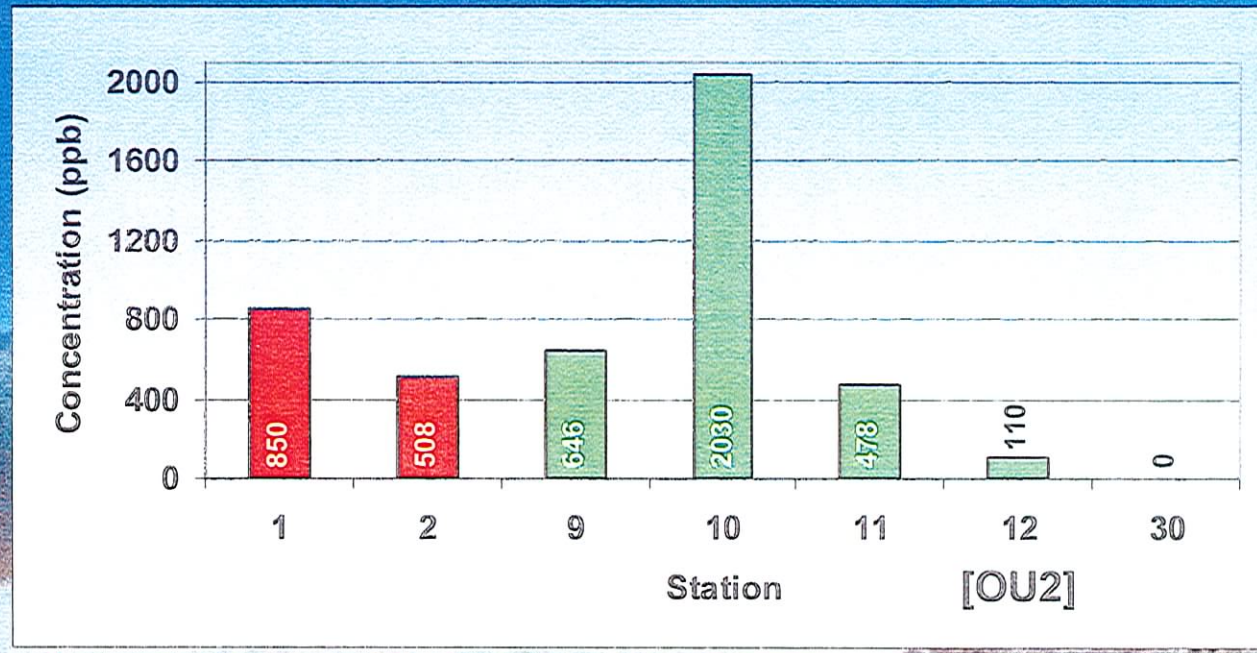
Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Sediment Quality

Total PCBs 1991-1998



Total PCBs 2000

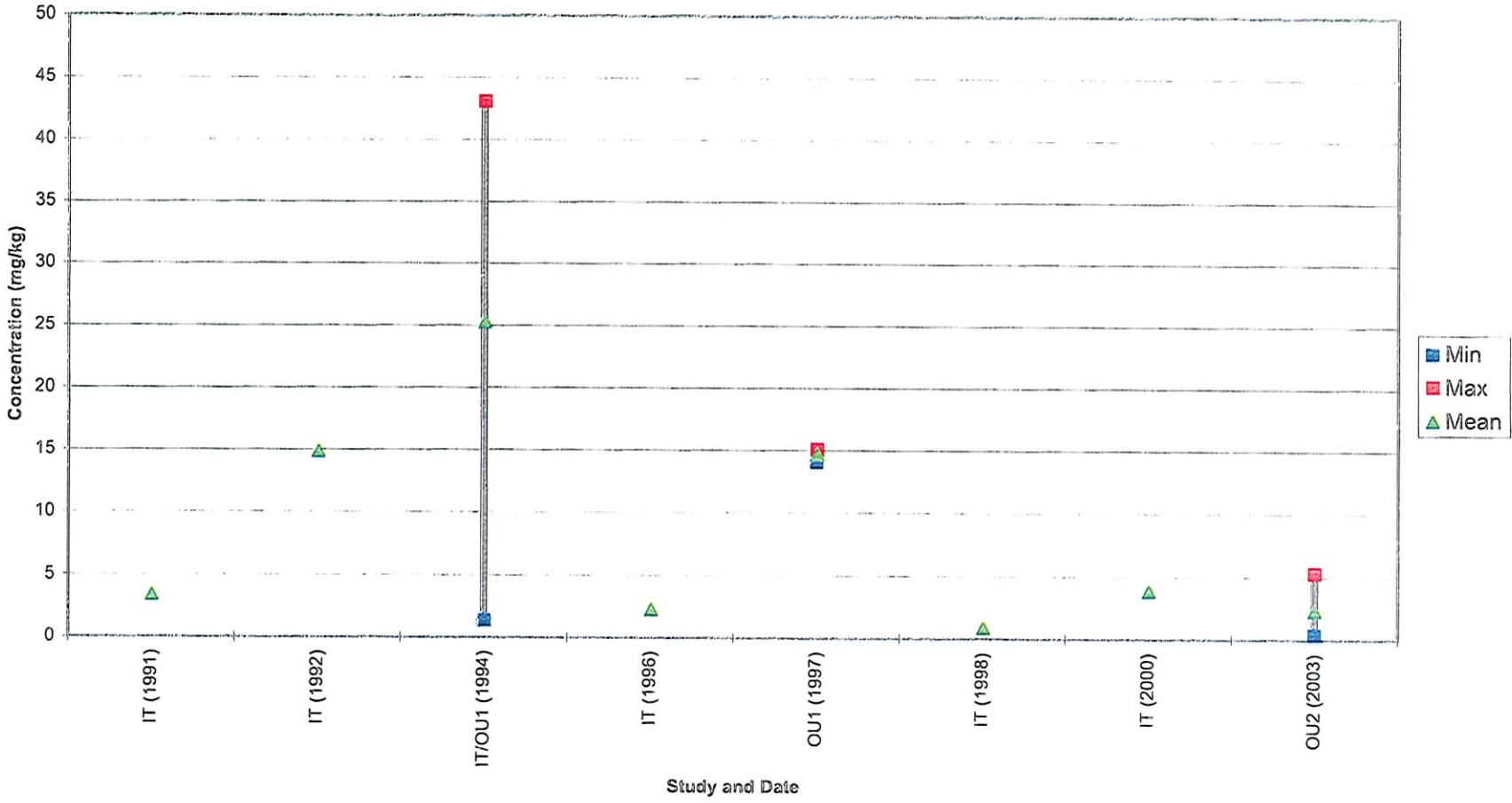


Arthur Kill | Rich. Creek Tidal | Rich. Creek Fresh

Source: IT Corp, LTMP

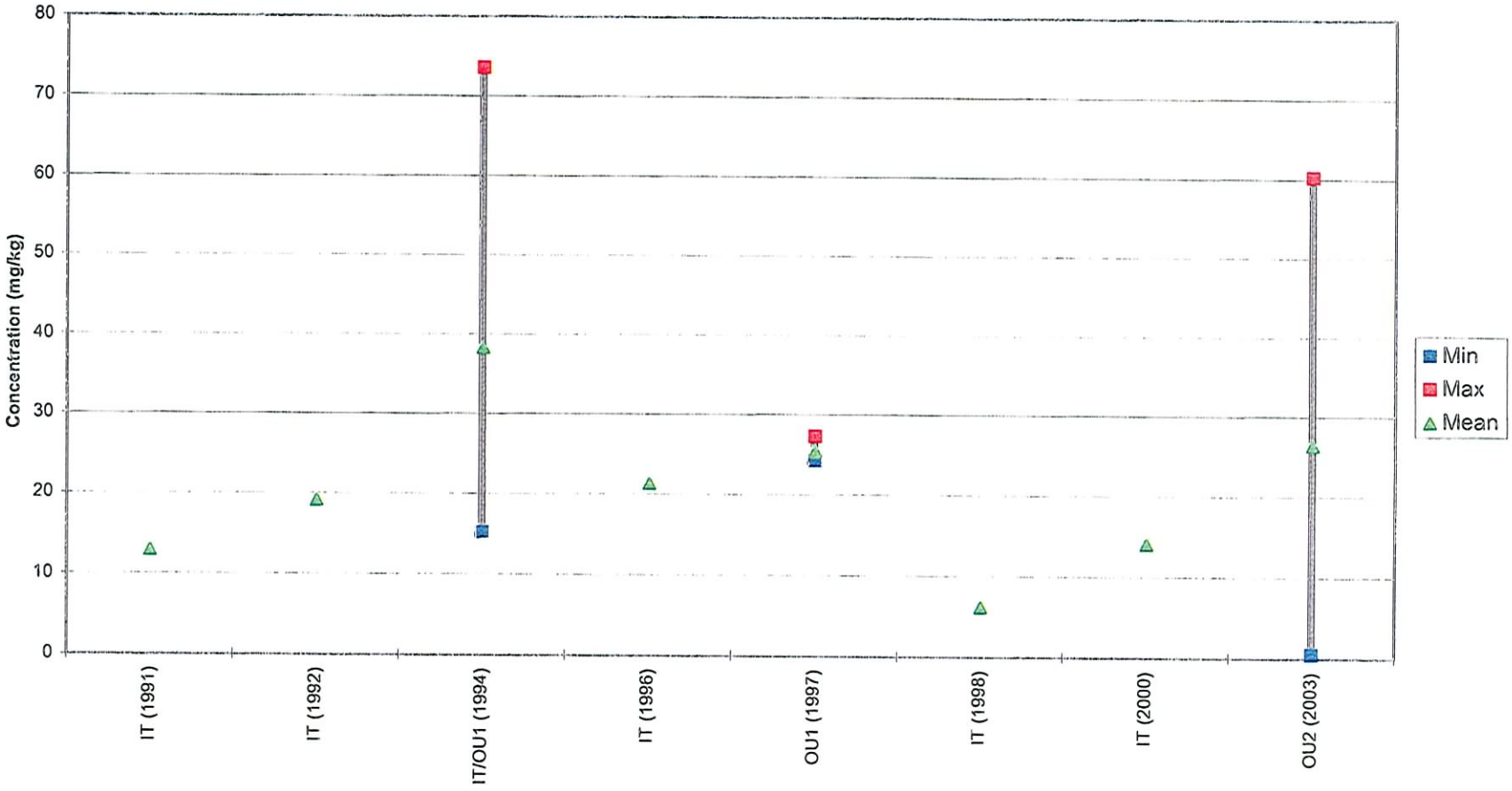
Appendix A.5

Antimony Concentrations in Sediment



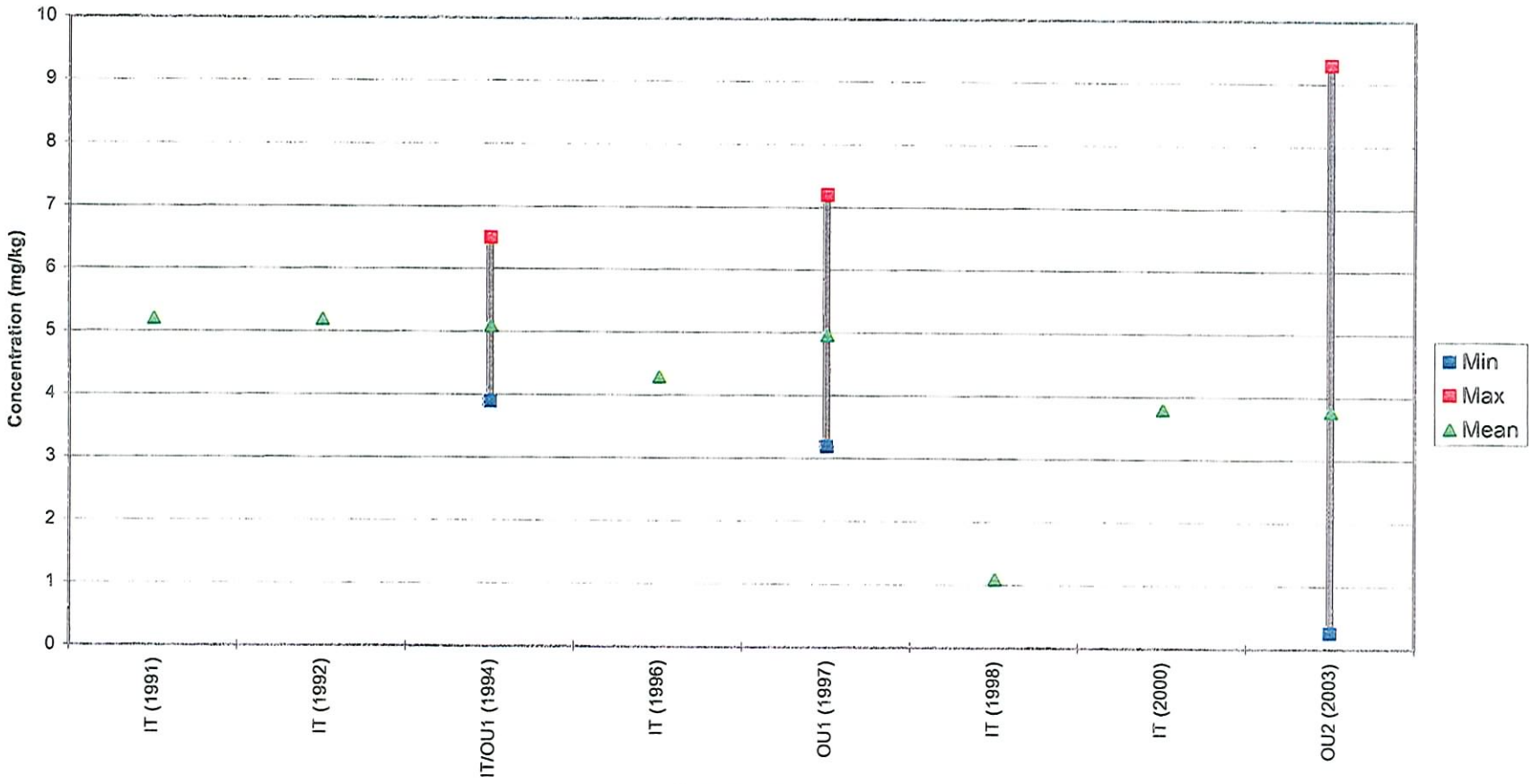
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Arsenic Concentrations in Sediment



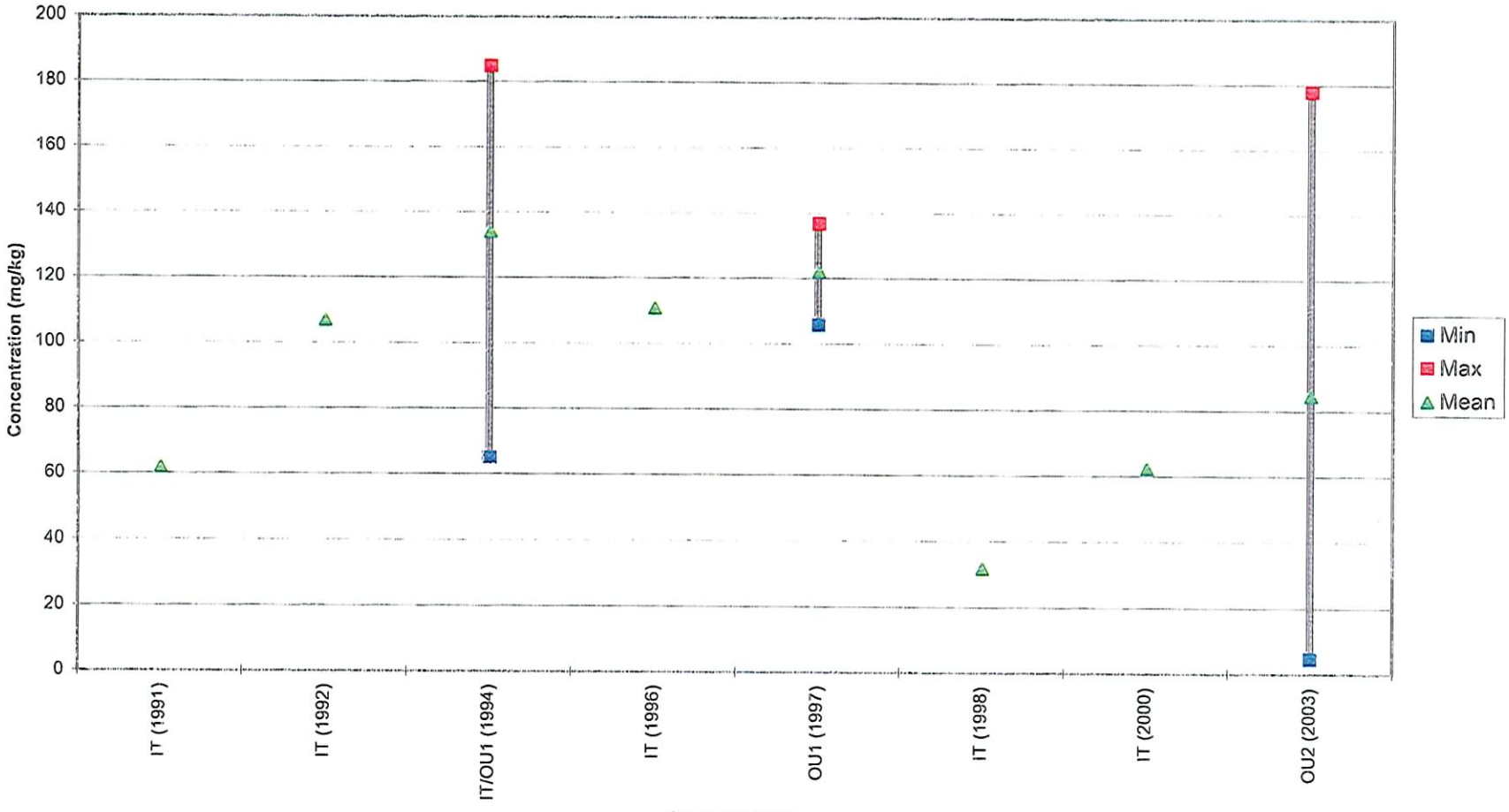
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Cadmium Concentrations in Sediment



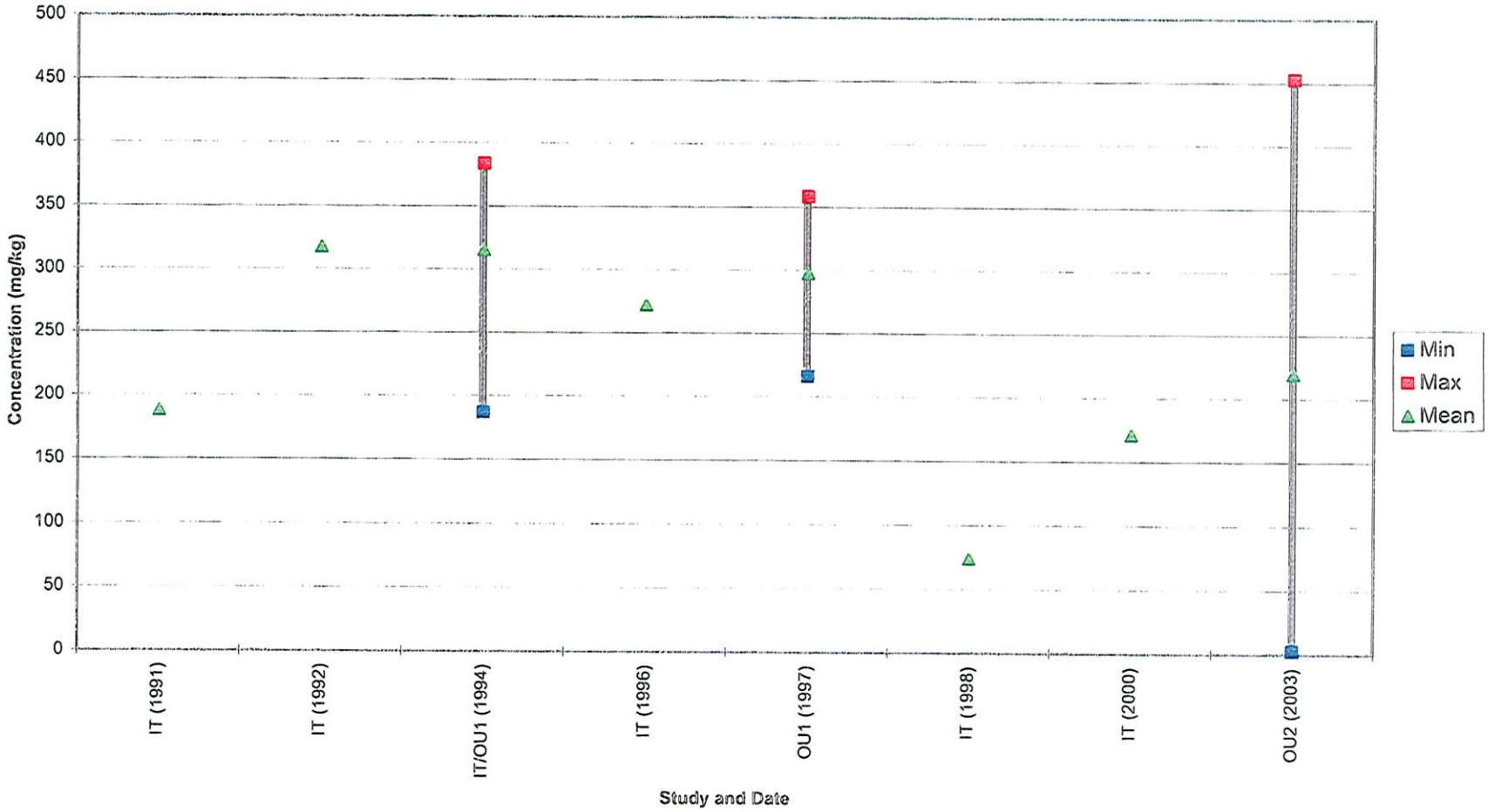
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Chromium Concentrations in Sediment

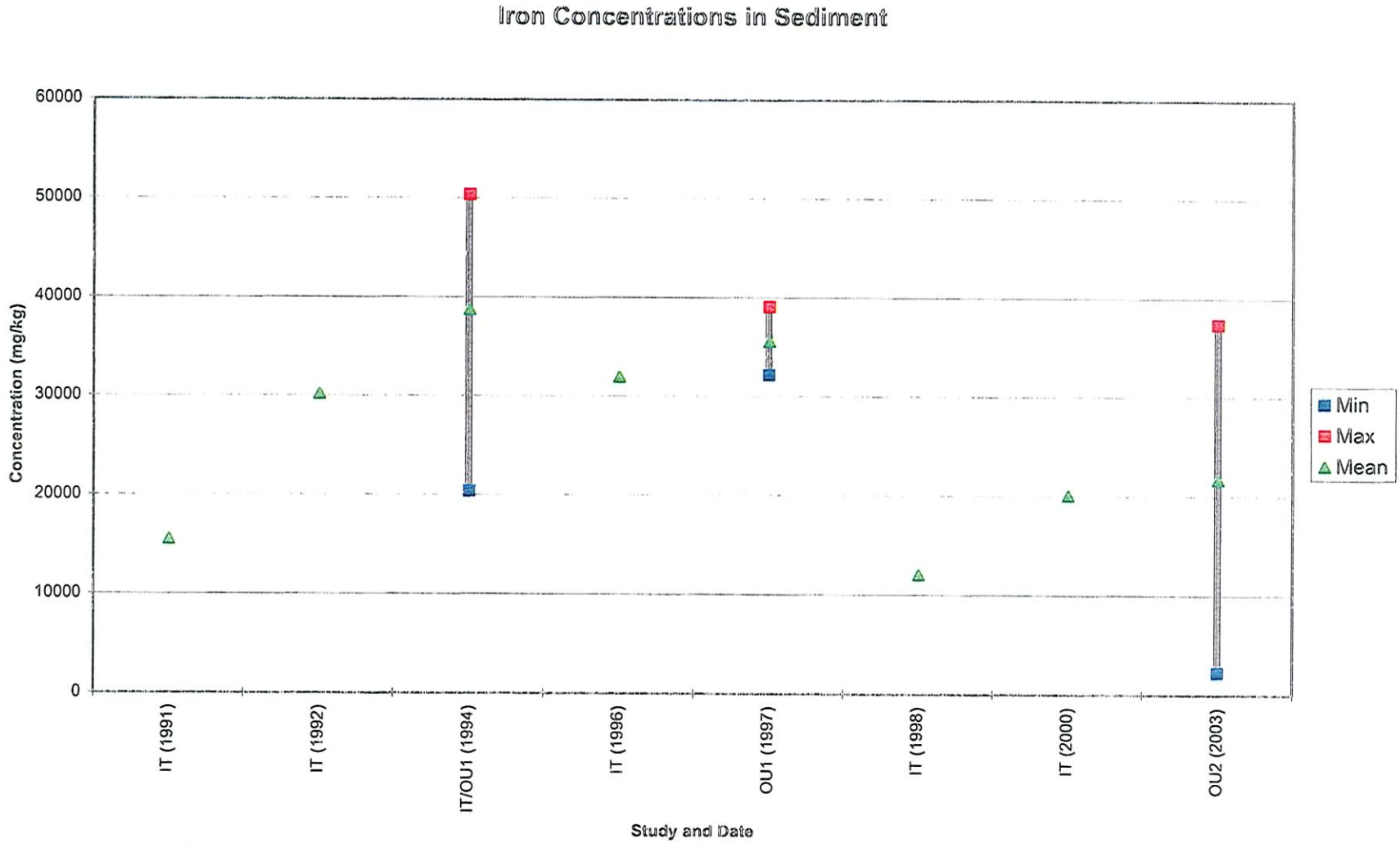


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

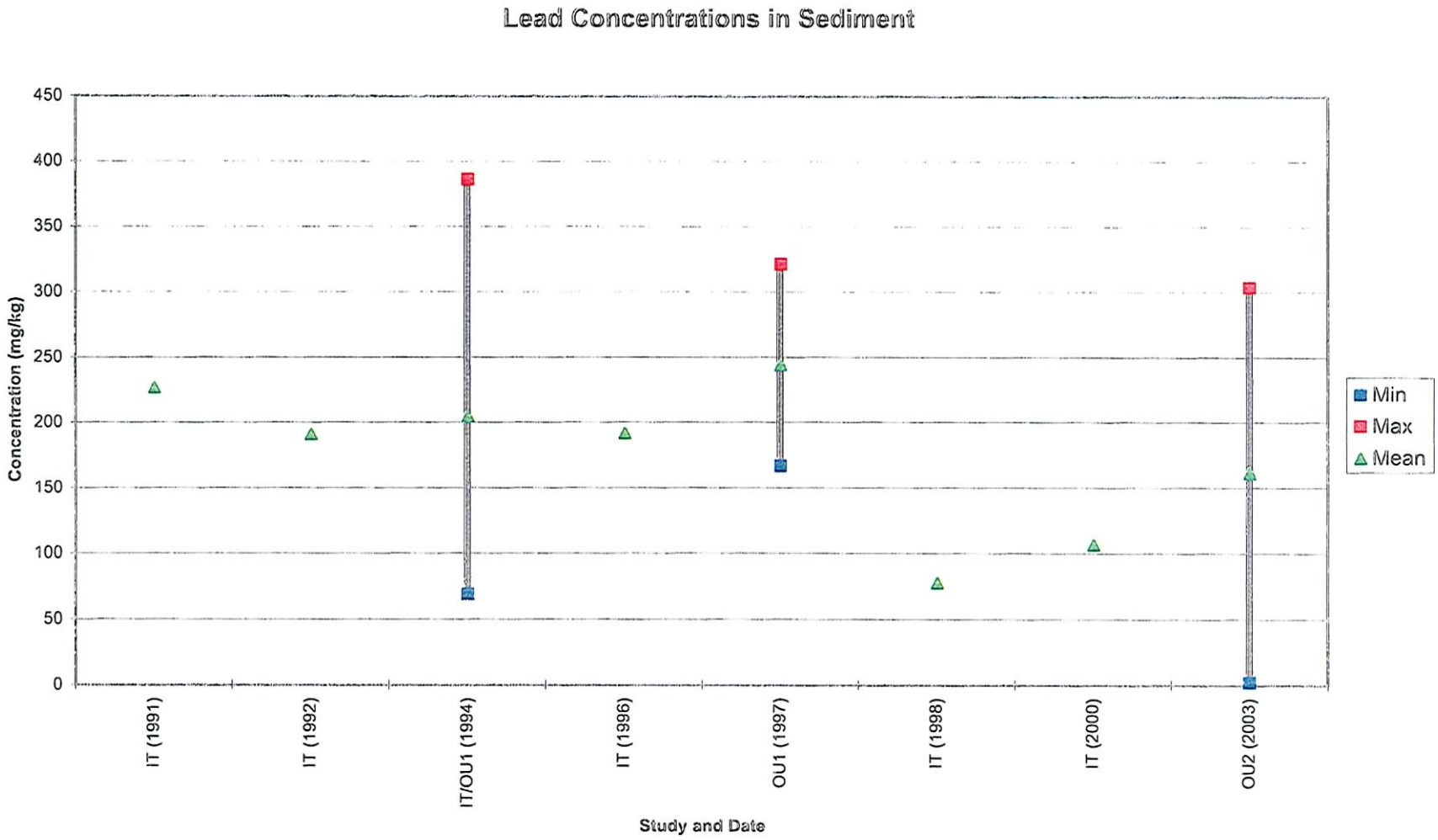
Copper Concentrations in Sediment



IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

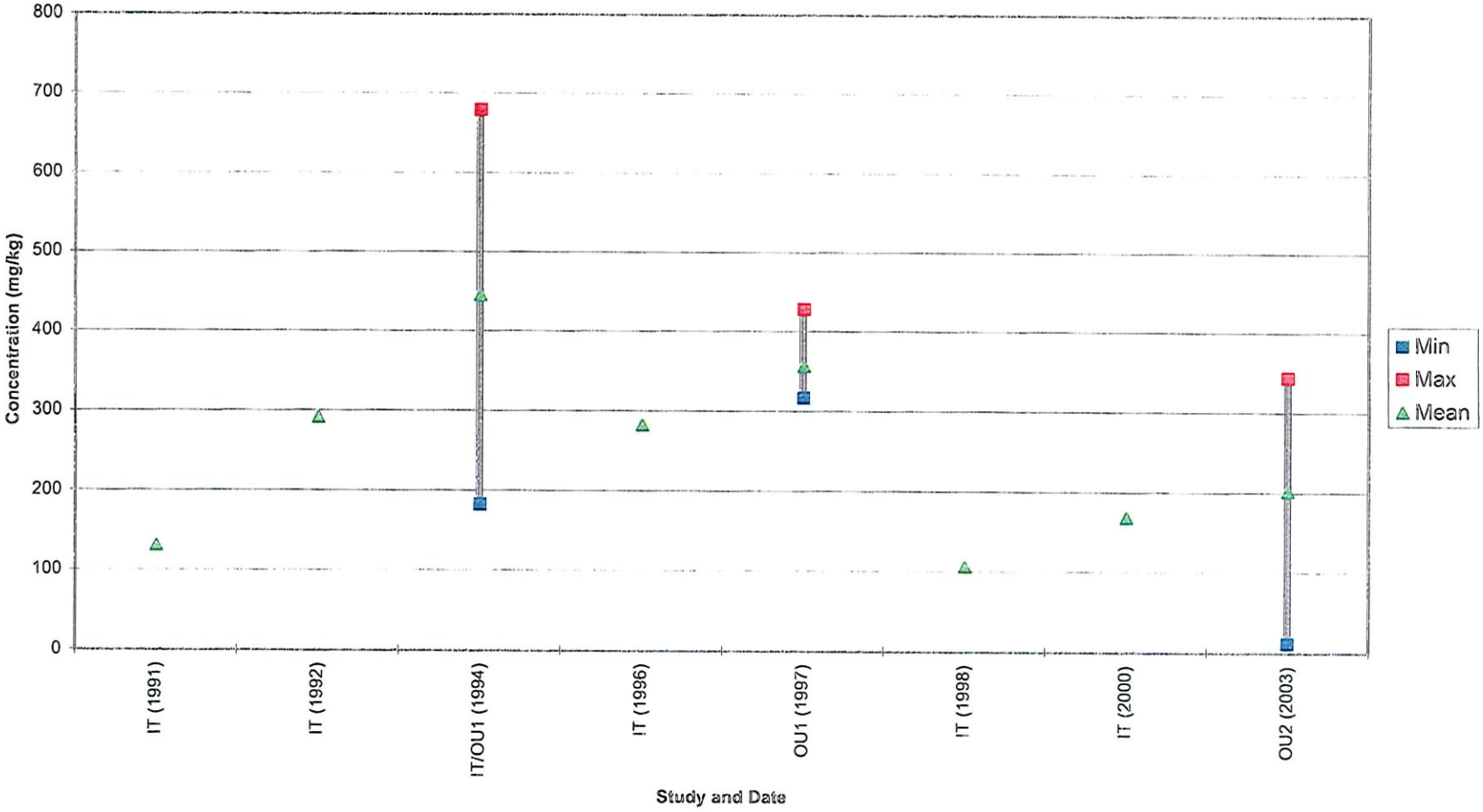


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

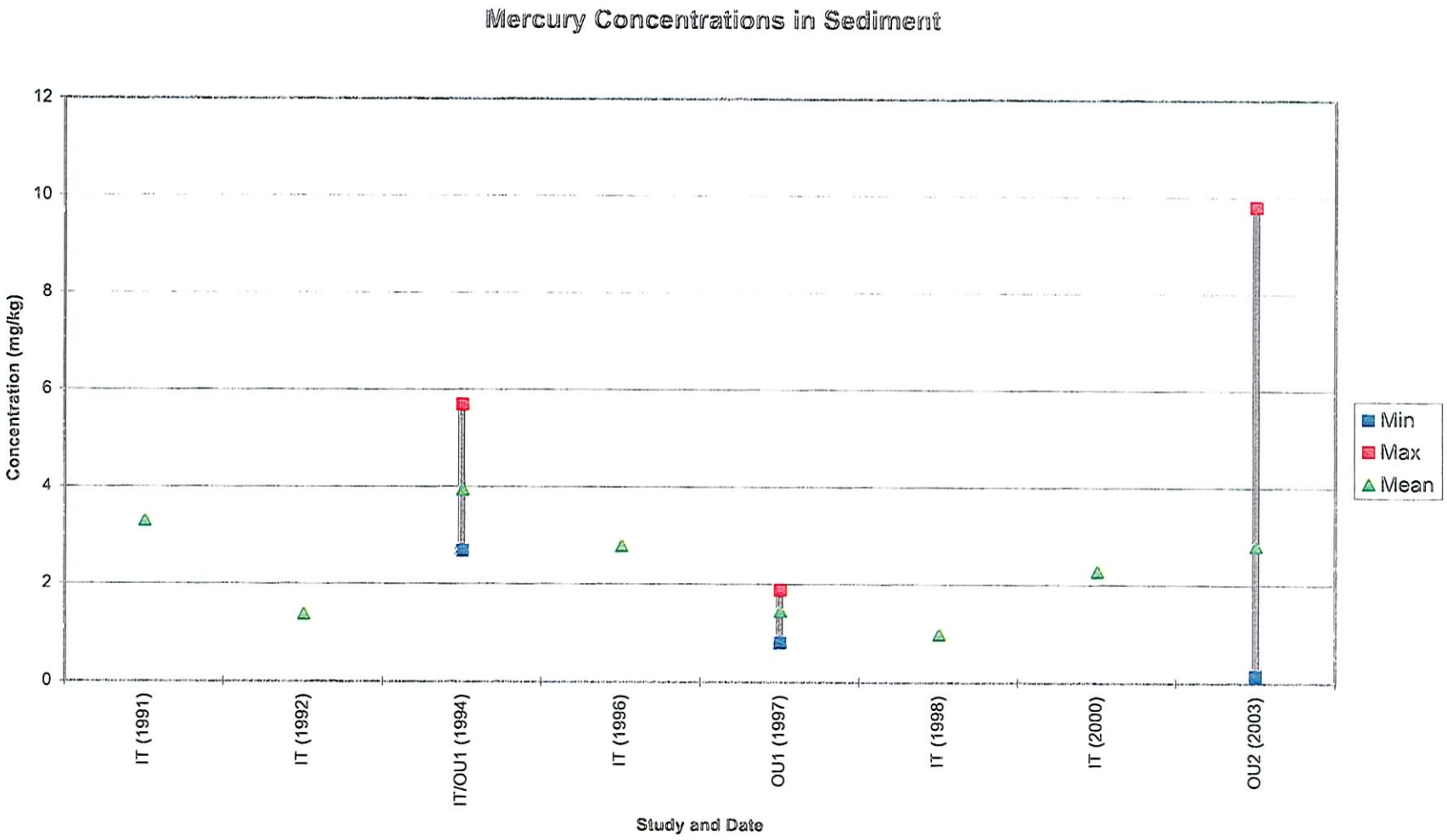


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Manganese Concentrations in Sediment

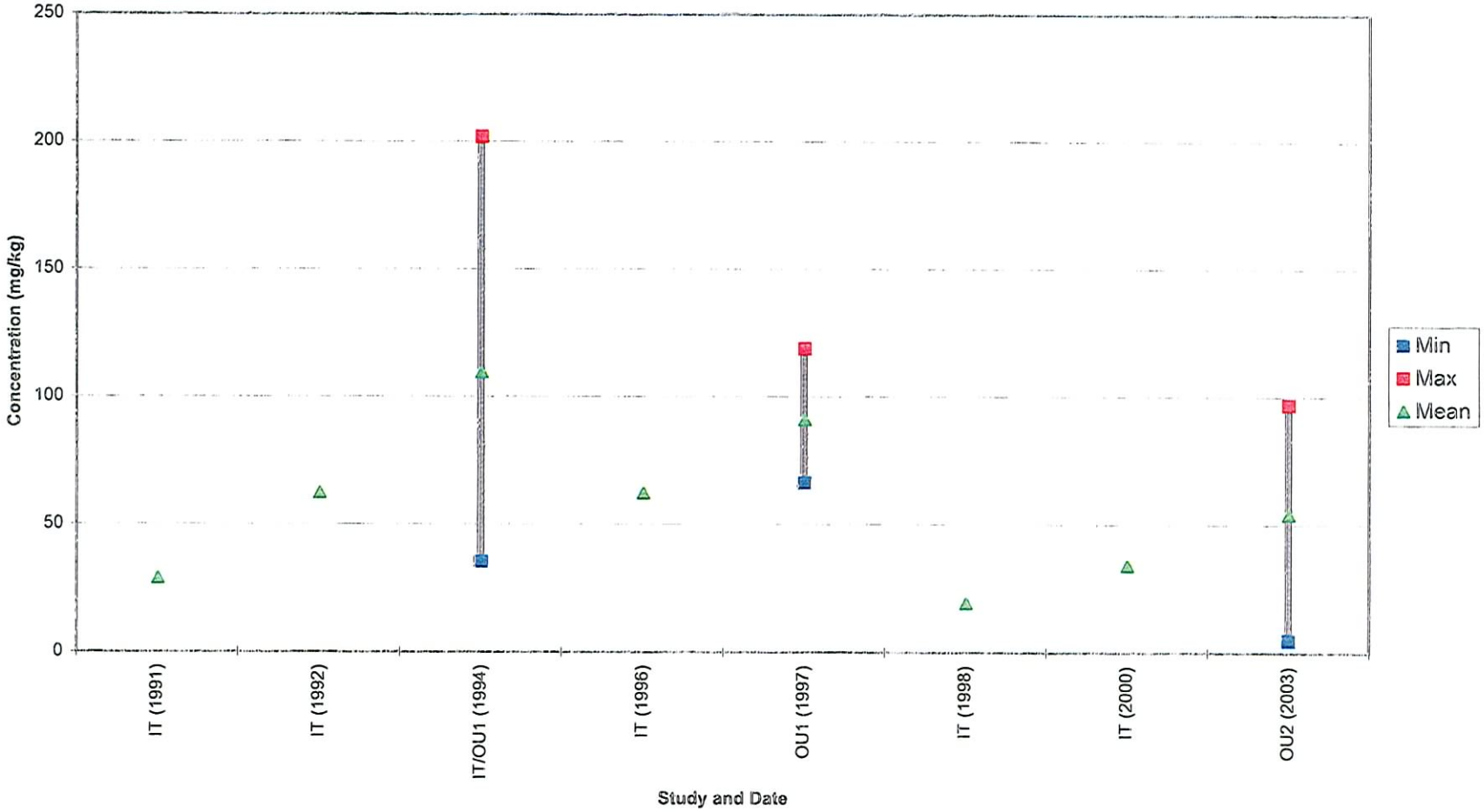


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

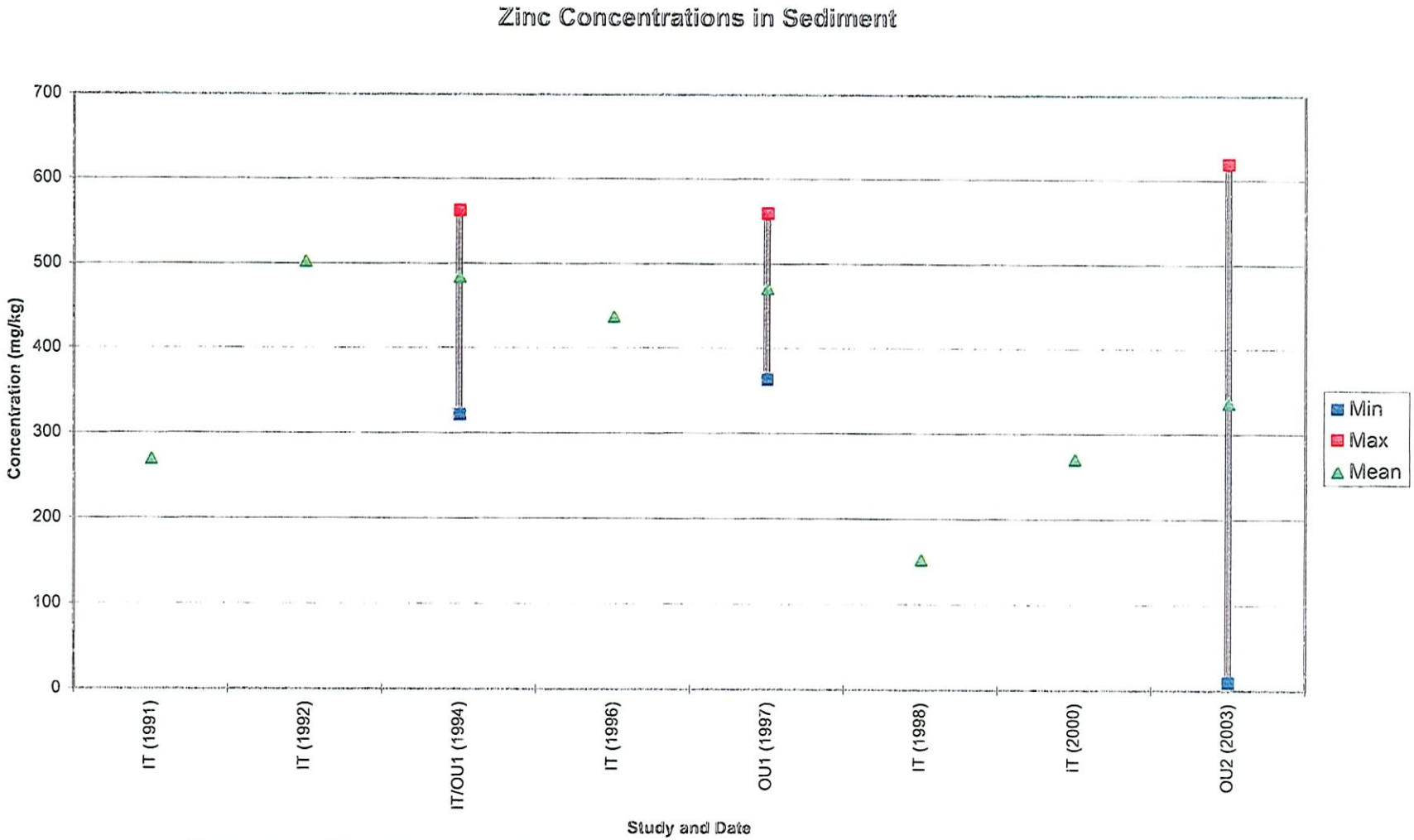


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Nickel Concentrations in Sediment

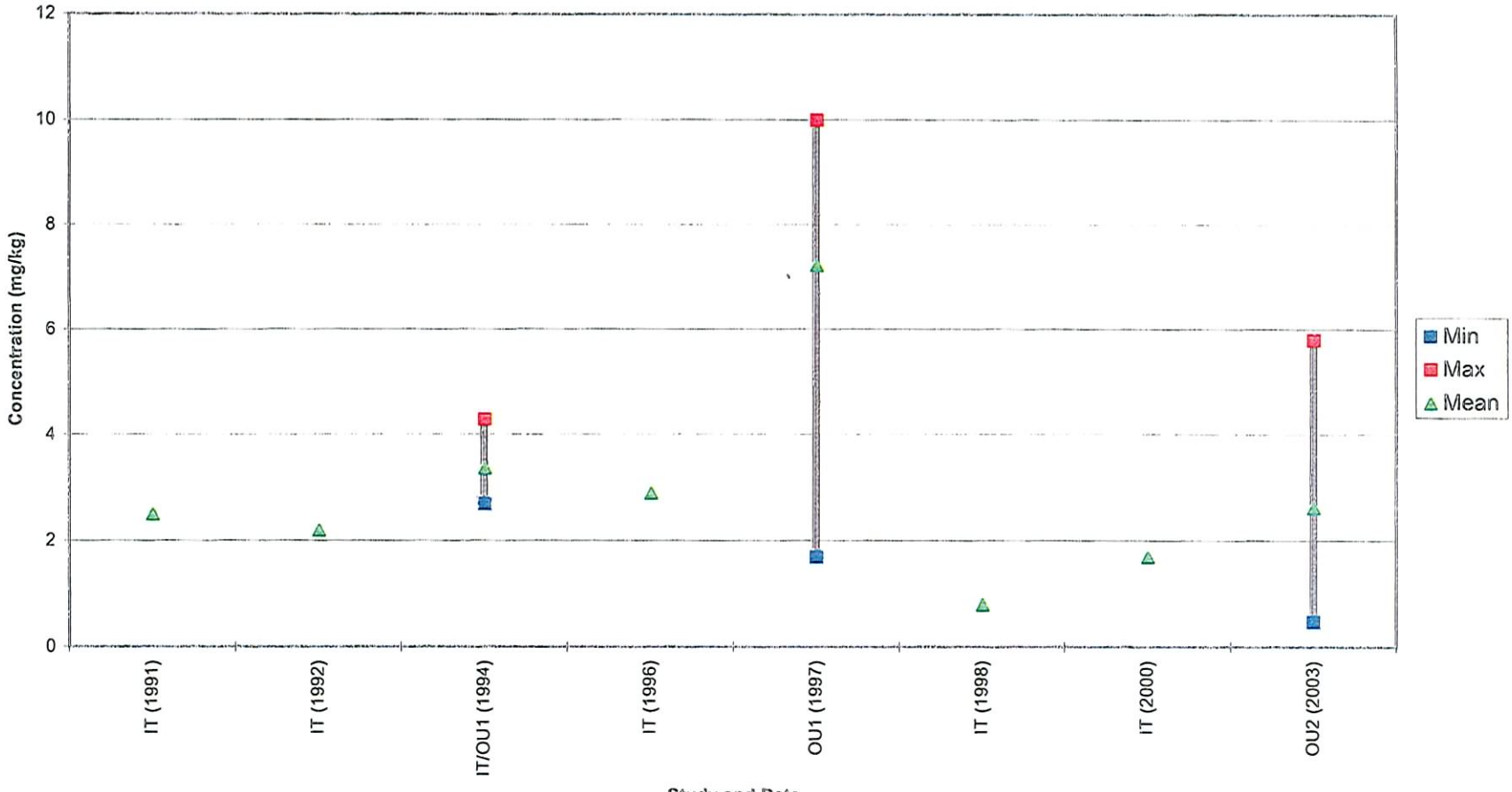


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)



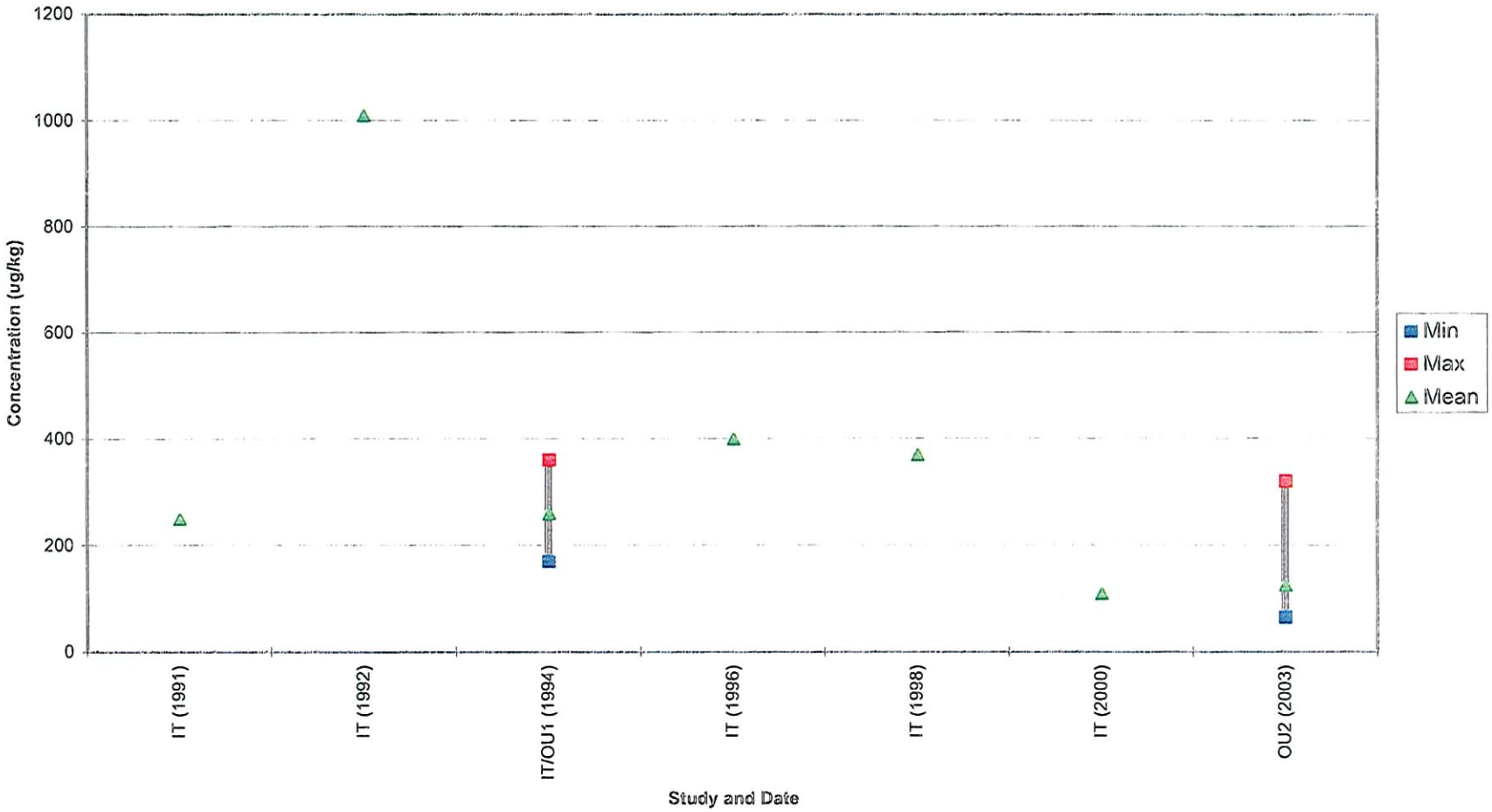
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Silver Concentrations in Sediment



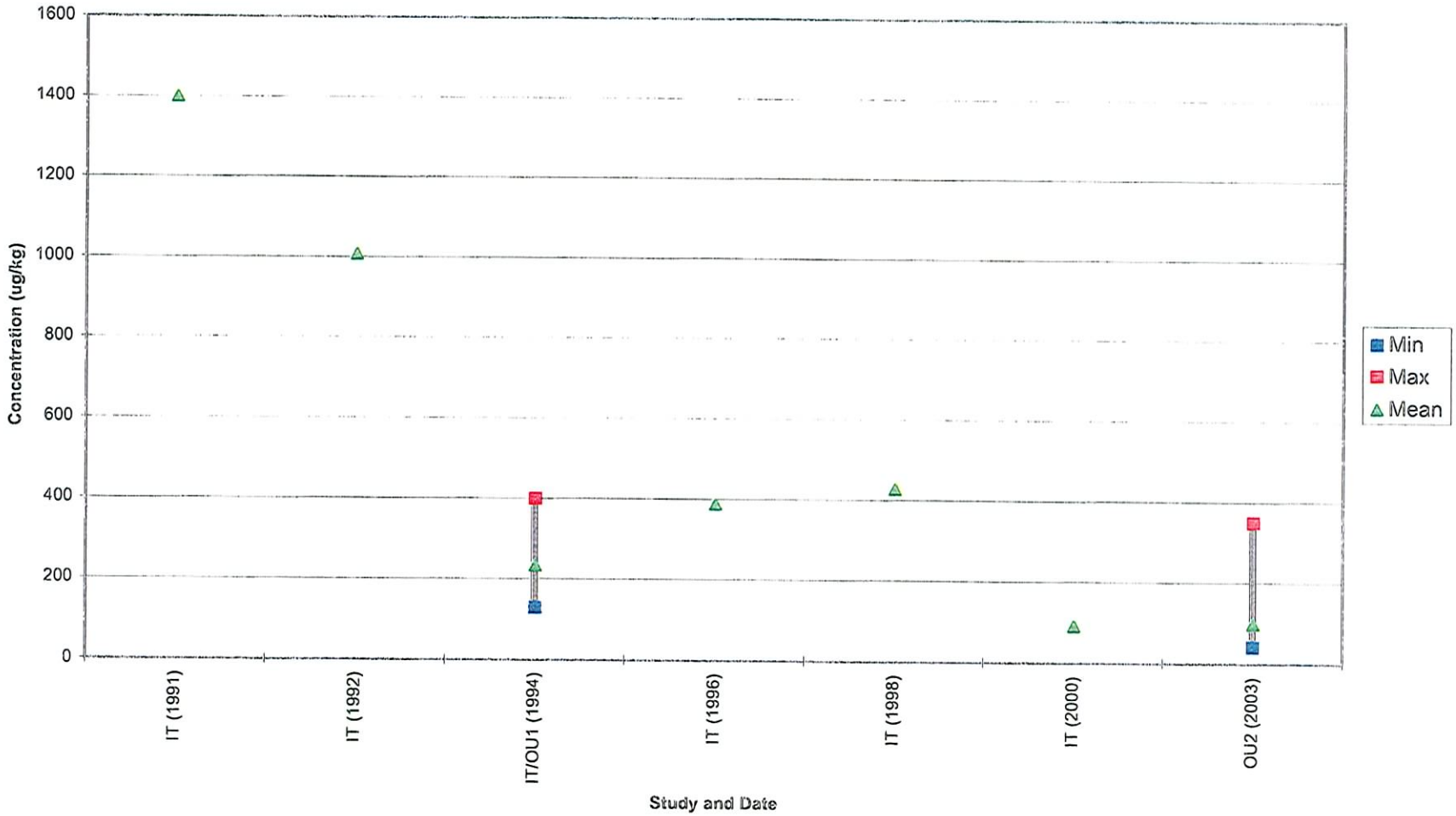
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Benzo(a)pyrene Concentrations in Sediment



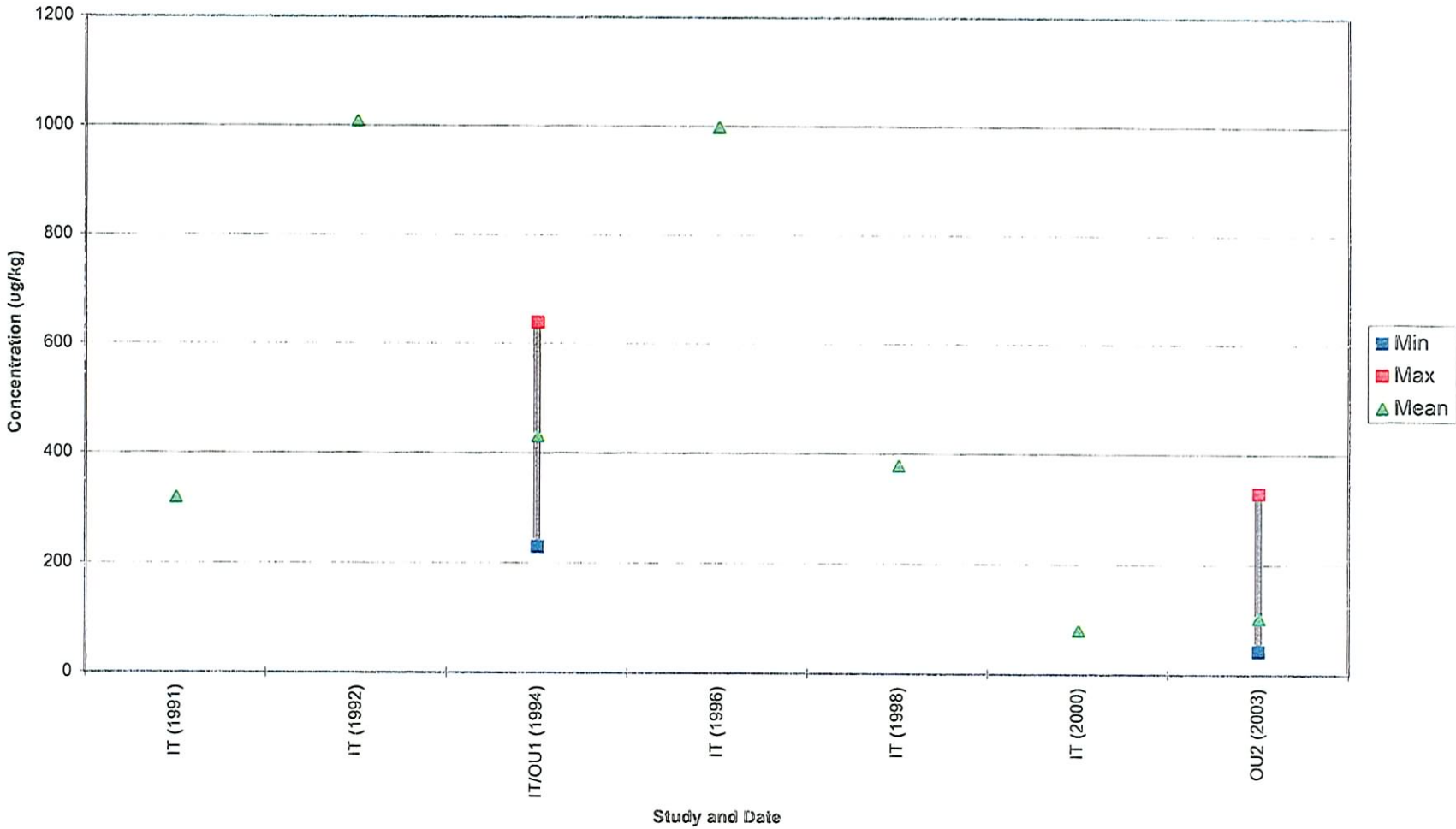
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Benzo(a)anthracene Concentrations in Sediment



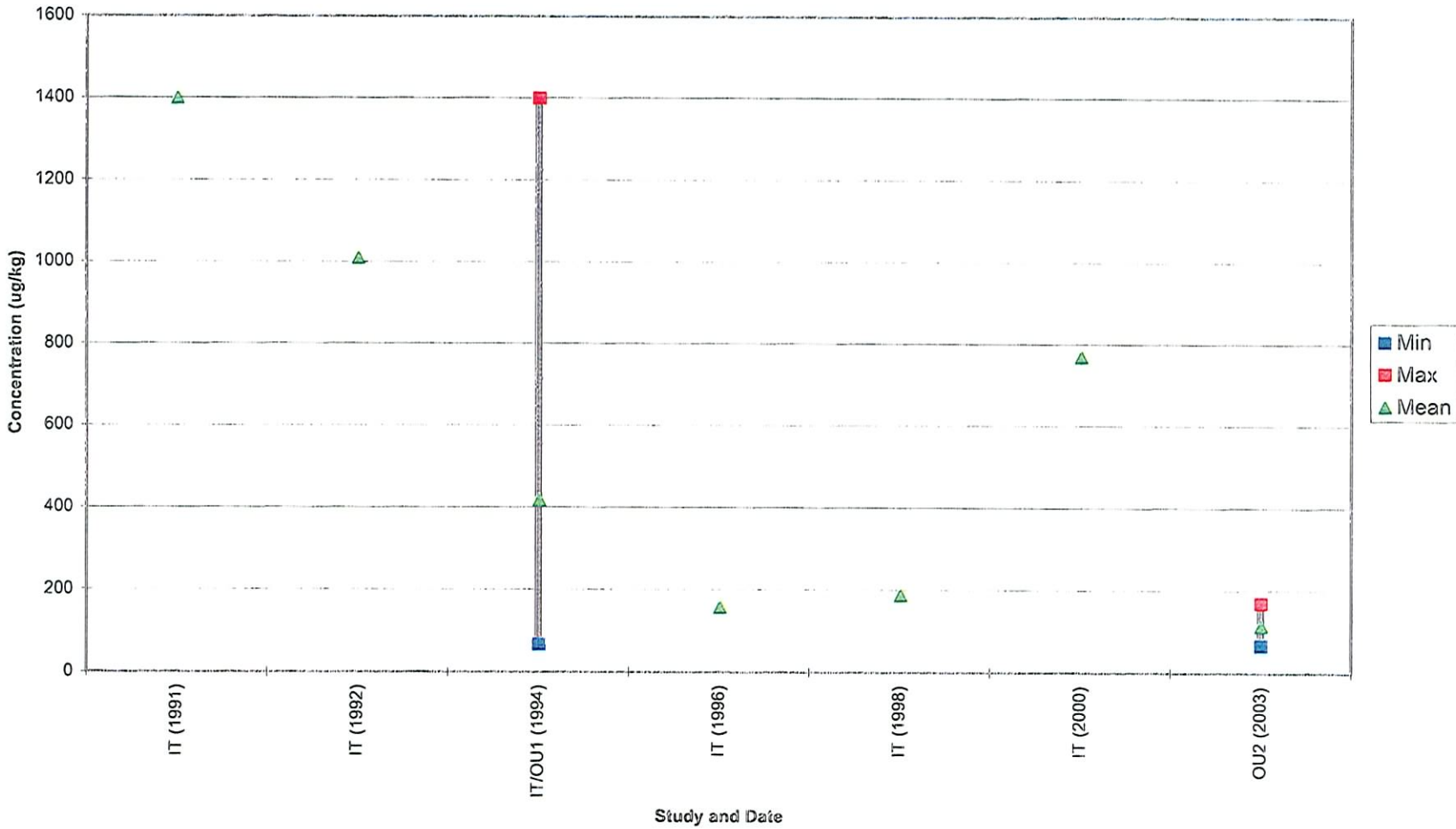
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Benzo(b)fluoranthene Concentrations in Sediment



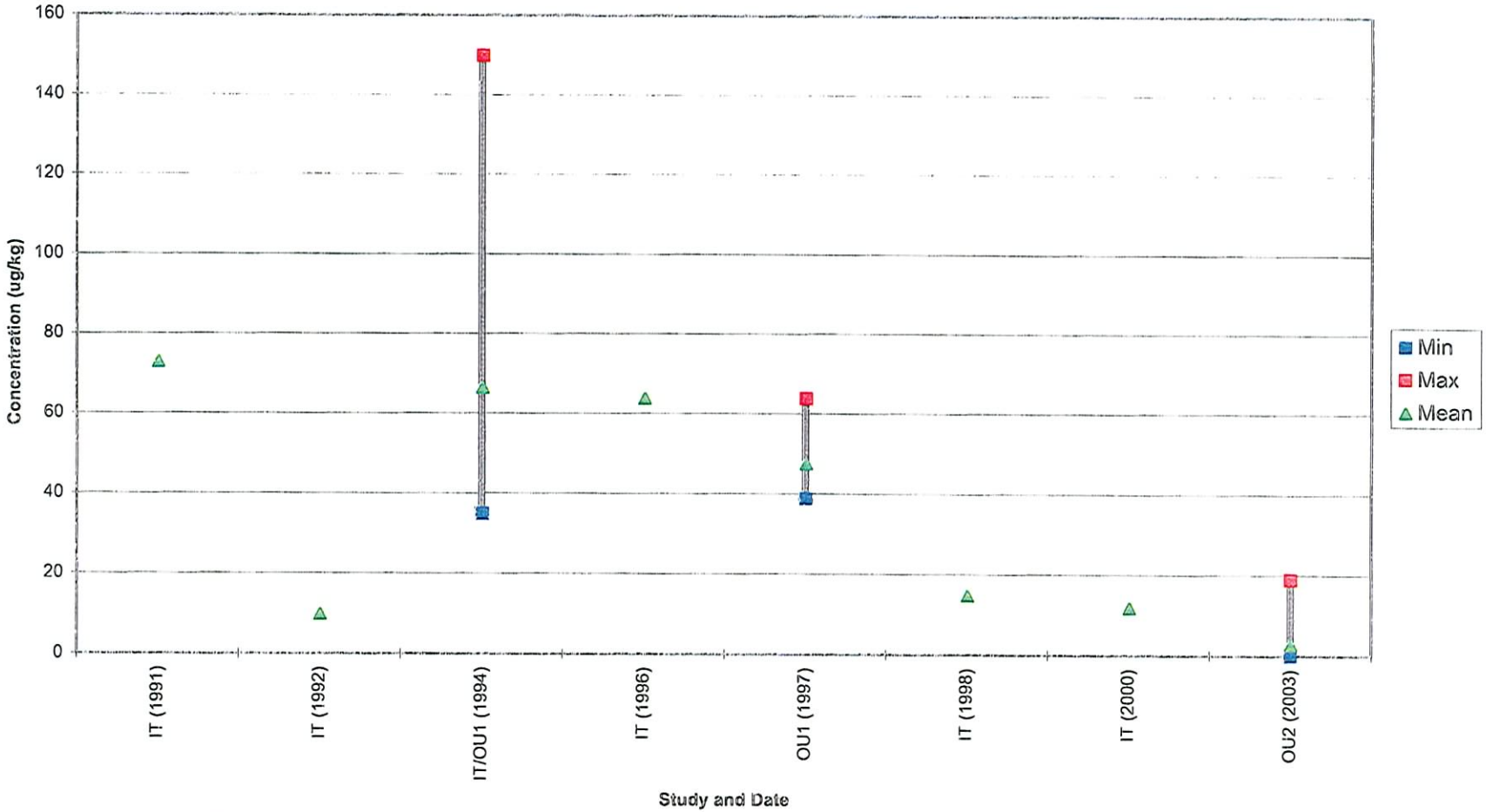
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Indeno(1,2,3-cd)pyrene Concentrations in Sediment



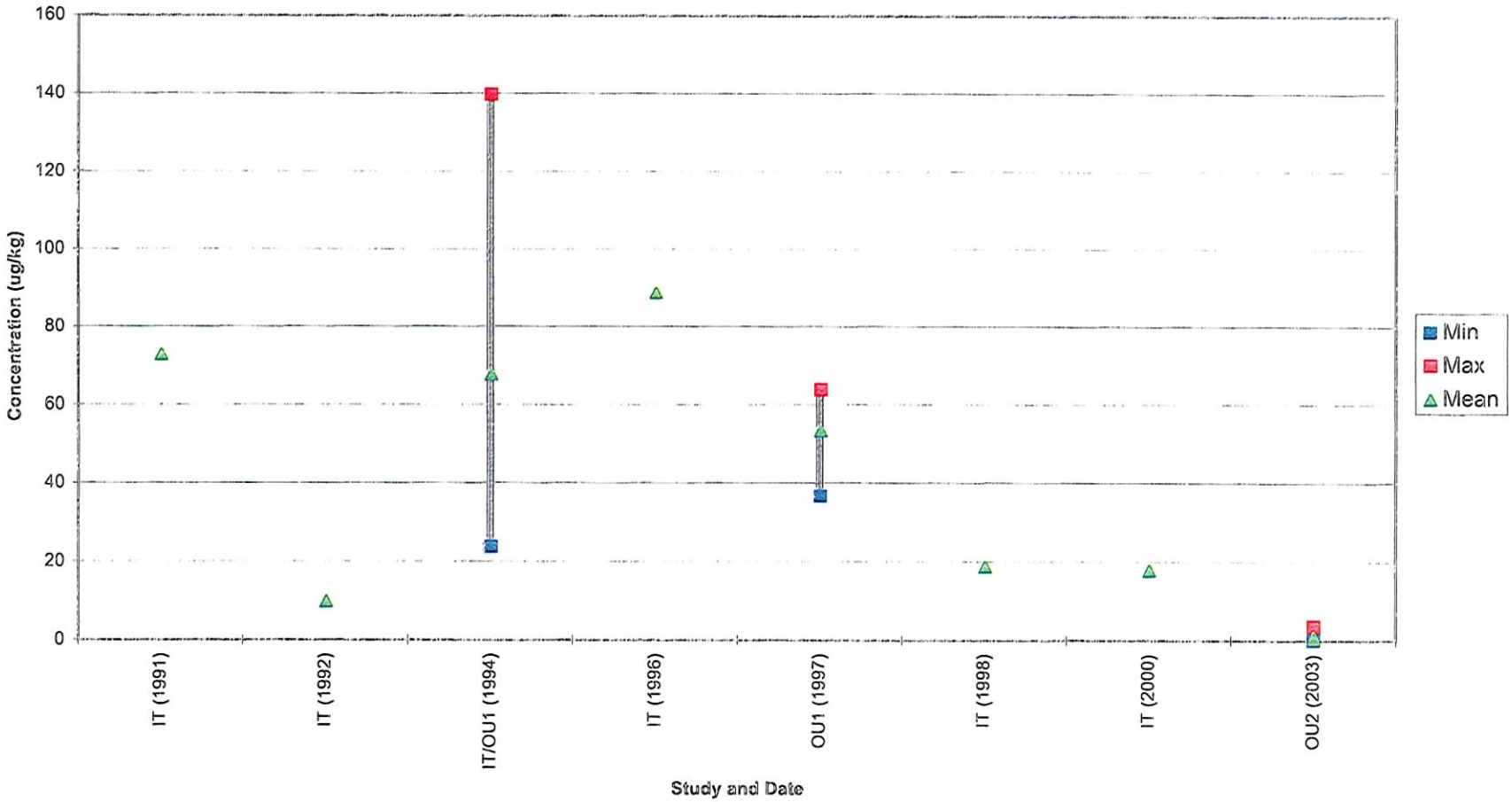
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

4,4'-DDE Concentrations in Sediment

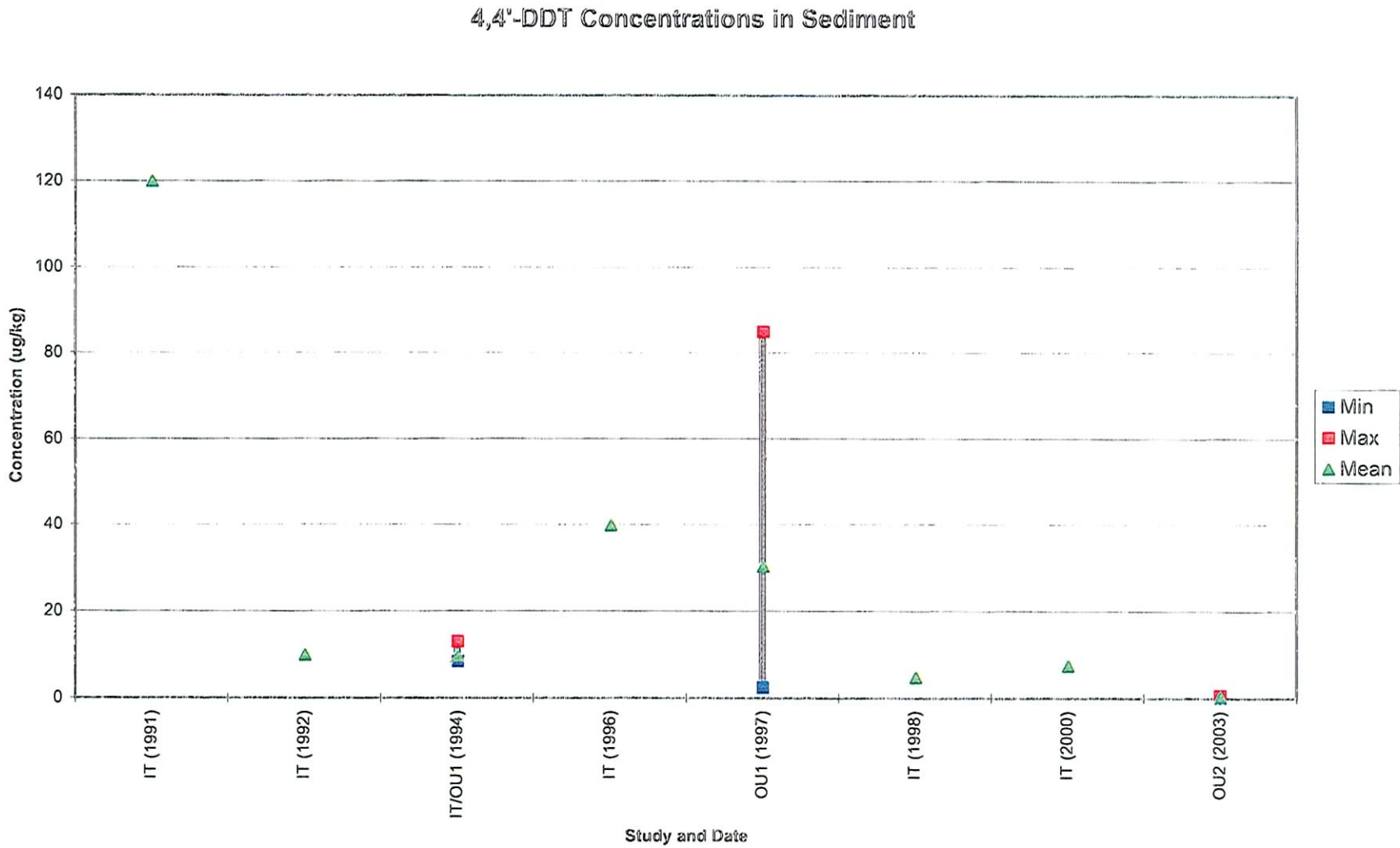


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

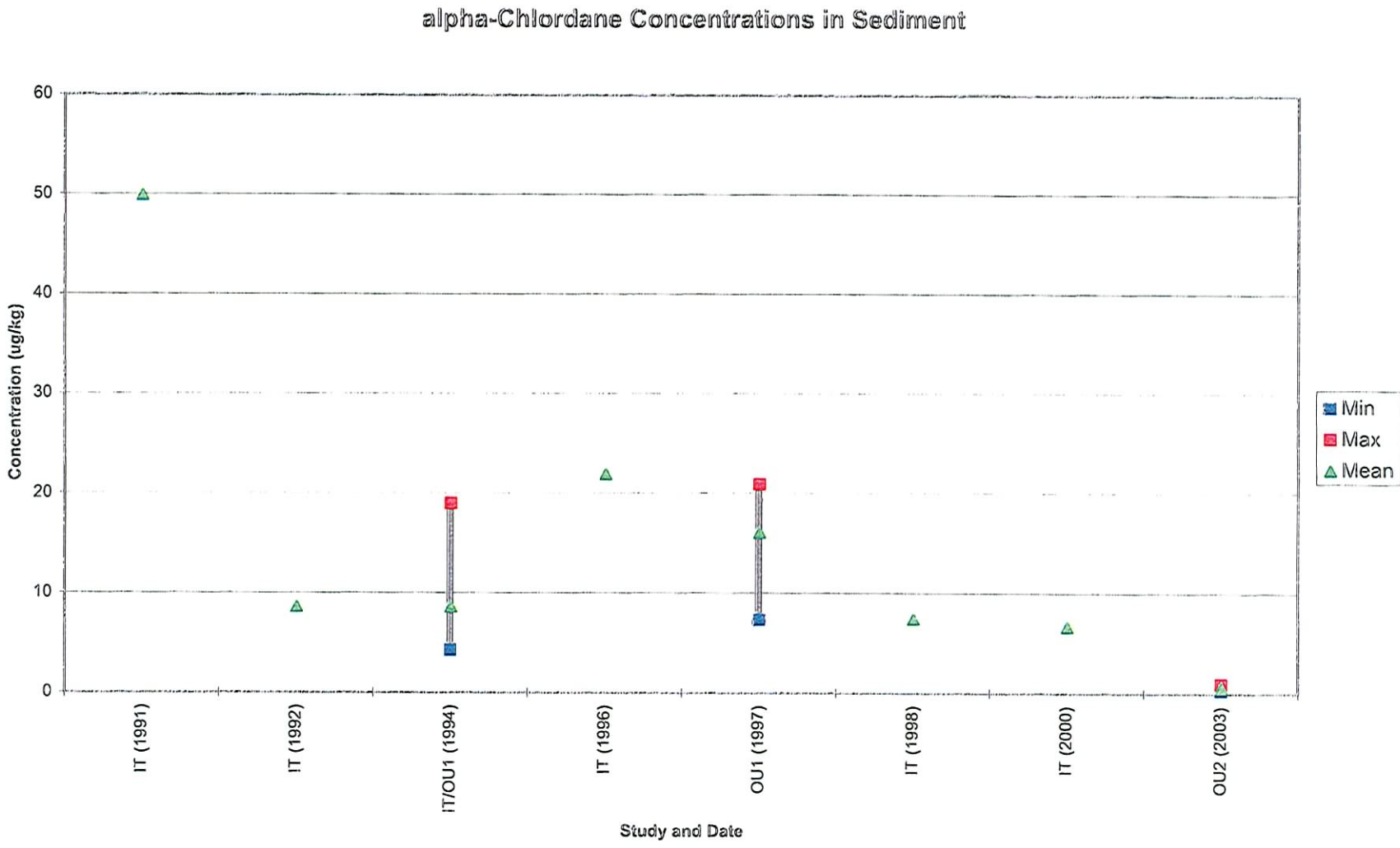
4,4'-DDD Concentrations in Sediment



IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

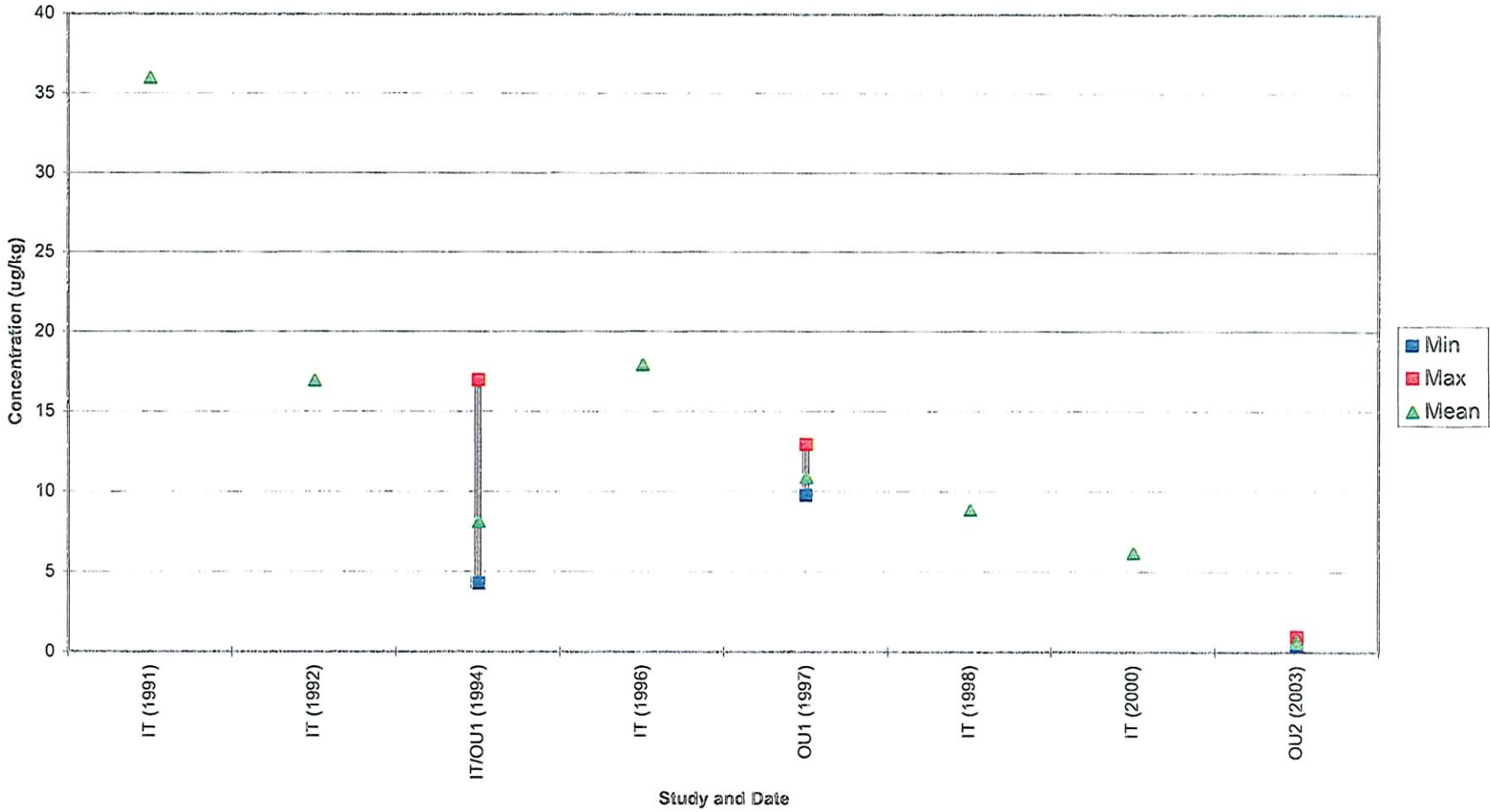


IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)



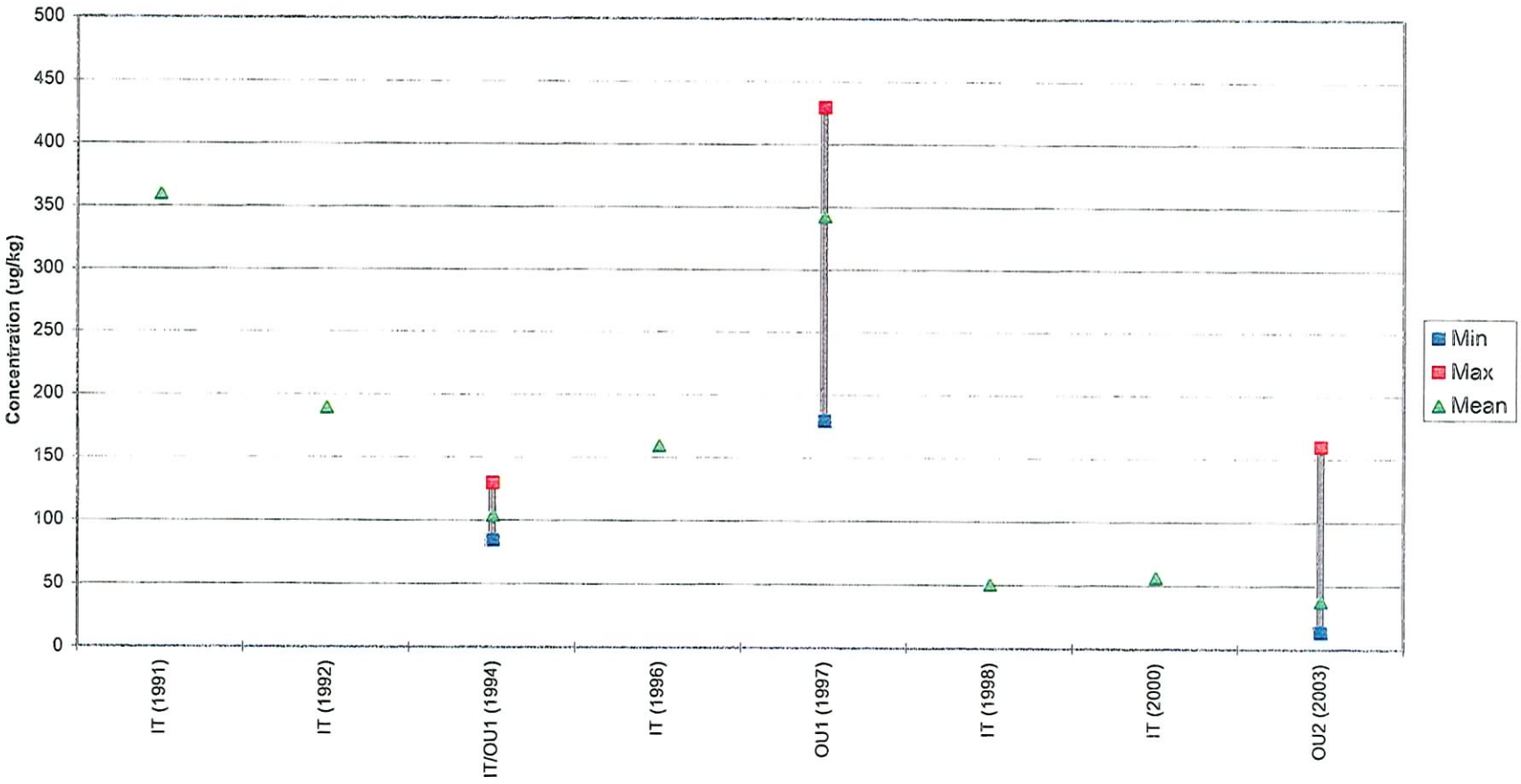
IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

gamma-Chlordane Concentrations in Sediment



IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Aroclor 1254 Concentrations in Sediment



IT sample results from location WC-12 in Richmond Creek (0-5 cm)
OU1 sample results from locations SD-1, 2, and 3 in Richmond Creek (0-6 inches)
OU2 sample results from locations SD-1 through SD-12 in Richmond Creek (0-6 inches)

Appendix B

Location SD-4		10/8/2003
Parameter	Conc.	Exceedance
Pesticides		
Total PCBs	160	E
Metals		
Antimony	4.4 J	E
Arsenic	60.0	E
Cadmium	5.4	E
Chromium	133.0	E
Copper	389.0	E
Iron	25,200	E
Lead	239.0	E,F
Mercury	9.8	E,F
Nickel	60.8	E,F
Silver	3.2	E
Zinc	484.0	E,F

Location SD-7		10/9/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	2.6 J	E
Arsenic	29.7 J	E
Cadmium	5.0 J	E
Chromium	122.0 J	E
Copper	343.0 J	E,F
Iron	33,500 J	E
Lead	236.0 J	E,F
Mercury	2.1 J	E,F
Nickel	63.6 J	E,F
Silver	4.5 J	E,F
Zinc	508.0 J	E,F

Location SD-11			10/10/2003		
Parameter	Conc.	Exceedance	Parameter	Conc.	Exceedance
Pesticides			*Metals*		
4,4-DDD	0.51 J	A	Arsenic	23.1 J	E
4,4-DDE	13.0 J	E	Cadmium	3.6 J	E
alpha-BHC	3.1 J	C	Chromium	91.4 J	E
Total PCBs	125 J	E	Copper	257.0 J	E
Camphechlor	8.2 J	A,B,C	Iron	26,800 J	E
Endosulfan I	1.3 J	C	Lead	189.0 J*	E
Endosulfan II	0.77 J	C	Mercury	1.8 J*	E,F
gamma-Chlordane	0.77 J	A,C,D	Nickel	81.2 J	E,F
Heptachlor	2.6 J	A,C	Silver	3.1 J	E
Heptachlor epoxide	0.77 J	A	Zinc	401.0 J	E

Location BACKGROUND		10/15/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	2.9 J	E
Lead	271.0 J	E,F
Nickel	174.0 J	E,F

Location SD-1		10/8/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	2.1 J	E
Arsenic	11	E
Cadmium	3.2	E
Chromium	83.3	E
Copper	148.0	E
Lead	109.0	E
Mercury	2.3	E,F
Nickel	36.6	E
Silver	2.1	E
Zinc	277.0	E

Location SD-12		10/10/2003
Parameter	Conc.	Exceedance
Semi-Volatiles		
Fluoranthene	850 J	E
Phenanthrene	520 J	E
Pyrene	920 J	E
Metals		
Antimony	2.6 J	E
Arsenic	15.1 J	E
Copper	94.5 J	E
Iron	20,500 J	E
Lead	105.0 J	E
Mercury	0.4 J	E
Nickel	88.4 J	E,F
Silver	1.1 J	E
Zinc	199.0 J	E

Location SD-2		10/8/2003
Parameter	Conc.	Exceedance
Pesticides		
4,4-DDD	3.7 J	A
Metals		
Lead	127.0	E
Mercury	0.16	E

Location SD-9		10/10/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	31.1 J	E
Cadmium	4.5 J	E
Chromium	87.1 J	E
Copper	258.0 J	E
Iron	29,000 J	E
Lead	180.0 J	E
Mercury	1.7 J	E,F
Nickel	97.1 J	E,F
Silver	2.6 J	E
Zinc	429.0 J	E,F

Location SD-10		10/10/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	0.43 J	A
alpha-BHC	2.6 J	C
Total PCBs	74.9 J	E
Camphechlor	7.0 J	A,B,C
Endosulfan I	1.1 J	C
Endosulfan II	0.65 J	C
gamma-Chlordane	0.65 J	A,C,D
Heptachlor	2.2 J	A,C
Heptachlor epoxide	0.65 J	A
Metals		
Mercury	0.52 J*	E

Location SD-6		10/9/2003
Parameter	Conc.	Exceedance
Metals		
Copper	41.7 J	E
Mercury	0.4	E

Location SD-3		10/8/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	4.5 J	E
Arsenic	50.0	E
Cadmium	5.3	E
Chromium	108.0	E
Copper	246.0	E
Iron	22,600	E
Lead	149.0	E
Mercury	4.7	E,F
Nickel	40.4	E
Silver	2.4	E
Zinc	357.0	E

Location SD-5		10/9/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	3.3 J	E
Arsenic	31.5	E
Cadmium	6.2	E
Chromium	127.0	E
Copper	377.0	E,F
Iron	32,600	E
Lead	254.0	E,F
Mercury	2.1 J	E,F
Nickel	57.5	E,F
Silver	5.0	E,F
Zinc	556.0	E,F

Location SD-8		10/9/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	5.3 J	E
Arsenic	60.3 J	E
Cadmium	9.3 J	E
Chromium	178.0 J	E
Copper	453.0 J	E,F
Iron	37,400 J	E
Lead	304.0 J	E,F
Mercury	7.9 J*	E,F
Nickel	93.4 J	E,F
Silver	5.8 J	E,F
Zinc	620.0 J	E,F

Notes:
All concentrations in ug/kg (organics) and mg/kg (metals).
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

300 0 300 600 Feet

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CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

SCG Exceedances in Creek Sediment
0 to 6 Inch Depth Interval

Figure 4-3

Location SD-4	10/8/2003	
Parameter	Conc.	Exceedance
Metals		
Antimony	4.1 J	E
Arsenic	52.9	E
Cadmium	4.8	E
Chromium	116.0	E
Copper	340.0	E,F
Iron	21,900	E
Lead	209.0	E
Mercury	4.7	E,F
Nickel	52.6	E,F
Silver	2.8	E
Zinc	404.0	E

Location SD-7	10/9/2003	
Parameter	Conc.	Exceedance
Metals		
Antimony	2.5 J	E
Arsenic	12.9 J	E
Iron	30,400 J	E
Nickel	27.4 J	E

Location SD-11	10/10/2003	
Parameter	Conc.	Exceedance
Semi-Volatiles		
Phenanthrene	300 J	E
Pesticides/PCBs		
4,4-DDD	0.42 J	A,C,D
alpha-BHC	2.5 J	C
Total PCBs	74.7 J	E
Camphechlor	6.8 J	A,B,C
Endosulfan I	1.1 J	C
Endosulfan II	0.64 J	C
gamma-Chlordane	0.64 J	A,C,D
Heptachlor	2.1 J	A,C
Heptachlor epoxide	0.64 J	A

Parameter	Conc.	Exceedance
Metals		
Arsenic	23.8 J	E
Cadmium	3.4 J	E
Chromium	81.5 J	E
Copper	228.0 J	E
Iron	23,600 J	E
Lead	164.0 J*	E
Mercury	1.1 J	E,F
Nickel	72.5 J	E,F
Silver	2.9 J	E
Zinc	350.0 JN	E

Location BACKGROUND	10/15/2003	
Parameter	Conc.	Exceedance
Semi-Volatiles		
2-Methylnaphthalene	250 J	E
Acenaphthene	220 J	E
Acenaphthylene	160 J	E
Fluorene	140 J	E
Napthalene	250 J	E
Pesticides/PCBs		
4,4-DDD	0.7 J	A
alpha-BHC	4.3 J	C
Total PCBs	123.5 J	E
Camphechlor	11.0 J	A,B,C
Endosulfan I	1.8 J	C
Endosulfan II	1.1 J	C
gamma-Chlordane	1.1 J	A,C,D
Heptachlor	3.6 J	A,C
Heptachlor epoxide	1.1 J	A
Metals		
Antimony	3.4 J	E
Arsenic	12.2 J	E
Iron	23,000 J	E
Nickel	251.0 J	E,F

Location SD-1	10/8/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	12.2	E
Cadmium	5.1	E
Chromium	83.1	E
Copper	207.0	E
Lead	143.0	E
Mercury	2.2	E,F
Nickel	44.6	E
Silver	2.6	E
Zinc	314.0	E

Location SD-8	10/9/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	24.9	E
Iron	45,400	E,F
Manganese	652.0	E
Mercury	0.26	E
Nickel	52.6	E,F
Silver	2.8	E

Location SD-12	10/10/2003	
Parameter	Conc.	Exceedance
Semi-Volatiles		
2-Methylnaphthalene	75 J	E
Acenaphthene	75 J	E
Acenaphthylene	75 J	E
Anthracene	95 J	E
Benzo(a)anthracene	490 J	E
Dibenz(a,h)anthracene	98 J	E
Fluoranthene	1200 J	E
Fluorene	70 J	E
Hexzchloro-1,3-Butadiene	95 J	A,C,D
Hexachlorocyclopentadiene	240 J	B,C
Phenanthrene	740 J	E
Pyrene	1100 J	E
Metals		
Arsenic	8.7 J	E
Copper	44.8 J	E
Nickel	74.4 J	E,F

Location SD-2	10/8/2003	
Parameter	Conc.	Exceedance
Semi-Volatiles		
Anthracene	130 J	E
Benzo(a)anthracene	780	E
Benzo(a)pyrene	750	E
Fluoranthene	1700	E
Phenanthrene	790	E
Pyrene	1400	E
Pesticides/PCBs		
Total PCBs	27.0	E
Metals		
Copper	40.8	E
Lead	61.6	E
Mercury	0.35	E

Location SD-5	10/9/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDT	48.0 J	E,F
Metals		
Antimony	3.3 J	E
Arsenic	32.9 J	E
Cadmium	6.8 J	E
Chromium	128.0 J	E
Copper	375.0 J	E,F
Iron	33,100 J	E
Lead	260.0 J	E,F
Mercury	1.7 J	E,F
Nickel	64.1 J	E,F
Silver	5.0 J	E,F
Zinc	573.0 J	E,F

Location SD-6	10/9/2003	
Parameter	Conc.	Exceedance
Pesticides		
4,4-DDD	11.0 J	A,D
Metals		
Lead	55.0	E
Mercury	0.17	E

Location SD-9	10/10/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	32.0 J	E
Cadmium	4.7 J	E
Chromium	114.0 J	E
Copper	330.0 J	E,F
Iron	32,500 J	E
Lead	238.0 J	E,F
Mercury	1.7 J	E,F
Nickel	92.4 J	E,F
Silver	3.6 J	E
Zinc	500.0 J	E,F

Location SD-10	10/10/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	0.42 J	A,C,D
alpha-BHC	2.5 J	C
Total PCBs	73.7 J	E
Camphechlor	6.8 J	A,B,C
Endosulfan I	1.1 J	C
Endosulfan II	0.64 J	C
gamma-Chlordane	0.64 J	A,C,D
Heptachlor	2.1 J	A,C
Heptachlor epoxide	0.64 J	A
Metals		
Arsenic	18.6 J	E
Copper	35.7 J	E
Iron	35,100 J	E
Lead	71.7 J*	E
Mercury	0.31 J	E
Nickel	91.1 J	E,F

Location SD-3	10/8/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	12.6	E
Iron	25,400	E
Mercury	0.27	E
Nickel	21.3	E

Notes:
All concentrations in ug/kg (organics) or mg/kg (metals)
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

300 0 300 600 Feet

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New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

SCG Exceedances in Creek Sediment
6 to 12 Inch Depth Interval

Figure 4-4

Location SD-4	10/8/2003	
Parameter	Conc.	Exceedance
Metals		
Antimony	2.3 J	E
Arsenic	48.5	E
Cadmium	1.6	E
Chromium	84.9	E
Copper	248.0	E
Iron	20,900	E
Lead	181.0	E
Mercury	2.0	E,F
Nickel	61.2	E,F
Silver	1.6	E
Zinc	298.0	E

Location SD-1 (41-46 in.)	10/8/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	11.7	E
Mercury	0.25	E

Location SD-2	10/8/2003	
Parameter	Conc.	Exceedance
Metals		
Antimony	3.1 J	E
Arsenic	31.0	E
Cadmium	7.9	E
Chromium	122.0	E
Copper	352.0	E,F
Lead	191.0	E
Mercury	0.26	E
Nickel	51.7	E,F
Silver	3.7	E
Zinc	458.0	E,F

Location SD-3	10/8/2003	
Parameter	Conc.	Exceedance
Volatiles		
1,1-Dichloroethylene	2.3 J	A
Vinyl Chloride	2.1 J	A
Metals		
Iron	24000	E

Location SD-7 (and Duplicate)	10/9/2003			
Parameter	Conc. Sampl.	Dup.	Exceedance Sampl.	Dup.
Metals				
Antimony	2.3 J	-	E	-
Arsenic	41.3 J	12.9 J	E	E
Cadmium	8.4 J	-	E	-
Chromium	177.0 J	-	E	-
Copper	501.0 J	59.7 J	E,F	E
Iron	35,800 J	20,900 J	E	E
Lead	344.0 J	-	E,F	-
Mercury	1.9 J*	0.54 J	E,F	E
Nickel	117.0 J	50.8 J	E,F	E
Silver	5.2 J	1.5 J	E,F	E
Zinc	696.0 J	-	E,F	-

Location SD-9 (and Duplicate)	10/10/2003			
Parameter	Conc. Sampl.	Dupl.	Exceedance Sampl.	Dupl.
Metals				
Arsenic	33.7 J	38.2 J	E	E
Cadmium	3.9 J	4.3 J	E	E
Chromium	105.0 J	132.0 J	E	E
Copper	290.0 J	372.0 J	E,F	E,F
Iron	34,000 J	33,800 J	E	E
Lead	246.0 J	272.0 J	E,F	E,F
Mercury	1.4 J	1.1 J	E,F	E,F
Nickel	125.0 J	90.0 J	E,F	E,F
Silver	3.1 J	4.0 J	E	E,F
Zinc	470.0 J	477.0 J	E,F	E,F

Location SD-8	10/9/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	11.4	E
Iron	35,500	E
Nickel	29.4	E
Silver	2.1	E

Location SD-5	10/9/2003	
Parameter	Conc.	Exceedance
Metals		
Antimony	3.6 J	E
Arsenic	41.3 J	E
Cadmium	9.6 J	E
Chromium	169.0 J	E
Copper	516.0 J	E,F
Iron	32,900 J	E
Lead	326.0 J	E,F
Mercury	4.3 J	E,F
Nickel	87.2 J	E,F
Silver	6.0 J	E,F
Zinc	625.0 J	E,F

Location SD-6	10/9/2003
No exceedances at 30-36 inches	

Location SD-10	10/10/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	9.9 J	E
Iron	31,500 J	E
Nickel	72.5 J	E,F

Location SD-11	10/10/2003	
Parameter	Conc.	Exceedance
Semi-Volatiles		
Acenaphthene	51 J	E
Acenaphthylene	51 J	E
Dibenz(a,h)anthracene	66 J	E
Fluorene	48 J	E
Hexachloro-1,3-Butadiene	65 J	A,C,D
Hexachlorocyclopentadiene	160 J	B,C
Metals		
Antimony	2.1 J	E
Arsenic	23.3	E
Copper	74.6	E
Lead	120.0 *	E
Mercury	0.28	E
Nickel	95.1	E,F
Zinc	182.0 N	E

Location BACKGROUND	10/15/2003	
Parameter	Conc.	Exceedance
Metals		
Nickel	76.5 J	E,F

Location SD-12	10/10/2003	
Parameter	Conc.	Exceedance
Semi-Volatiles		
Acenaphthene	53 J	E
Acenaphthylene	53 J	E
Dibenz(a,h)anthracene	67 J	E
Fluorene	49 J	E
Hexachloro-1,3-Butadiene	67 J	A,C,D
Hexachlorocyclopentadiene	170 J	B,C
Metals		
Nickel	44.1	E

Notes:
All concentrations in ug/kg (organic) and mg/kg (metals)
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

300 0 300 600 Feet

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CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

SCG Exceedances in Creek Sediment
24 to 30 Inch Depth Interval

Figure 4-5

BKGD.

No BACKGROUND sample below 24-30 in.

Location SD-7 (and Duplicate) 10/9/2003

Parameter	Conc. Sampl.	Conc. Dup.	Exceedance Sampl.	Exceedance Dup.
Metals				
Iron	22,700 J	20,200	E	E
Nickel	47.8 J	43.3	E	E
Silver	-	1.2 J	-	E

Location SD-9 10/10/2003

Parameter	Conc.	Exceedance
Metals		
Nickel	40.0	E

Location SD-4 10/8/2003

Parameter	Conc.	Exceedance
Metals		
Nickel	85.6	E,F

Location SD-12 10/10/2003

Parameter	Conc.	Exceedance
Semi-Volatiles		
Acenaphthene	48 J	E
Acenaphthylene	48 J	E
Fluorene	44 J	E
Hexachloro-1,3-Butadiene	60 J	A,C,D
Hexachlorocyclopentadiene	150 J	B,C
Metals		
Nickel	174	E,F

Location SD-11 10/10/2003

Parameter	Conc.	Exceedance
Semi-Volatiles		
Acenaphthene	49 J	E
Acenaphthylene	49 J	E
Fluorene	46 J	E
Hexachloro-1,3-Butadiene	63 J	A,C,D
Hexachlorocyclopentadiene	160 J	B,C
Metals		
Nickel	104	E,F

Location SD-1 10/8/2003

No exceedances

Location SD-2 10/8/2003

No exceedances

Location SD-3 10/8/2003

No exceedances

Location SD-8 10/9/2003

Parameter	Conc.	Exceedance
Metals		
Nickel	28.8	E

Location SD-10 (54-60 in.) 10/10/2003

Parameter	Conc.	Exceedance
Metals		
Arsenic	9.1	E
Iron	28,500	E
Nickel	34.8	E

Location SD-6 10/9/2003

Parameter	Conc.	Exceedance
Metals		
Copper	35.1 J	E
Manganese	672.0	E

Location SD-5 (44-50 in. and Duplicate) 10/9/2003

Parameter	Conc. Sampl.	Conc. Dup.	Exceedance Sampl.	Exceedance Dup.
Metals				
Antimony	-	2.3 J	-	E
Arsenic	12.5 J	32.3 J	E	E
Cadmium	-	7.0 J	-	E
Chromium	-	127.0 J	-	E
Copper	-	375.0 J	-	E,F
Iron	28,000 J	33,900 J	E	E
Lead	-	253.0 J	-	E,F
Mercury	-	1.8 J	-	E,F
Nickel	26.0 J	70.7 J	E	E,F
Silver	-	4.8 J	-	E,F
Zinc	-	559.0 J	-	E,F

Notes:
All concentrations in ug/kg (organics) or mg/kg (metals)
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

SD-1 SD-2 SD-3 SD-4 SD-5 SD-6 SD-7 SD-8 SD-9 SD-10 SD-11 SD-12

Richmond Creek

Forest Hill Rd
Richmond Ave
Emery Ct
Token St
Ladd Ave
Berry Ave
Crestfield Ave
Drumgoole Rd W
Drumgoole Rd
Gurley Ave
Getz Ave
Ridgewood Ave
Brandis Ave
E Macon Ave
Bartlett Ave
Ellingville Blvd
Cortelyou Ave
Armstrong Ave
Abingdon Ave
Brookfield Ave
Colon Ave
Duane Ave
Arkansas Ave
Elverton Ave
Steg Ave
Arthur Kill Rd
Giffords Ave
Miles Ave
Daleham St
Fairfield St
Elkhart St
Teakwood Ct
Nutwood Ct
Country Woods Ln
Islington St
Barlow Ave
Jurral St
Kennington St
Ironwood St
Cottonwood Ct
Nahant St
Linton Pl
Hereford St
United Hebrew Cemetary

N W E S

300 0 300 600 Feet

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CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION DEP

SCG Exceedances in Creek Sediment
72 to 78 Inch Depth Interval

Figure 4-6

Location SD-BREF1		10/17/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	24.2 J	E
Cadmium	2.0 J	E
Chromium	103.0 J	E
Copper	217.0 J	E
Iron	26,700 J	E
Lead	205.0 J	E
Mercury	2.4 J	E,F
Nickel	32.9 J	E
Silver	2.8 J	E
Zinc	369.0 J	E

Location SD-BREF2		10/16/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4'-DDD	11.0 P	A
4,4'-DDT	66.0 D	E,F
Total PCBs	55.0 J	E
Metals		
Antimony	5.6 J	E
Arsenic	72.6	E,F
Cadmium	4.9	E
Chromium	190.0 *	E
Copper	388.0	E,F
Iron	21,200 *	E
Lead	332.0 *	E,F
Mercury	7.7	E,F
Nickel	36.7	E
Silver	4.2	E,F
Zinc	439.0 N*	E,F

Location SD-B5		10/20/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	19.8 J	E
Cadmium	4.0 J	E
Chromium	89.8 J	E
Copper	267.0 J	E
Iron	22,600 J	E
Lead	175.0 J	E
Mercury	3.5 J	E,F
Nickel	43.0 J	E
Silver	3.1 J	E
Zinc	400.0 J	E

Location SD-B6		10/19/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	47.0 J	E
Cadmium	3.1 J	E
Chromium	96.0 J	E
Copper	323.0 J	E,F
Iron	47,200 J	E,F
Lead	254.0 J	E,F
Mercury	1.9 J	E,F
Nickel	61.4 J	E,F
Silver	4.5 J	E,F
Zinc	452.0 J	E,F

Location SD-B7		10/17/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4'-DDT	120 D	E,F
Metals		
Copper	56.2 J	E
Lead	92.7 J	E
Nickel	22.3 J	E
Zinc	240.0 J	E

Location SD-B4		10/18/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	20.9 J	E
Cadmium	3.9 J	E
Chromium	93.0 J	E
Copper	271.0 J	E,F
Iron	23,500 J	E
Lead	184.0 J	E,F
Mercury	2.9 J	E,F
Nickel	44.3 J	E
Silver	3.4 J	E
Zinc	451.0 J	E,F

Location SD-B3		10/21/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	49.3 J	E
Cadmium	4.4 J	E
Chromium	144 J	E
Copper	368 J	E,F
Iron	26,700 J	E
Lead	287.0 J	E,F
Mercury	4.0 J	E,F
Nickel	86.5 J	E,F
Silver	3.9 J	E,F
Zinc	456.0 J	E,F

Location SD-B2		10/17/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	25.0 J	E
Cadmium	2.9 J	E
Copper	222.0 J	E
Iron	25,300 J	E
Lead	197.0 J	E
Mercury	1.5 J	E,F
Nickel	40.5 J	E
Silver	3.5 J	E
Zinc	357 J	E

Location SD-B1		10/16/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4'-DDD	4.9 P	A
Metals		
Arsenic	15.8	E
Cadmium	2.6	E
Copper	162.0	E
Iron	23,600	E
Lead	131.0	E
Mercury	1.0	E,F
Nickel	35.1	E
Silver	2.6	E
Zinc	320.0	E

SD-B1
SD-B2
SD-B3
SD-B4
SD-B5
SD-B6
SD-B7

Forest Hill Rd
Richmond Ave
Arthur Kill Rd
Newvale Ave
Graves Ave
Cromer St
Elkhart St
Miles Ave
Daleham St
Fairfield St
Teakwood Ct
Nutwood Ct
Giffords Ave
Country Woods Ln
Gurley Ave
Hereford St
Islington St
Barlow Ave
Jumel St
Kennington St
Ironwood St
Cottonwood Ct
Nahant St
Limon Pl
Elverton Ave
Arkansas Ave
Brookfield Ave
Colon Ave
Duane Ave
Abingdon Ave
Steig Ave
Getz Ave
Ridgewood Ave
Ellingville Blvd
Barlett Ave
Emery Ct
Token St
Ladd Ave
Berry Ave
Crestfield Ave
Drumgoole Rd W
Drumgoole Rd E
Richmond Creek
Hebrew Cemetary

N
W
E
S

300 0 300 600 Feet

Notes:
All concentrations in ug/kg (organic) and mg/kg (metals)
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

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CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION DEP

SCG Exceedances in Creek Sediment
at Biota Sampling Locations
0 to 6 Inch Depth Interval

Figure 4-7

Location SM-5	10/10/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	15 J	A
4,4-DDE	20 J	E
4,4-DDT	12 J	E
alpha-BHC	3.9 J	C
Total PCBs	112.7 J	E
Camphechlor	10 J	A,B,C
Endosulfan I	1.6 J	C
Endosulfan II	1 J	C
gamma-Chlordane	1 J	A,C,D
Heptachlor	3.2 J	A,C
Heptachlor epoxide	1 J	A
Metals		
Antimony	4.4 J	E
Arsenic	35.9 J	E
Copper	144 J	E
Lead	124 J*	E
Manganese	482 J	E
Mercury	1.4 J	E,F
Nickel	33.1 J	E

Location SM-10	10/14/2003	
Parameter	Conc.	Exceedance
Metals		
Antimony	3.6 J	E
Arsenic	37.2 J	E
Cadmium	1.3 J	E
Chromium	126.0 J	E
Copper	299.0 J	E,F
Iron	38,400 J	E
Lead	267.0 J	E,F
Mercury	3.0 J	E,F
Nickel	91.9 J	E,F
Silver	3.8 J	E,F
Zinc	388.0 J	E

Location SM-3	10/8/2003	
Parameter	Conc.	Exceedance
Volatiles		
1,1-Dichloroethylene	3.5 J	A
Metals		
Antimony	5.9 J	E
Arsenic	129 J	E,F
Chromium	219 J	E
Copper	517 J	E,F
Iron	22,800 J	E
Lead	402 J	E,F
Manganese	570 J	E
Mercury	7.1 J*	E,F
Nickel	74.9 J	E,F
Silver	2.3 J	E
Zinc	377 J	E

Location SM-9	10/14/2003	
Parameter	Conc.	Exceedance
Metals		
Arsenic	11.7 J	E
Copper	52.5 J	E
Lead	50.7 J	E
Mercury	0.2 J	E

Location SM-7	10/10/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	1 J	A
alpha-BHC	5.7 J	C
Total PCBs	164.7 J	E
Camphechlor	15 J	A,B,C
Endosulfan I	2.4 J	C
Endosulfan II	1.4 J	C
gamma-Chlordane	1.4 J	A,C,D
Heptachlor	4.8 J	A
Heptachlor epoxide	1.4 J	A
Metals		
Antimony	3.4 J	E
Arsenic	50.9 J	E
Chromium	104 J	E
Copper	265 J	E
Iron	21,100 J	E
Lead	456 J*	E,F
Manganese	911 J	E
Mercury	3.6 J*	E,F
Nickel	75.9 J	E,F
Silver	2.4 J	E
Zinc	188 JN	E

Location SM-8	10/13/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	60 J	A
4,4-DDE	90 J	E,F
alpha-BHC	5.7 J	C
Total PCBs	164.7 J	E
Camphechlor	15 J	A,B,C
Endosulfan I	2.4 J	C
Endosulfan II	1.4 J	C
gamma-Chlordane	1.4 J	A,C,D
Heptachlor	4.7 J	A
Heptachlor epoxide	1.4 J	A
Metals		
Antimony	19.7 J	E
Arsenic	144 J	E,F
Cadmium	4.2 J	E
Chromium	125 J	E
Copper	938 J	E,F
Iron	22,100 J	E
Lead	851 J	E,F
Mercury	3.3 J	E,F
Nickel	122 J	E,F
Silver	6.3 J	E,F
Zinc	510 J	E,F

Location SM-2	10/8/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDE	530 JD	E,F
4,4-DDT	190 JD	E,F
Metals		
Antimony	11.9 J	E
Arsenic	349	E,F
Chromium	269	E
Copper	628 J	E,F
Iron	51,400	E,F
Lead	984	E,F
Manganese	7680	E,F
Mercury	7.9	E,F
Nickel	197	E,F
Silver	2.1 J	E
Zinc	428	E,F

Location SM-4	10/7/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	19 P	A
4,4-DDE	19	E
Dieldrin	20 P	A
Metals		
Arsenic	34.6	E
Cadmium	3.8	E
Copper	211	E
Lead	171	E
Mercury	1.3	E,F
Nickel	53.8	E,F
Silver	1.5 J	E
Zinc	229	E

Location SM-1	10/8/2003	
Parameter	Conc.	Exceedance
Metals		
Antimony	11.3 J	E
Arsenic	45.7	E
Chromium	100	E
Copper	363 J	E,F
Lead	389	E,F
Mercury	2.9	E,F
Nickel	52.6	E,F
Silver	3.2 J	E
Zinc	160	E

Location SM-6	10/9/2003	
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDE	39 J	E
Metals		
Antimony	8 J	E
Arsenic	46.2	E
Cadmium	1.3 J	E
Chromium	117	E
Copper	341 J	E,F
Iron	22,100	E
Lead	362	E,F
Manganese	3,730	E,F
Mercury	4.6	E,F
Nickel	118	E,F
Silver	2.5 J	E
Zinc	423	E,F

Notes:
All concentrations in ug/kg (organics) or mg/kg (metals)
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

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CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

SCG Exceedances in Marsh Sediment
0 to 6 Inch Depth Interval

Figure 4-8

Location SM-2		10/8/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	8 J	E
Arsenic	122 J	E,F
Chromium	112 J	E
Copper	441 J	E,F
Lead	453 J	E,F
Manganese	2,590 J	E,F
Mercury	4.4 J	E,F
Nickel	98 J	E,F
Silver	2.1 J	E
Zinc	228 J	E

Location SM-3		10/9/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	5.4 J	E
Arsenic	177 J	E,F
Chromium	98.8 J	E
Copper	533 J	E,F
Iron	24,100 J	E
Lead	369 J	E,F
Mercury	2.2 J	E,F
Nickel	142 J	E,F
Silver	1.7 J	E
Zinc	305 J	E

Location SM-5		10/10/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	1.2 J	A
alpha-BHC	7 J	C
Total PCBs	203.6 J	E,F
Camphechlor	19 J	A,B,C
Endosulfan I	2.9 J	C
Endosulfan II	1.8 J	C
gamma-Chlordane	1.8 J	A,C,D
Heptachlor	5.8 J	A
Heptachlor epoxide	1.8 J	A
Metals		
Antimony	9.1 J	E
Arsenic	50 J	E
Copper	101 J	E
Lead	97.9 J*	E
Mercury	0.4 J	E
Nickel	37.5 J	E

Location SM-10		10/14/2003
Parameter	Conc.	Exceedance
Metals		
Arsenic	64.7 J	E
Cadmium	1.7 J	E
Chromium	165 J	E
Copper	328 J	E,F
Iron	40,300 J	E,F
Lead	404 J	E,F
Manganese	884 J	E
Mercury	2.7 J	E,F
Nickel	224 J	E,F
Silver	4.7 J	E,F
Zinc	601 J	E,F

Location SM-9		10/14/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDE	30 J	E,F
Metals		
Antimony	8 J	E
Arsenic	128 J	E,F
Copper	545 J	E,F
Iron	20,400 J	E
Lead	362 J	E,F
Mercury	1.3 J	E,F
Nickel	116 J	E,F
Silver	2.6 J	E
Zinc	212 J	E

Location SM-1		10/8/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDE	8.6 J	A
Metals		
Arsenic	9 J	E
Copper	80.3 J	E

Location SM-4		10/7/2003
Parameter	Conc.	Exceedance
Semivolatiles		
Penanthrene	370 J	E

Location SM-6		10/9/2003
Parameter	Conc.	Exceedance
Semi-Volatiles		
2-Methylnaphthalene	570 J	E
Metals		
Antimony	2.4 J	E

Location SM-6 (Duplicate)		10/9/2003
Parameter	Conc.	Exceedance
Metals		
Antimony	3.7 J	E
Mercury	0.4 J	E
Silver	21.5 J	E

Location SM-7		10/10/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	0.9 J	A
alpha-BHC	5.4 J	C
Total PCBs	157.9 J	E
Camphechlor	14 J	A,B,C
Endosulfan I	2.3 J	C
Endosulfan II	1.4 J	C
gamma-Chlordane	1.4 J	A,C,D
Heptachlor	4.5 J	A
Heptachlor epoxide	1.4 J	A
Metals		
Antimony	11.5 J	E
Arsenic	80.1 J	E,F
Chromium	110 J	E
Copper	415 J	E,F
Lead	908 J*	E,F
Manganese	632 J	E
Mercury	5.4 J*	E,F
Nickel	129 J	E,F
Silver	2 J	E
Zinc	498 JN	E,F

Location SM-8		10/13/2003
Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	1.1 J	A
4,4-DDE	17 J	E
alpha-BHC	6.6 J	C
Total PCBs	193.2 J	E,F
Camphechlor	18 J	A,B,C
Endosulfan I	2.8 J	C
Endosulfan II	1.7 J	C
gamma-Chlordane	1.7 J	A,C,D
Heptachlor	5.5 J	A
Heptachlor epoxide	1.7 J	A
Metals		
Antimony	11.7 J	E
Arsenic	96.4 J	E,F
Copper	759 J	E,F
Lead	429 J	E,F
Mercury	0.7 JN	E
Nickel	70.8 J	E,F
Zinc	213 J	E

Notes:
All concentrations in ug/kg (organics) or mg/kg (metals)
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

300 0 300 600 Feet

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CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

SCG Exceedances in Marsh Sediment
6 to 12 Inch Depth Interval

Figure 4-9

Location SM-5, 52 to 58 inches 10/10/2003

Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	2 J	A
4,4-DDT	2 J	E
alpha-BHC	12 J	C
Total PCBs	351 J	E,F
Camphechlor	32 J	A,B,C
Endosulfan I	5 J	C
Endosulfan II	3 J	C
gamma-Chlordane	3 J	A,C,D
Heptachlor	9.9 J	A,C
Heptachlor epoxide	3 J	A
Metals		
Antimony	41.7 J	E,F
Arsenic	365 J	E,F
Chromium	275 J	E
Copper	756 J	E,F
Iron	182,000 J	E,F
Lead	724 J*	E,F
Manganese	3,720 J	E,F
Nickel	288 J	E,F
Silver	3.1 J	E
Zinc	1,010 J	E,F

Location SM-10, 24 to 30 inches 10/14/2003

Parameter	Conc.	Exceedance
Semi-Volatiles		
Anthracene	100 J	E
Metals		
Arsenic	11.1 J	E
Iron	34,600 J	E
Nickel	66.2 J	E,F

Location SM-9, 69 to 75 inches 10/14/2003

Parameter	Conc.	Exceedance
Metals		
Nickel	26.8 J	E

Location SM-3, 30 to 36 inches 10/9/2003

Parameter	Conc.	Exceedance
Metals		
Antimony	3.3 J	E
Arsenic	14 J	E
Iron	35,300 J	E
Manganese	588 J	E
Nickel	31.2 J	E

Location SM-8, 44 to 50 inches 10/13/2003

Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	1.8 J	A
4,4-DDT	1.8 J	E
alpha-BHC	11 J	C
Total PCBs	315 J	E,F
Camphechlor	29 J	A,B,C
Endosulfan I	4.5 J	C
Endosulfan II	2.7 J	C
gamma-Chlordane	2.7 J	A,C,D
Heptachlor	9.1 J	A,C
Heptachlor epoxide	2.7 J	A

Location SM-2, 24 to 30 inches 10/8/2003

Parameter	Conc.	Exceedance
Metals		
Antimony	5.7 J	E
Arsenic	39.4 J	E
Nickel	73.5 J	E,F
Zinc	297 J	E

Location SM-6, 24 to 30 inches 10/9/2003

Parameter	Conc.	Exceedance
Volatiles		
Carbon Tetrachloride	2.8 J	A
Pesticides/PCBs		
alpha-BHC	1.7 J	C
Total PCBs	48.7 J	E
beta-BHC	0.1 J	C
Camphechlor	4.5 J	A,B,C
delta-BHC	0.3 J	C
Endosulfan I	0.7 J	B,C
Endosulfan II	0.4 J	C
gamma-BHC (Lindane)	0.1 J	C
gamma-Chlordane	0.4 J	A,B,C,D
Heptachlor	1.4 J	A,C
Heptachlor epoxide	0.4 J	A,C

Location SM-7, 44 to 50 inches 10/10/2003

Parameter	Conc.	Exceedance
Pesticides/PCBs		
4,4-DDD	0.6 J	A
alpha-BHC	3.7 J	C
Total PCBs	108 J	E
Camphechlor	10 J	A,B,C
Endosulfan I	1.6 J	C
Endosulfan II	0.9 J	C
gamma-Chlordane	0.9 J	A,C,D
Heptachlor	3.1 J	A,C
Heptachlor epoxide	0.9 J	A
Metals		
Antimony	4.6 J	E
Arsenic	9.2 J	E
Iron	29,400 J	E
Nickel	27.6 J	E

Location SM-1, 24 to 30 inches 10/8/2003

No exceedances

Location SM-4, 24 to 30 inches 10/7/2003

No exceedances (volatile fraction rejected)

Notes:
All concentrations ug/kg (organics) or mg/kg (metals)
A = Exceeds human health bioaccumulation level of protection
B = Exceeds benthic aquatic life acute toxicity level of protection
C = Exceeds benthic aquatic life chronic toxicity level of protection
D = Exceeds wildlife bioaccumulation level of protection
E = Exceeds ERL
F = Exceeds ERM
Reference: NYSDEC, "Technical Guidance for Screening Contaminated Sediments", January 25, 1999.

SM-1 SM-2 SM-3 SM-4 SM-5 SM-6 SM-7 SM-8 SM-9 SM-10

Richmond Creek

Forest Hill Rd
Richmond Ave
Arthur Kill Rd
Lewvale Ave
Lewood Dr
United Hebrew Cemetary
Elkhart St
Teakwood Ct
Nutwood Ct
Country Woods Ln
Ironwood St
Cottonwood Ct
Islington St
Barlow Ave
Jumel St
Kennington St
Arkansas Ave
Nahant St
Miles Ave
Union Pl
Everton Ave
Stieg Ave
Colon Ave
Duane Ave
Brookfield Ave
Abingdon Ave
Armstrong Ave
Cortelyou Ave
Ridgewood Ave
Ettingville Blvd
Bartlett Ave
Getz Ave
Gurley Ave
Brandis Ave
E Macon Ave
Emery Ct
Token St
Ladd Ave
Berry Ave
Crestfield Ave
Drumgoole Rd W
Drumgoole Rd E

N W E S

300 0 300 600 Feet

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CDM

New York City Department of Environmental Protection
Brookfield Avenue Landfill Operable Unit 2

NEW YORK CITY DEPARTMENT OF ENVIRONMENTAL PROTECTION DEP

SCG Exceedances in Marsh Sediment
24 to 75 Inch Depth Intervals

Figure 4-10