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ARCS II

Contract No. 68-W9-0051

LI TUNGSTEN
Glen Cove, New York
Work Assignment No. 025-2L4L

Draft Final
Remedial Investigation (RI) Report
Volume I of IV

Remedial Planning Activities at Selected
Uncontrolled Hazardous Substance Disposal Sites
USEPA Region II (NY, NJ, PR, VI)

Malcolm Pirnie, Inc.
104 Corporate Park Drive
White Plains, NY 10602

May 1998

MALCOLM PIRNIE

300932

CONTRACT NO. 68-W9-0051

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SITE NAME: LI TUNGSTEN SITE
GLEN COVE, NEW YORK

DRAFT FINAL REMEDIAL INVESTIGATION (RI) REPORT
VOLUMES I - IV

May 1998

CONTRACTOR QA/QC SIGN-OFF

Malcolm Pirnie, Inc. has reviewed this draft document in accordance with the contractor's ARCS II QAPP and is submitting it to USEPA, Region II in compliance with the requirements under Work Assignment No. 025-2L4L and Contract No. 68-W9-0051.

This document has not been approved by USEPA Region II and is not intended for release to the public.

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ARCS PMO QUALITY ASSURANCE MANAGER

Date: 5/14/98

Dennis G. McGrath, CPG
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Date: May 14, 1998

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EXECUTIVE SUMMARY

INTRODUCTION

The purpose of this Draft Final Remedial Investigation (RI) Report is to present and evaluate the results of the RI performed at the Li Tungsten Superfund Site (hereinafter referred to as the Site), Glen Cove, New York. The RI was performed by Malcolm Pirnie, Inc. (Malcolm Pirnie) on behalf of the United States Environmental Protection Agency (USEPA), Region II under the Alternative Remedial Contracting Strategy (ARCS), Contract Number 68-W9-0051, Work Assignment Number 025-2L4L. The RI was performed in accordance with the approved RI/FS Work Plan (Malcolm Pirnie, 1993) to characterize the nature and extent of contamination associated with the Site and to assess the risks posed to human health and the environment by the presence of that contamination. In addition, the RI provides sufficient information to subsequently perform a Feasibility Study (FS).

BACKGROUND

The Site is located at 63 Herb Hill Road in the City of Glen Cove, Nassau County, Long Island, New York. The geographic coordinates of the Site are latitude 40^0 51' 36" North and longitude 73^0 38' 25" West. Also located nearby is the Mattiace Petrochemical National Priorities List (NPL) site which was the subject of a RI/FS directed by the USEPA (Ebasco, 1991) and is currently undergoing remedial design and cleanup activities.

The Site is approximately 26 acres and consists of four parcels designated A, B, C and C'. Parcel A is approximately seven acres and served as the main operations center when the Site was active. Historically, Parcel A contained the majority of buildings and structures (mostly aboveground tanks). Until 1995, Parcel A contained numerous drums and crates of processed tungsten ore residues. The ore residues were relocated in 1995 -1996 to the Dickson Warehouse on Parcel C during interim remedial actions (IRAs) conducted at the Site. Ongoing removal actions being conducted by the USEPA has demolished two of the buildings and is removing all of the tanks on Parcels A and C.

Parcel B is approximately six acres and is located north of Parcel A. Parcel B is undeveloped but contains a small pond, an intermittent stream and a small wetland. Two separate areas on Parcel B, south of the pond and directly opposite the Benbow Building

were used as parking areas when the Site was active. The northernmost area of Parcel B was used an employee picnic area (Personal communication, 1996). The area between the two parking areas was used for disposal of ore residues. This disposal area has been referred to in previous reports (Hart, 1990; NUS, 1989, 1990a, 1990b) as a "landfill". Observations of partially buried drums and mounds of ore residue made during the field investigation confirmed that disposal activities have taken place in this portion of Parcel B.

Parcel C is the largest of the three parcels, approximately 10 acres. Parcel C contains two buildings (the Dickson Warehouse and the Benbow Building), a 500,000 gallon aboveground fuel oil tank, two additional aboveground storage tanks (one hydrogen tank that was reportedly never placed into service and a propane tank), and three surface impoundments (one lined impoundment called Mud Pond and two unlined structures called "Mud Holes". All of the tanks currently on Parcel C are scheduled for removal by the end of the Summer 1998 as part of the USEPA's ongoing removal action at the Site.

The current site owner, the Glen Cove Development Corporation (GCDC), acquired approximately four acres of undeveloped property adjacent to Parcel C sometime after 1984. This area has been designated Parcel C′. Parcel C′ was not part of the Site during active operations, however, evidence of disposal activities on Parcel C′ were discovered during the RI.

The Site facility became substantially operational in October 1942. During its' operating life, the Site had a complex history of name and ownership changes. Operations consisted of processing ore concentrates and scrap tungsten to produce ammonium paratungstate (APT) and subsequently formulating APT to metal tungsten powder and tungsten carbide powder. Other specialty products that were produced included: tungsten carbide powder for plasma spraying; tungsten titanium carbide powder; tantalum carbide powder; tungsten spray powder; crystalline tungsten powder; and molybdenum spray powder.

There is very little specific documentation regarding waste volumes that were generated or waste disposal practices. Some radioactive waste from the Site, however, was taken to a nearby municipal landfill that later began to be developed as the Captain's Cove Condominium project (Hart, 1989). Drummed waste was reported to have been buried on-site in a portion of Parcel B (NUS, 1989, 1990). Numerous partially buried drums are visible at the ground surface on Parcel B. Liquid wastes are believed to have been disposed of

through numerous subsurface drainage pipes that have been noted in the bulkhead and empty directly into Glen Cove Creek. SPDES permits allowed for up to as many as 250,000 gallons per day of discharge to Glen Cove Creek. The Mud Pond and the two Mud Holes were also reportedly used to dispose of liquid wastes.

Beginning in 1988 and continuing through the present, the Site has been the subject of several environmental site assessments, investigations and removal actions. Previous environmental investigations were performed at the Site by the Nassau County Department of Health (NCDOH), the New York State Department of Environmental Conservation (NYSDEC), the potentially responsible parties (PRPs), and the USEPA. Results of these sampling activities indicated the presence of heavy metals, radioactive isotopes of uranium (^{238}U), thorium (^{230}Th and ^{232}Th) and radium (^{226}Ra and ^{228}Ra), fuel oil constituents, and volatile organics in the groundwater, surface water, sediments and soils. In July 1991, USEPA proposed that Li Tungsten be included on the NPL after the Site scored a 50 in the hazard ranking score (HRS) (NUS, 1991).

FIELD INVESTIGATIONS

Surface and Subsurface Soils

An electromagnetic (EM) and a magnetometer survey were performed to determine the presence and distribution of buried metallic objects (e.g., drums of ore residues) on the Site and to assist in the selection of test pit locations. No anomalies were identified along the three transects on Parcel A. EM survey data collected on Parcel B identified five anomalies. Two anomalies were identified on Parcel C; no anomalies were identified on Parcel C′.

Seven test pits were excavated on Parcel B and one test pit was excavated on Parcel C to investigate the seven anomalies detected during the electromagnetic and magnetometer surveys, and the one radiological anomaly identified during exposure rate scanning. The objectives of the test pit excavations were to determine vertical boundaries of buried wastes (ore residues) or metallic debris, assess changes in soils and aid in the location of radiological soil borings. Fill materials were observed in four test pits: TP-1, TP-3, TP-5 and TP-7. No fill materials or debris were observed in TP-2, TP-4, TP-6 or TP-8. An asphalt

layer (0.5-inch thick) was observed in TP-3 approximately 4.5 feet below grade and may represent a former employee parking area.

Eighteen surface soil samples were collected from locations on Parcels A, B, C and off-site. The purpose of surface soil sampling was to determine the risk to plants and terrestrial receptors through ingestion, assess the dermal/inhalation pathway associated with surface soil contaminants (SS-1 through SS-12) and to determine site-specific background radionuclide concentrations (SS-13 through SS-18).

Twenty-six source area soil borings were drilled to provide additional information on the vertical limits of buried waste and to reassess the presence, nature and extent of contamination in the vadose zone that was detected in previous investigations (NUS, 1990). Eight source area borings (SB-1 through SB-8) were drilled on Parcel A; 12 source area soil borings (SB-9 through SB-20) were drilled on Parcel B; and six source area borings (SB-23 through SB-28) were drilled on Parcel C. Of the six borings on Parcel C, three were located in the northwest corner in the area of "scarred vegetation" (NUS, 1990). Three source area borings were located in the southern portion of Parcel C adjacent to the 500,000-gallon aboveground fuel oil tank.

Eleven storm sewer soil borings were drilled on Parcel A (SB-29, SB-31, SB-32, SB-33, SB-34, SB-35, SB-36 and SB-37) and on Parcel C (SB-40, SB-41 and SB-42. The purpose of these borings was to assess the extent and potential that storm sewer piping is functioning as a conduit and continued contaminant source to the groundwater and Glen Cove Creek.

Twenty radiological soil borings (RT-1 through RT-20) were completed on Parcels B and C to a depth of approximately 15 feet. The purpose of the radiological soil borings was to define the extent (depth and volume) of radiological contamination. Soil borings were drilled at biased locations to collect soil samples based on field screening data and to collect downhole gamma logging data. Gamma logging data was collected over 30-second intervals at six-inch depth increments from the ground surface to the bottom of each radiological boring.

Groundwater

A geoprobe/soil gas survey was performed to: (1) verify the presence and extent of the volatile organic compounds that were previously detected (NUS, 1990) in the groundwater in four areas of the Site and; (2) assist in the selection of monitoring well locations. The four areas of the Site where volatile organics or petroleum constituents were detected previously correspond to the Crown Dykman site on the north side of Herb Hill Road opposite the main gate to Parcel A and adjacent to the southeast corner of Parcel B; the southwest corner of Parcel A; the 500,000-gallon aboveground fuel oil tank on Parcel C; and the "scarred vegetation" area on Parcel C.

Fifteen new monitoring wells were installed. New monitoring wells were designated "MP" to distinguish them from the existing monitoring wells installed as part of at least three earlier investigations. The existing monitoring wells were named using different nomenclature system including "GM", "EMW" and "MW".

Two rounds of groundwater samples were collected from a total of 32 monitoring wells (17 existing and 15 new). It became necessary to resample nine monitoring wells during the first round because the laboratory performing the TAL/TCL analyses was unable to complete all analyses. The first round of groundwater sampling was conducted from December 3-18, 1996. The resampling of the nine wells was conducted from January 6-8, 1997. Samples collected during resampling have been designated with an "R" (e.g., MP-4R). The second round of groundwater sampling was conducted from January 20-31, 1997.

Surface Water/Sediment

Seven surface water samples (SW-1, SW-4, SW-5, SW-8, SW-9, SW-10 and SW-11) were collected to verify previously collected data (NUS, 1990) and to characterize areas not previously sampled (e.g., the intermittent stream and unnamed pond on Parcel C).

Eight sediment samples (SED-2 through SED-5 and SED-8 through SED-11) were collected to verify previously collected data (NUS, 1990) and to characterize areas not previously sampled. In general, sediment samples were collected from the same locations as the surface water samples, however, samples SED-2 and SED-3 were collected at the two Mud Holes which were dry at the time of sampling.

Four additional storm sewer sediment samples (SED-DP-1, SED-DP-2, SED-DP-3, SED-DP-5, and SED-DP-29) were collected from manhole grates in the existing storm sewer system on Parcel A.

Building Materials

Ten building material samples were collected from buildings on Parcel A in areas exhibiting elevated exposure rates. These areas included portions of the Dice Building (BM-1 through BM-7) and the northern portion of the East Building (BM-8, BM-9 and BM-10). Samples of wall and floor materials were collected with a hammer and chisel. Thorium-232 and ^{226}Ra concentrations were determined by counting their gamma-emitting decay products.

Ecological Investigation

Wetland-nonwetland boundaries were identified using the Corps of Engineers Wetlands Delineation Manual (Dept. of the Army, 1987) and the Memorandum on Clarification and Interpretation of the 1987 Manual (Dept. of the Army, March 1992). The routine determination method was applied for the collection of data, since wetland areas delineated were small and had little vegetation diversity. Application of this procedure required identification of plant community types and characterization of vegetation, soils and hydrology using established criteria. Data were collected at the sampling stations (designated as "SS") noted on the forms in the Wetland Delineation Report (Appendix G).

In support of the Ecological Assessment, ecological investigations were performed. Vegetation patterns were mapped within the site boundaries, based on observations made during field surveys. Since considerable tree cover was disturbed due to interim remedial measures and site clearing, the percent areal cover for the Site was estimated based on aerial photography taken in 1995. Vegetational communities providing wildlife habitat were noted and indicated on a Site map. Wildlife species likely to utilize specific area vegetational communities were identified based on New York Fish and Wildlife data for the area. Wildlife observations were recorded and observations were made concerning the ability of habitat to support Federal or State threatened or endangered species, if present. Data collected include the numbers of individuals observed, species utilization of the site (i.e., foraging, nesting, migratory stopover) and species utilization of vegetation stratum (i.e., open

field, shrub/scrub, wooded). In addition, data supplied by New York State Natural Heritage Program were used to identify possible habitat for documented threatened or endangered species utilizing the area.

Cultural Resource Surveys

A Stage 1a Archaeological Survey was conducted to determine whether: 1) portions of the Site were sensitive for the presence of potentially significant archaeological resources; 2) a preliminary evaluation of the architectural and historical significance of Site buildings was warranted; and 3) further archaeological investigations at the Site were warranted and, if warranted, make recommendations on the scope of that work.

The results and analysis of the Stage Ia Archeological Survey indicated the following:

- Some of the existing structures within Parcel A may be associated with the early twentieth century Ladew Leather Belting Works and may possess architectural and/or historical value;
- Parcel B is sensitive for the presence of possibly significant prehistoric period and historic period archaeological resources; and
- The artificially filled area behind the bulkhead along Glen Cove Creek (Parcel A) may possibly constitute an historic period cultural resource.

Subsurface testing was recommended for Parcel B and the area behind the bulkhead along Glen Cove Creek on Parcel A. It was also recommended that an industrial archaeologist evaluate the potential significance of the buildings on Parcel A that may have been associated with the Ladew Leather Belting Works.

Once the interim remedial actions were initiated in 1995-996, it became apparent that repair to the bulkhead would necessitate disturbance to the artificially filled areas behind the bulkhead. Subsurface investigations in the vicinity of the bulkhead did not reveal the presence of fill layers or other archaeological deposits that are potentially eligible for listing on the New York State or National Registers of Historic Places. It was concluded, therefore, that further archaeological investigations on this portion of Parcel A were not warranted.

Due to the archaeological sensitivity of Parcel B, test pits excavations were monitored by an archaeologist. Test pit excavations did not encounter any Native American or Historic

Period deposits of potential significance. Test pits in the middle and southern portions of Parcel B revealed recent fill deposits overlying former ground surface layers and sequentially, glacial deposits and/or wetland associated deposits. The former ground surfaces were not archaeologically sampled. Only the natural soil sequence was observed in the test pits excavated in the northern portion of Parcel B.

The architectural assessment on Parcel A determined that the Loung Building and parts of the East Building were associated with the early twentieth century Ladew Leather Belting Works. The assessment concluded that the Loung Building and the East Building were unspectacular vernacular examples of early twentieth century industrial/commercial architecture.

RESULTS OF THE FIELD INVESTIGATION

The nature and extent of contamination at the Site is based on validated data obtained from the sampling events. These samples include surface and subsurface soil, surface water, sediment, groundwater and building materials. These samples were analyzed for a full range of TCL organics, TAL inorganics (including cyanide) and radionuclides (^{238}U, ^{230}Th, ^{232}Th, ^{226}Ra and ^{228}Ra). Selected soil and sediment samples were also analyzed for other chemical parameters such as total organic carbon (TOC), TCLP Parameters and physical properties (grain size, moisture content, bulk density, Atterberg limits and hydraulic conductivity). Selected aqueous samples were analyzed for pH, hardness and total dissolved solids (TDS).

Determination of Site-Specific Background

Seven samples collected at four sample locations (MP-11D/11DB on Parcel C′ and MP-5/5B, SB-13/13B and TP-6 on the northern portion of Parcel B) were selected as representing site-specific background for volatile organics, semi-volatile organics, pesticides/PCBs and inorganics. These samples were chosen because the sample locations were in areas that are removed from known sources of contamination and in areas believed to be relatively undisturbed.

Site-specific radionuclide background concentrations were determined from the same four sample locations plus six off-site sampling locations. No site-specific background was determined for surface water because no areas could be identified that were not potentially

affected by operations at the Site; TAGM guidance values were used to compare sediment data.

Contaminant Sources

A variety of contaminants were detected in both the soils and groundwater samples at a wide range of concentrations. The distribution pattern of many of the constituents in a particular group (e.g., volatiles, semi-volatiles, inorganics and radionuclides), however, often showed some similarities in the areas of the Site where they were detected. The selection of individual chemical or radiological constituents for graphical presentation was based on one of three primary criteria:

- represents that group of constituents (e.g, inorganics, volatiles, etc.,);
- represents a unique or particularly significant distribution for that group of constituents;
- represents a health-risk.

The source of much of the contamination at the Site is the tungsten ore residues that were previously left on-site or currently remain buried on-site. Prior to the start of this RI, approximately 3,000 - 4,000 cubic yards of the ore residues were present on the Site in drums, wooden crates and mounds both inside some of the buildings and outside on driveways and walkways, primarily on Parcel A, but also to a lesser extent on Parcel C. These ore residues were temporarily relocated to the Dickson Warehouse as part of the 1995-1996 IRAs. Other primary contaminant sources include an area in the center of Parcel B that is believed to have been used as a disposal area for ore residues; the "scarred" vegetation area in the northern portion of Parcel C that was also used as a disposal area for ore residues; the Mud Pond and two Mud Holes which were used for disposal of wastewater; underground storage tanks on Parcel A; and a 500,000-gallon aboveground fuel oil tank on Parcel C. Secondary sources of contamination include the on-site storm sewer lines and groundwater from three off-site sources: the Mattiace Petrochemical site, the Konica property (formerly Powers-Chemco) and the Crown Dykman site.

Surface and Subsurface Soils

Volatile organic compounds (VOCs) were detected in relatively few soil samples, at low concentrations (less than 5 µg/Kg) and at shallow depths (0-4 feet). The distribution of VOCs in the soils is limited to three areas: the northern portion of Parcel A; the southern portion of Parcel B; and the southern portion of Parcel C around the aboveground fuel oil tank and Mud Pond.

Thirteen semi-volatile organic compounds (SVOCs) were detected in the surface and subsurface soils at concentrations that exceeded the TAGM or USEPA SSL guidance values. The distribution of benzo(a)anthracene was selected as representative of all SVOCs. Benzo(a)anthracene was detected in 33 samples and exceeded the USEPA SSL guidance value (80 µg/Kg) in 28 samples and the TAGM guidance value (112 µg/Kg) in 21 samples. In the 28 samples exceeding the more restrictive (lower) USEPA SSL guidance, the concentration ranged from 81 J µg/Kg (SS-2) to 9,900 µg/Kg (SB-31). Benzo(a)anthracene was detected mostly frequently in the soil samples collected on Parcel A, however, it was also detected in the central portion of Parcel B, and in the northern ("scarred vegetation area") and southern (Mud Pond) portions of Parcel C.

The pesticide/PCBs detected in the surface and subsurface soils which exceeded the TAGM guidance or the USEPA SSL values included total PCBs (the summation of Aroclor-1242, 1248, 1254, and 1260), Endrin, and 4-4-DDT. Total PCBs exceeded the TAGM guidance value (1,000 µg/Kg) in four samples. Three samples were located near the mounds of ore residue in middle Parcel B. The fourth sample collected from a source area soil boring near the former sodium hydroxide tank on Parcel A. Endrin was detected in three samples on Parcel B including one source area soil boring sample and two test pit samples. One test pit sample (TP-5) exceeded both the USEPA SSL value and TAGM guidance value (50 µg/Kg). 4,4'-DDT was detected in one test pit sample on Parcel B, but below the TAGM guidance value (1,050 µg/Kg).

Many of the inorganics present in the soils are the accessory metals naturally occurring in tungsten ore concentrates that were removed as impurities during the tungsten extraction process. The accessory metals include: antimony, arsenic, barium, copper, cobalt, chromium, lead, manganese, mercury, nickel, thorium, uranium, vanadium and zinc. The horizontal and vertical distribution of many of these inorganics are very similar, therefore,

only selected metals have been presented graphically. The distribution of three inorganics in the surface and subsurface soils (0-4 feet) selected for graphical presentation include arsenic, cobalt and manganese.

Arsenic is an accessory metal commonly found in tungsten ore. The highest concentrations of arsenic from 0-4 feet were found in four areas including: middle Parcel B; lower Parcel B; the northwest corner of Parcel C in the area of "scarred vegetation"; and lower Parcel C near Mud Pond and the aboveground fuel oil tank. The highest concentration of arsenic was found in a storm sewer boring on Parcel C. In the deeper soils (greater than four feet), arsenic was detected in three of the same areas: middle of Parcel; the area of "scarred vegetation" on Parcel C; and on the northern rim of Mud Pond on lower Parcel C.

Cobalt, another common accessory metal in tungsten ore, was detected in 102 samples at concentrations ranging from 1.7 mg/Kg (SB-26B) to 4,660 mg/Kg (SB-20). The distribution of cobalt is somewhat different to other accessory metals. In the surface soils, cobalt was detected in some similar and some dissimilar areas to the other accessory metals. The common areas include middle and lower Parcel B and in the vicinity of the Mud Pond and fuel oil tank area on Parcel C. Cobalt was also detected in two areas on Parcel A. The concentration of cobalt at depths greater than four feet decreased to a maximum of 107 mg/Kg.

Manganese, another common accessory metal in tungsten ore, was detected in all samples at a concentration ranging from 59.4 E mg/Kg to 90,000 mg/Kg. The areas of highest concentration occur in the middle of Parcel And two areas on Parcel C: between the Dickson Warehouse and the Benbow Building and in the "scarred vegetation" area. Another small area occurs on Parcel A, outside of the fence near the intersection of Herb Hill Road and Garvies Point Road.

At sampling depths below four feet, manganese was detected in 22 samples at concentrations ranging from 46.9 mg/Kg (SB-4B) to 6,300 mg/Kg (SB-17B). a total of four of these samples exceeded site-specific background (676.6 mg/Kg). The sampling locations that exceeded site-specific background are all located in the middle of Parcel B.

The average site-specific background concentrations of radionuclides (^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th, and ^{232}Th) were calculated from on-site and off-site sampling locations are as follows: ^{238}U (0.7 pCi/g), ^{226}Ra (1.0 pCi/g), ^{228}Ra (1.1 pCi/g), ^{230}Th (0.7 pCi/g) and ^{232}Th (0.8

pCi/g). There are five main areas showing measurable concentrations of ^{238}U have been detected greater than 1.5X above site-specific background in the surface soils (0-4 feet) including:

- outside the fence along Herb Hill Road in the northeast corner of Parcel A as defined by two surface soil samples;
- the middle portion of Parcel B as defined by five radiological boring samples: three source area soil boring, and one test pit sample;
- the upper portion of Parcel C as defined by one surface soil sample;
- the vegetated area north of the Dickson Warehouse on Parcel C as defined by one radiological boring and one surface soil sample;
- the lower portion of Parcel C as defined by two radiological borings.

At depths greater than four feet, the concentration of ^{238}U in four of the five areas decreased (there were no samples collected at depth outside the fence along Herb Hill Road on Parcel A). a maximum value of 15 pCi/g was detected in a source area soil boring sample (SB-17B) in the middle of Parcel B. Other sampling points in the middle portion of Parcel B that reflected concentrations of ^{238}U greater than 1.5X above site-specific background included TP-4 (5.4 pCi/g), SB-15B (2.8 pCi/g) and RT-3B (1.5 pCi/g). The upper portion of Parcel C continued to show concentrations of ^{238}U greater than 1.5X the site-specific background in one source area soil boring sample (8.5 pCi/g in SB-28B). The vegetated area north of the Dickson Warehouse reflects levels of ^{238}U less than 1.5X site-specific background in three samples; the lower portion of Parcel C reflected ^{238}U concentrations greater than 1.5X above site-specific background in three samples.

Overall the distribution of ^{232}Th closely matched ^{238}U in the five areas discussed above, but also included several other small areas on Parcels A and B. Two surface soil samples (SS-1 and SS-3) collected along Herb Hill Road in the northeast corner of Parcel A exceeded 1.5X background. Other areas on Parcel A where the concentration of ^{232}Th exceeded 1.5X site-specific background included three storm sewer soil boring samples in the eastern portion of Parcel A, and two surface soil samples along the bulkhead on Parcel A.

In the middle of Parcel B, the concentration of ^{232}Th exceeded 1.5X background (1.4 pCi/g) in six radiological soil boring samples; four source area soil boring samples; and four test pit samples. Several samples collected in the lower portion of Parcel B also exceeded 1.5X background including one surface soil sample; two source area soil boring samples; and one radiological soil boring sample.

The highest concentration of ^{232}Th (220 pCi/g) was measured in a surface soil sample (SS-12) located north of the Dickson Warehouse on Parcel C. Other sample locations north of the Dickson Warehouse where the concentration of ^{232}Th exceeded 1.5X background included three radiological borings. One sample collected from a source area soil boring in the upper potion of Parcel C exceeded 1.5X background. Four samples collected in the lower portion of Parcel C exceeded 1.5X background including two radiological soil boring samples; one surface soil sample; and one source area soil boring sample.

At depths greater than four feet, ^{232}Th was detected in 34 samples at concentrations that ranged from less than background to a maximum of 5.1 pCi/g (approximately 6X background). The distribution pattern again closely followed that of ^{238}U. None of the samples collected on Parcel A exceeded 1.5X site-specific background. a maximum value of 5.1 pCi/g was detected in a source area soil boring sample (SB-28B) in the upper portion of Parcel C. Sampling points in the middle portion of Parcel B that reflected concentrations of ^{232}Th greater than 1.5X above site-specific background included TP-4 (3 pCi/g), SB-14B (13 pCi/g), SB-17B (3.9 E pCi/g) and RT-4B (1.7 E pCi/g). One source area soil boring sample (8.5 pCi/g in SB-28B) in the upper portion of Parcel C showed a concentration of ^{238}U greater than 1.5X above site-specific background. Samples collected in the vegetated area north of the Dickson Warehouse reflect greater than 1.5X site-specific background in two radiological boring samples. The lower portion of Parcel C reflected ^{232}Th concentrations above 1.5X site-specific background in one samples.

Overall the distribution of ^{226}Ra closely matched ^{238}U and ^{232}Th in the areas discussed above. Two surface soil samples collected along Herb Hill Road in the northeast corner of Parcel A exceeded 1.5X site-specific background. Two storm sewer soil boring samples and one source area soil boring sample in the eastern portion of Parcel A, and two surface soil samples along the bulkhead on Parcel A also exceeded 1.5X site-specific background.

In the middle of Parcel B, the concentration of ^{226}Ra exceeded 1.5X site-specific background (1.5 pCi/g) in seven radiological soil boring samples; eight source area soil boring samples; and three test pit samples. Several samples collected in the lower portion of Parcel B also exceeded 1.5X site-specific background including one surface soil sample; two source area soil boring samples and one radiological soil boring sample.

The highest concentration of ^{226}Ra (250 pCi/g) was measured in a surface soil sample located in the upper portion of Parcel C. Other sample locations in the upper portion of Parcel C where the concentration of ^{226}Ra exceeded 1.5X site-specific background included two source area soil boring samples. Other areas on Parcel C where the concentration of Ra exceeded 1.5X site-specific background included three radiological borings and one surface soil sample north of the Dickson Warehouse. Four samples collected in the lower portion of Parcel C exceeded 1.5X site-specific background including two radiological soil boring samples; two surface soil samples; and three source area soil boring samples.

Groundwater

Two rounds (December 1996 and January 1997) of groundwater samples were collected from each of the monitoring wells. The first round and the resampling episode (completed in early January 1997) were combined as the December 1996 sampling event). A groundwater sample was also collected from an upgradient monitoring well (Konica-1) located on The Place and adjacent to the Konica property.

In general, the highest concentration of VOCs were detected in the four wells (MW-8S, MW-8D, MW-10 and GM-10) adjacent to the Mattiace Petrochemical site. Other areas reflecting concentrations of volatile organics include the cluster of wells in the middle portion of Parcel A/lower portion of Parcel B that are downgradient or cross-gradient to the Crown Dykman site; the middle portion of Parcel B; the area south of the Benbow Building on Parcel C; and to a lesser extent, the area around the aboveground fuel oil tank on Parcel C.

The second round of groundwater sampling yielded results similar to the first round in terms of the specific compounds and concentration, but a few differences were noted. TCE was detected in thirteen samples, ranging in concentration from 1 J µg/L (MP-17) to 28,000 µg/L (MW-10) and exceeded the MCL (5 µg/L) in ten samples. The distribution of

TCE in the second round and the concentration at each well are virtually identical to the first round with two exceptions. At well GM-1 on the eastern end of Parcel A, the concentration of TCE increased to 2,200 µg/L from 4.1 J ug/L and was undetected at well M-16D after being detected at a concentration of 3 µg/L during the first round.

One groundwater sample was collected from an off-site monitoring well (Konica-1), located on The Place approximately 400 feet from the northeast corner of Parcel B. This location is hydraulically upgradient from each of the three parcels. Methylene chloride and acetone were detected at concentrations of 170 J µg/L and 16 µg/L, respectively.

Several SVOCs were detected in both rounds of groundwater sampling. There were no SVOCs detected in the sample collected from off-site background monitoring well (Konica-1). The primary SVOCs detected included phenols, polynuclear aromatic hydrocarbons (PAHs) and phthalates. SVOCs were most frequently detected in the wells north of the Mattiace Petrochemical site (MW-8S, MW-8D and MW-10). Less frequent detections were found in the following locations: in the southwestern corner of Parcel A; in the vicinity of the aboveground fuel oil tank on Parcel C; and in isolated wells on Parcel A, Parcel B and Parcel C.

Several pesticides were detected at low concentrations in both rounds groundwater sampling (see detailed discussion in Section 5.2.2.3). The pesticides that were detected were limited to wells MW-8D, MW-10, GM-14A and MP-18. Polychlorinated biphenyls (PCBs) were not detected in any of the samples during either round. The second round sampling results indicate similar specific compounds at comparable concentrations.

Filtered and unfiltered groundwater samples were collected. Since unfiltered sample results are not considered to represent true aquifer conditions, the discussion below and in Chapter 5 of this Report, refers only to the filtered sample results. Overall, many individual inorganic constituents were detected in the groundwater. Upon review of the data, it became apparent that the distribution of many of the individual inorganic constituents exhibited a replicable pattern. The highest concentrations of any individual metal were generally detected in wells near the aboveground fuel oil tank, Mud Pond and the two Mud Holes on Parcel C. The distribution of arsenic, antimony and manganese were chosen to present graphically because they were either representative of all other inorganics or represented a health risk.

In the first sampling round, arsenic was detected in 10 samples at concentrations ranging from 4.2 J (GM-1) to 14,500 µg/L (GM-14B). The highest concentration of arsenic occurs in the southern portion of Parcel C (14,500 µg/L in GM-14B) and rapidly decreases in a cross-gradient direction extending to the western Site boundary and in a downgradient direction to the southern portion of Parcel A. Arsenic was not detected in any other wells at a concentration that exceeded the NYSDEC standard.

Antimony was detected in seven wells at concentrations ranging from 5.8 J µg/L (MP-22D) to 4,300 µg/L (GM-14B). Similar to arsenic, the highest concentration of antimony appears in the southern portion of Parcel C (4,300 µg/L in GM-14B) and gradually decreases in a cross-gradient direction extending to the western Site boundary (48.1 J and 16.6 µg/L in MP-18 and MP-18D, respectively) and in a downgradient direction to the southern portion of Parcel A (52.8 J and 6.1 µg/L in MP-22 and GM-2, respectively). Antimony was not detected in any other wells across the Site.

Manganese was among the most frequently detected metal and was detected at all wells locations except one (MP-21D on Parcel A) at concentrations ranging from 2 J µg/L (MP-2D) to 64,700 E µg/L (MP-18D). The highest concentration of manganese was detected in the lower portion of Parcel C. The second highest concentration of manganese was detected in the south-central portion of Parcel A. The wells north of the Mattiace Petrochemical site also reflected high concentrations of manganese. Other areas of high manganese concentration were centered on two wells on Parcel A, one well on Parcel B and one well on Parcel C.

During the second round of groundwater sampling, arsenic was again detected in 10 samples, but not in all the same wells. The NYSDEC standard (25 µg/L) was exceeded in only four wells. The highest concentration again occurred in lower Parcel C and concentrations decrease in a cross-gradient direction extending to the western Site boundary on Parcel C and in a downgradient direction to the southern portion of Parcel A. Arsenic was not detected in any other wells at a concentration that exceeded the NYSDEC standard or MCL.

Antimony was detected in only five wells at lower concentrations than those measured during the first round. Overall, the concentrations ranged from 7.5 J µg/L (MP-18D) to 824 E µg/L (GM-14B). The MCL (3 µg/L) was exceeded in all five samples.

Similar to the first round, the highest concentration of antimony appears in the southern portion of Parcel C. The concentration of antimony decreases in a cross-gradient direction extending to the western Site boundary and in a downgradient direction to the southern portion of Parcel A. Antimony was not detected in the south central portion of Parcel A or in any other wells across the Site.

Manganese was detected at all wells locations except the site-specific background well on Parcel B. Concentrations ranged from 0.42 µg/L (MP-22D) to 69,800 µg/L (MP-18D). The highest concentration of manganese was again detected in MP-18D, but slightly higher than in the first round (69,800 µg/L compared to 64,700 µg/L). Other wells in the lower portion of Parcel C reflected comparable concentrations to the first round. The second highest concentration of manganese was again detected in the south-central portion of Parcel A. The wells north of the Mattiace Petrochemical site again reflected high concentrations of manganese at comparable levels. Other areas of high manganese concentration were centered on two wells on Parcel A, one well on Parcel B and on well on Parcel C.

Two rounds of groundwater samples were analyzed for radionuclides (^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th and ^{232}Th). During the second sampling round, the concentration of ^{238}U exceeded the site-specific background concentration (2.2 pCi/L) in nine samples and ranged from 2.5 pCi/L (GM-14A) to 80 pCi/L (GM-14B). Other wells where the concentration of ^{238}U exceeded the site-specific background concentration included two wells on Parcel A; two wells on the lower portion of Parcel B; and three wells on Parcel C.

The site-specific background concentration of ^{232}Th (0.8 pCi/L) was exceeded in eight samples and ranged from 0.98 pCi/L (MP-16D) to 6.8 E pCi/L (GM-14B). Other wells where the concentration of ^{232}Th exceeded the site-specific background concentration included three wells on Parcel A; one well on Parcel B; and three wells on Parcel C.

Fifteen samples contained concentrations of ^{226}Ra that exceeded the site-specific background (1.9 pCi/L) and 11 samples exceeded the NYSDEC standard (3 pCi/L). The total radium standard (5 pCi/L) was exceeded in ten samples. Overall the measured concentrations above the site-specific background ranged from 2 pCi/L (GM-13) to 11 pCi/L (MP-16D). Other wells where the concentration of ^{226}Ra exceeded the site-specific background concentration included three wells on Parcel A; three wells on Parcel B; and seven wells on Parcel C.

Surface Water

Seven surface water samples were collected from the ponds and wetland areas on Parcels B and C, and two concrete surface impoundments on Parcel A. VOCs were not detected in any of the three surface water samples on Parcel C. The pond on Parcel B (SW-8) contained acetone (13 E µg/L), total 1,2-DCE (15 µg/L) and PCE (6 J µg/L). The wetland associated with the pond on Parcel B (SW-9) only contained trace levels of 1,1-DCA (2 J µg/L). There are no NYSDEC surface water standards for acetone or the two chlorinated hydrocarbons.

SVOCs were not detected in two samples on Parcel C (SW-4 and SW-10) or the pond on Parcel B (SW-8). Bis(2-ethylhexyl)phthalate was detected in samples SW-9 (1 J µg/L) and SW-11 (4 J µg/L), exceeding the Class C Surface Water Standard of 0.6 µg/L. Di-n-butylphthalate was detected in sample SW-11 (1 J µg/L). Sample SW-5 contained 1 J µg/L of diethylphthalate.

PCBs were detected in two of the seven surface water samples. Two PCB congeners (aroclor 1254 and aroclor 1260) were detected in SW-1 at concentrations of 3.8 E µg/L and 2.3 E µg/L, respectively; one PCB congener (aroclor-1254) was detected in SW-4 (1 E µg/L). The Class D Surface Water Standard for total PCBs is 0.01 µg/L. Pesticides were detected in only one of seven surface water samples. Three pesticide compounds, 4,4'-DDE, 4,4'-DDD and 4,4'-DDT were detected in SW-8 at concentrations of 1.6 JN µg/L, 9.1 JN µg/L and 4.6 JN µg/L, respectively. The Class D Surface Water Standard for DDE, DDD and DDT is 0.001 µg/L.

All of the surface water samples exceeded surface water standards for some inorganics. The sample from Mud Pond on Parcel C (SW-4) contained aluminum, cobalt, copper, iron, magnesium, manganese and selenium at concentrations that exceeded the surface water standards. The pond on Parcel B (SW-8) showed aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, selenium, silver, thallium, vanadium and zinc at concentrations that exceeded the appropriate surface water standards. Surface water adjacent to the pond on Parcel B (SW-9) contained aluminum, cobalt, iron and manganese at concentrations exceeding surface water standards. The pond and wetland area on Parcel C (SW-10 and SW-11) contained aluminum, cadmium, copper,

iron, manganese and zinc at concentrations that exceeded surface water standards. Sample SW-10 also contained chromium at a concentration that exceeded surface water standards.

The Class A Surface Water Standard for ^{226}Ra is 3 pCi/L; the Class A Surface Water Standard for the sum of the ^{226}Ra and ^{228}Ra is 5 pCi/L. Uranium-238 was detected in each of the five surface water samples at a concentration ranging from less than 0.23 pCi/L (SW-9) to 4.8 pCi/L (SW-4). Radium-226 was detected in five samples at concentrations that ranged from less than 0.45 pCi/L (SW-10) to 4.5 pCi/L (SW-8). Radium-228 was detected in samples SW-4 and SW-8 at concentrations of less than 1.0 pCi/L and 2.4 pCi/L, respectively. SW-8 exceeded both the regulatory standard for ^{226}Ra and the combined standard for ^{226}Ra and ^{228}Ra. Concentrations of ^{232}Th were detected in four of the five samples ranging in concentration from less than 0.23 pCi/L (SW-11) to less than 0.41 pCi/L (SW-4). Thorium-230 was detected in samples SW-4 and SW-8 at concentrations of 0.64 pCi/L and less than 0.46 pCi/L, respectively.

Sediment

Sediment samples were collected from locations where surface water samples were collected. Sediment results for VOC, SVOC, inorganics, pesticides and PCBs are compared to the NYSDEC TAGM values. Sediment results for radiological parameters are compared to background concentrations because TAGM guidance do not exist. Trace levels (below NYSDEC standards) of several VOCs were detected in five sediment samples. Principal organic contaminants included 2-butanone, carbon disulfide and chlorinated and aromatic hydrocarbons. Acetone was detected at a concentration (240 E µg/Kg and 160 E µg/Kg) in samples SED-9 and SED-8, respectively that exceeded the appropriate TAGM value (15 µg/Kg).

SVOCs were detected in each sediment sample except SED-10. The principal semi-volatile organic contaminants included PAHs and phthalates, but at concentrations that were below TAGM guidance values. Sample SED-5 contained concentrations of benzo(a)anthracene (290 µg/Kg), chrysene (580 µg/Kg), benzo(b)fluoranthene (600 µg/Kg) and benzo(k)fluoranthene (260 µg/Kg) at concentrations that exceeded the respective TAGM guidance values.

Analytical results indicate that PCBs were detected in three sediment samples (SED-2, SED-3 and SED-9. The PCBs detected were primarily aroclor-1254, aroclor-1260, and to a lesser frequency aroclor-1248. Total PCB concentrations of 2,891 μg/Kg, 1,806 μg/Kg and 873 μg/Kg were detected in samples SED-2, SED-9 and SED-3, respectively. The TAGM value for total PCBs in sediment is 328 μg/Kg. The only pesticides (4,4'-DDD and 4,4'-DDE) detected in one sediment sample (SED-8) was above the TAGM guidance values.

Inorganic analytical results were compared to available TAGM guidance values for sediment (e.g., arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc). Concentrations of arsenic, cadmium, copper and iron in all eight sediment samples exceeded the TAGM guidance values for that individual constituent. The concentration of chromium exceeded the TAGM guidance value (26 mg/Kg) in three samples (SED-4, SED-5 and SED-11). The concentration of lead exceeded the TAGM guidance value (31 mg/Kg) in all but one sample (SED-8). The concentration of manganese exceeded the TAGM guidance value (460 mg/Kg) in four samples (SED-2, SED-4, SED-5 and SED-9). Mercury exceeded the TAGM guidance value (0.2 mg/Kg) in five samples (SED-2, SED-3, SED-4, SED-5 and SED-11). The TAGM guidance value for nickel (16 mg/Kg) was exceeded in all samples except SED-10 and SED-11. The concentration of zinc exceeded the TAGM guidance value (120 mg/Kg) in all samples except SED-3, SED-8 and SED-9.

The sediment samples were analyzed for the same radiological parameters (e.g., ^{238}U, ^{226}Ra, ^{228}Ra, ^{220}Th and ^{232}Th) as the surface and subsurface soils. Since there are no available Federal or State guidance values for these parameters in sediment, the analytical results are compared to site-specific background that was calculated for the soils.

The three sediment samples collected from the two Mud Holes (SED-2 and SED-3) and Mud Pond (SED-4) exceeded the site-specific background for each radionuclide except ^{228}Ra in SED-2. The concentration of ^{238}U in the three samples ranged from 4.5 (SED-2) to 46 pCi/g (SED-4); the concentration of ^{232}Th ranged from 2.1 pCi/g (SED-2) to 5.7 pCi/g (SED-4); and the concentration of ^{226}Ra ranged from 2.2 pCi/g (SED-2) to 5.7 pCi/g (SED-4). The concentration of each radionuclide in the two samples collected on Parcel B (SED-8 and SED-9) and one sample on the upper portion of Parcel C (SED-10) were all less than the site-specific background level. The concentration of ^{226}Ra (2.2 pCi/g), ^{230}Th (1.3 pCi/g) and ^{232}Th (1.5 pCi/g) in SED-11 exceeded site-specific background.

Storm Sewer Sediment

Sediment samples were collected from locations on Parcels A and C. Storm sewer sediment results for VOC, SVOC, inorganics, pesticides and PCBs are compared to the NYSDEC TAGM values. Storm sewer sediment results for radiological parameters are compared to background concentrations because TAGM guidance do not exist. Trace levels (below NYSDEC standards) of several VOCs were detected in four storm sewer sediment samples. Principal organic contaminants included 2-butanone, carbon disulfide and chlorinated and aromatic hydrocarbons. Acetone was detected at a concentration (22 E µg/Kg and 16 µg/Kg) in samples SED-DP-2 and SED-DP-29, respectively that slightly exceeded the appropriate TAGM value (15 µg/Kg).

SVOCs were detected in each of the four storm sewer sediment samples. The principal semi-volatile organic contaminants included PAHs and phthalates. Concentrations of pyrene (3,100 E µg/Kg), chrysene (3,000 E µg/Kg), benzo(b)fluoranthene (3,700 E µg/Kg), benzo(a)pyrene (4,800 E µg/Kg), indeno(1,2,3-cd)pyrene (1,100 E µg/Kg) and benzo(g,h,i) perylene (1,100 E µg/Kg) were detected in sample SED-DP3 at concentrations that exceeded the TAGM guidance values. Sample SED-DP5 contained 13,000 E µg/Kg of pyrene and benzo(b)fluoranthene, 7,400 E µg/Kg benzo(a)pyrene, and 560 E µg/Kg of indeno(1,2,3-cd)pyrene and 3,600 E µg/Kg of benzo(g,h,i)perylene, thereby exceeding their respective TAGM guidance values. Concentrations of pyrene (1,600 µg/Kg), benzo(a)anthracene (1,200 µg/Kg), chrysene (1,100 µg/Kg), benzo(b)fluoranthene (1,600 E µg/Kg), benzo(k)fluoanthene (500 E µg/Kg), benzo(a)pyrene (570 E µg/Kg), indeno(1,2,3-cd)pyrene (330 J µg/Kg) and benzo(g,h,i)perylene (260 J µg/Kg) were detected above the TAGM guidance values in sample SED-DP29.

Analytical results indicate that PCBs were detected in two storm sewer sediment samples (SED-DP-3, SED-DP-5) at concentrations that exceeded the TAGM guidance values. The PCBs detected were primarily aroclor-1254, aroclor-1260, and to a lesser frequency aroclor-1248. Total PCB concentrations of 853 µg/Kg, and 614 µg/Kg were detected in samples SED-DP-3 and SED-DP-5, respectively. The TAGM value for total PCBs in sediment is 328 µg/Kg. No pesticides were detected in any storm sewer sediment sample.

Inorganic analytical results were compared to available TAGM guidance values for sediment. The concentrations of all inorganic constituents, for which there are TAGM guidance values (e.g., arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc), were exceeded in every storm sewer sediment sample.

The storm sewer sediment samples were analyzed for the same radiological parameters (e.g., ^{238}U, ^{226}Ra, ^{228}Ra, ^{220}Th and ^{232}Th) as the sediment, surface and subsurface soils. Since there are no available Federal or State guidance values for these parameters in sediment, the analytical results are compared to site-specific background that was calculated for the soils.

The majority of all storm sewer sediment samples exceeded 1.5X the site-specific background concentration of the five radionuclides. The exception occurred in sample SED-DP-29 where the concentration of ^{232}Th and ^{226}Ra were below the site-specific background concentration. The maximum and minimum concentrations of ^{238}U, ^{232}Th and ^{226}Ra each occurred in samples SED-DP-3. The concentration of ^{238}U in the four samples ranged from 1.7 (SED-DP-29) to 29 pCi/g (SED-DP-3); the concentration of ^{232}Th ranged from 1.1 pCi/g (SED-DP-29) to 15 pCi/g (SED-DP-3); and the concentration of ^{226}Ra ranged from 1.9 pCi/g (SED-DP-29) to 6.6 pCi/g (SED-DP-3).

Toxicity Characteristic Leaching Procedure (TCLP) Analyses

Toxicity characteristic leaching procedure (TCLP) analyses were performed on seven soil samples (SB-3B, SB-17, SB-27, SB-40, SB-41, TP-5, and TP-7). Three of these samples were collected from source area borings (SB-3, SB-17, and SB-27), two from storm sewer borings (SB-40 and SB-41), and two from test pits (TP-5 and TP-7). Results indicate that no organic compounds were detected in any of the seven soil samples. Trace levels (well below RCRA regulatory standards) of arsenic, barium, cadmium, lead, selenium, and silver were detected in the samples. Analytical results of the TCLP analyses are presented in Appendix N. Based upon the TCLP results, none of the seven soil samples would be characterized as a RCRA hazardous waste.

The purpose of the TCLP testing was to tentatively classify various areas that may be considered during the feasibility study for off-site analysis. Even though the TCLP sample results did not indicate that any of the soil samples tested can be classified as a

RCRA hazardous waste, additional sampling will be necessary prior to shipping any material off-site for disposal. Additional TCLP testing of the ore residues stored in Dickson Warehouse is proposed during the Captain's Cove FFS to determine if the ore residues may also be RCRA hazardous.

FATE AND TRANSPORT

The nature and extent of contamination at the Site is summarized in Section 5.0. The media evaluated include surface and subsurface soil, groundwater and surface water. While there has been frequent identification of the contaminants of concern (VOCs, SVOCs, pesticides/PCBs, metals and radionuclides) and frequent exceedences of the various guidance values, the gross exceedences appear to be isolated and associated with areas of previous disposal.

Several characteristics of the surface and subsurface soil favor advection, dispersion and volatilization of contaminants. The soil is primarily sand and gravel which would allow transport of groundwater and associated contamination. The hydraulic conductivity ranges from about 10^{-2} cm/s to 10^{-7} cm/s. The coarse particle distribution may also allow volatilization of contaminants in the surface soils. Low organic matter content (0.55%) and low clay content would result in low attenuation of contaminants, as clay particles and organic matter are soil components with high sorptive capacities.

Little data was collected regarding soil and groundwater chemistry or microbiology so conclusive statements regarding Site characterization that might influence biodegradation, biotransformation, bioactivation, oxidation-reduction reactions, precipitation or complexation can not be made. Patterns of contamination can be used to conjecture about some of those processes.

Groundwater flow at the Site is generally in the southeast direction perpendicular to Glen Cove Creek. The hydraulic gradient is gentle, in the range 0.031 to 0.039. The hydraulic gradient in the vicinity of the Mattiace Petrochemical site is steeper (0.075) and in the northeast direction. Groundwater flow is likely to follow preferential pathways that occur in the porous medium. Areas of high hydraulic conductivity are likely to carry the bulk of the flow. The hydraulic conductivity is known to vary widely with the average being about 3×10^{-3} cm/s. Another path of preferential flow known to exist at the Site is the areas

adjacent to the storm sewer lines which run perpendicular to Glen Cove Creek, and into it. A number of borings in the vicinity of the storm sewers confirm the preferential transport of contaminants along the sewer lines.

VOCs were detected widely in soils throughout the Site and often exceeded the USEPA SSL or the NYSDEC TAGM guidance values, but generally the exceedances were not excessive. This would indicate that VOCs in soils are subject to several processes which result in their reduction in concentration in soil. VOCs in soil may be volatilized, transported by advection, dispersion, facilitated transport, or biodegraded. Given that there were high concentrations of VOCs in groundwater in the vicinity of the Mattiace Petrochemical site property (MW-10, MW-8D, MW-8S) but not in the soils, it is likely that the compounds are being transported from the Mattiace Petrochemical site by advection.

In another instance where high levels of PCE were detected (EMW-1) there were also coincident detections of TCE and DCE at lesser concentrations. Given the proximity of EMW-1 to the Crown Dykman site and the use of PCE at that site, this may suggest that natural dechlorination of the chlorinated compounds is occurring. While anaerobic conditions seem unlikely in a water table aquifer, further evidence of natural dechlorination is found in samples from Round 2 at GM-1, MP-2D and MP-21D.

VOCs in soils at the Site were not detected often or at high concentrations except for a few specific cases. As was shown from other evidence, it is likely that VOCs in soil are subject to transport and biodegradation. There may also be some sorption of VOCs to soil, especially non-polar organic compounds.

The data regarding the nature and extent of contamination of soil and groundwater by SVOCs suggests transport and/or biodegradation of the lower molecular weight, lower ring compounds, and attenuation of the higher molecular weight, higher ring compounds on soil constituents.

Analysis of soil samples resulted in the detection of higher ring PAHs (3-ring: phenanthrene; 4-ring: pyrene, fluoranthene, benzo[a]anthracene, chrysene; 5-ring: benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene). These compounds have high sorption coefficients, low solubility and are more likely to be found sorbed to soil. Among these compounds, only phenanthrene, which is slightly soluble, was detected in groundwater. Other SVOCs detected in groundwater included naphthalene, and phenols. Naphthalene has

a relatively high solubility in water as do the phenols. Naphthalene and phenols also have sorption coefficients that are much lower than the high ring PAHs, and they are subject to higher rates of biodegradation due primarily to their higher solubility. Naphthalene and phenols were not detected in soils.

The observations regarding SVOCs leads to several conclusions about their likely fate and transport. It appears that naphthalene and the phenols were transported from the soils to the groundwater by advection. In addition it is likely that they were subject to biodegradation in soils but not in groundwater to the same degree. It is possible that biodegradation occurs at a faster rate in unsaturated soils than groundwater because oxygen does not become limited as quickly in soil as in the groundwater. Therefore, it is likely that biodegradation and advection of naphthalene and phenols in soil resulted in low concentrations being detected.

High ring PAHs are likely to become sorbed to the soil constituents to the extent that they will no longer be leached from the soil to the groundwater. The higher sorption coefficient of the PAHs and the low water solubility makes the high ring PAHs resistant to biodegradation. The higher ring PAHs are likely to remain at close to their current concentration in soil with a slow decline due to biodegradation, and without measurable impact to the groundwater.

Detection of pesticides in groundwater were limited to samples from wells in the vicinity of the Mattiace Petrochemical site. These pesticides were detected at the part-per-trillion concentration level in the groundwater. Given the generally low water solubility and high sorption coefficient of pesticides, and the high concentration of organic contaminants in this area, it is likely that the pesticides are coincident with the organic contaminants. Though the exact source of the contaminants in unknown, they may be trace contaminants associated with the organic contaminant plume suspected to be from the Mattiace Petrochemical site. It is also possible that there is a cosolvency effect from the organic compounds in the highly contaminated groundwater where low levels of pesticides in the saturated or unsaturated soil are extracted from a state of otherwise long term sorption. Again, the source may be applications decades ago.

PCBs were detected as total PCBs at concentrations above the NYSDEC TAGM guidance values in four samples. PCBs were not detected in any groundwater samples.

PCBs have low water solubility and are generally subject to slow rates of biodegradation. PCBs are not likely to leach to groundwater in significant quantity. The PCBs in soil are likely to remain at present concentration with only a slow biodegradation reducing the concentration.

A wide array of inorganics were detected in numerous soil samples at concentrations above their background concentration. This may be the result of widespread placement and storage of raw and partially processed ore throughout the Site. Inorganics in soil are subject to a variety of transport and transformation processes. Inorganics in soil will be subject to complexation reactions, redox reactions, precipitation, attenuation on soils, advection and dispersion when dissolved in the soil solution or groundwater, and facilitated transport. In general, inorganics introduced into soil will be affected by these processes until an equilibrium condition is achieved. However, as soil conditions change the equilibrium may change with a resultant change in the concentration of inorganics in the soil solution.

Inorganics were also found widely detected in groundwater samples from the Site. Metal concentrations were very high in many unfiltered groundwater samples but often the filtered counterpart sample had a very low concentration of the metal or no detection. This indicates that many of the inorganics and much of the mass of the inorganics in groundwater is in the form of colloids or sorbed to particulate matter. This reinforces commonly found evidence that facilitated transport is an important mechanism for transport of inorganics and demonstrates that this is the case at the Site.

Cobalt and nickel were also detected at relatively high concentrations in groundwater samples from wells between the warehouse where ore was off loaded from barges and the Glen Cove Creek. It is possible that contamination occurred as a result of the material handling of the raw ore in and around the area.

Nickel is considered to be one of the more mobile heavy metals. Under aerobic conditions and at near neutral pH precipitation reactions are discouraged. Complexation reactions occur with carbonate, sulfate and hydroxide. Carbonate and hydroxide compounds are generally insoluble, but the region in the vicinity of the saline Glen Cove Creek would have a high concentration of sulfate that would dominate complexation. Sulfate complexation reduces the sorption of nickel thus leading to greater mobility. Continued solubilization and transport of nickel is likely to occur in these areas at the Site.

Cobalt is also considered a relatively mobile metal under acid conditions in soil. This may be the reason for the high concentrations of cobalt detected in these groundwater monitoring wells. Cobalt is likely to remain mobile until it encounters regions of higher pH or sorbing material.

Radionuclides of uranium, thorium and radium were widely detected in the surface soils at the Site. Tungsten ore residues containing naturally occurring radiological materials was stockpiled throughout the Site. There is also some evidence that residue material was used to construct the berm around the aboveground fuel oil tank on Parcel C.

Radionuclides were detected in sediments and surface water samples at the Site indicating that surface runoff was a major transport mechanism, and may continue to be a significant transport mechanism of radionuclides at the Site.

Radionuclides were detected in only a few groundwater samples and many of the locations where they were detected were the same monitoring wells where significant inorganic contamination was found. These locations were in the vicinity of the bermed aboveground fuel oil tank and Mud Pond on Parcel C. Thorium and radium are virtually insoluble, so it is likely that they are transported to groundwater as colloids or as sorbed constituents on fine particles in a facilitated transport scenario. Uranium does have soluble species though the forms of uranium likely to be found in the original ore material would be insoluble. Chemical or biochemical oxidation of uranium species to a soluble U (VI) form is possible and may serve as an additional mechanism for which promotes the transport of uranium.

BASELINE RISK ASSESSMENT

This section presents evaluations of baseline human health and ecological risks associated with radiological and chemical contamination detected at the Site. The objectives of the assessment are:

- to provide an analysis of potential health risks, currently and in the future, in the absence of any major action to control or mitigate radiological and chemical contamination, and
- to assist in determining the need for and extent of remediation.

The assessment follows the USEPA Risk Assessment Guidance for Superfund (RAGS) and other USEPA guidance cited throughout this section. In addition to the methodology described in the USEPA RAGS, the RESRAD computer model is utilized in the human health evaluation of radiological contamination.

Although the uncertainties associated with any risk assessment may tend to over- or underestimate potential risk, a generally conservative approach was taken throughout the baseline risk assessment. This approach is consistent with USEPA which states that "it is important to minimize the chance of type II error (the likelihood that the actual risk is greater than that predicted)". It is probable, therefore, that the baseline risk assessment tends to overestimate rather than underestimate risk to both human and ecological receptors

Human Health Evaluation

The human health evaluation addresses the consequences of reasonable maximum exposure to radionuclides and chemicals of potential concern from hypothetical current and future exposure scenarios in the absence of remedial action at the Site. Based on the analytical results, soil data are evaluated by subdividing the Site into four areas, Areas A, B, B&C and C. Sediment data are evaluated by parcel, while groundwater data are evaluated site-wide. Potentially exposed populations in the current scenario include off-site residents and trespassers, while potentially exposed populations in the future scenario include site workers (assuming the Site is developed for industrial/commercial use), resident adults and children (assuming the Site is developed for residential use), and construction workers. Carcinogenic risks are estimated for potential exposure to the radionuclides of potential concern, the chemicals of potential concern, and both the radionuclides and the chemicals of potential concern. Noncarcinogenic risks are estimated for potential exposure to the chemicals of potential concern only as noncarcinogenic risks do not result from exposure to the radionuclides of potential concern.

Radiological Risk - Radionuclide analyses of soil samples indicate that thorium and uranium series radionuclides are present on all parcels at concentrations which exceed the range of natural background. For several current and future populations evaluated, the lifetime cancer risk due to exposure to these radioactive contaminants exceeds both the post-remediation risk range generally deemed acceptable at CERCLA sites as well as the dose-

based risk levels currently used to evaluate the impact of residual radioactivity at facilities formerly licensed to possess radioactive materials. As reflected in the risk calculations, the most highly contaminated soils were found in Area B&C; however, samples containing elevated radionuclide concentrations were collected from all areas (and all parcels) of the Site.

Radionuclide concentrations in sediments were within the background range. Exposure to sediments, therefore, do not pose any above background risk to current or future populations.

It is unclear if radionuclides have migrated to groundwater. The sum of the ^{226}Ra and ^{228}Ra concentrations in several wells ranged from 5-20 pCi/L, which exceed the 5 pCi/L maximum contaminant level (MCL) for drinking water set by the USEPA. However, these include the background Konica well and background well GW-MP-11D. Uranium-238 concentrations were, for the most part, less than 5 pCi/L, although three deep monitoring wells had approximately 30-80 pCi/L. Similarly, while most groundwater data for thorium were less than 1 pCi/L, three wells had ^{232}Th and ^{230}Th concentrations ranging from 3-9 pCi/L. These fluctuations in concentrations of naturally occurring radionuclides may reflect regional variability.

Chemical Risk - Potential exposure of off-site residents to respirable particulates originating in surface soil results in hazard indices for noncancer effects in excess of the USEPA acceptable level and estimated cancer risks at the upper bound of the USEPA acceptable risk range. The predominant contributors to the hazard indices are manganese and cobalt (at annual average concentrations in air based on the maximum detected concentrations in surface soil at Areas B, B&C, and C). The predominant contributor to the cancer risks is arsenic (at an annual average concentration in air based on the maximum detected concentrations in surface soil at Areas B, B&C, and C).

Potential exposure to soil at Area A results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations except the future scenario adolescent trespasser and estimated cancer risks that exceed the USEPA acceptable risk range for the future scenario resident adult. The predominant contributor to hazard indices and cancer risks is arsenic and, for inhalation by the future scenario construction worker,

cobalt. In addition, while not evaluated quantitatively, lead was detected in two of 28 samples at a concentration greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use.

Potential exposure to soil at Area B results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations and estimated cancer risks that exceed the USEPA acceptable risk range for the future scenario site worker, resident adult, and resident child. The predominant contributor to hazard indices and cancer risks is arsenic, at the maximum detected concentration. Cobalt, antimony, and nickel (at the maximum detected concentrations) and manganese contribute to a lesser extent to the hazard index for inhalation for the future scenario construction worker. In addition, while not evaluated quantitatively, lead was detected in four of 12 samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in two of 12 samples at concentrations, one within and one greater than, the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

Potential exposure to soil at Area B&C results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations and estimated cancer risks that exceed the USEPA acceptable risk range for all populations except the future scenario construction worker. The predominant contributors to hazard indices are arsenic (at the maximum detected concentration), antimony (at the maximum detected concentration in surface soil), manganese and, for inhalation by the future scenario construction worker, cobalt. The predominant contributor to cancer risks is arsenic. In addition, while not evaluated quantitatively, lead was detected in 13 of 37 samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in three of 37 samples at concentrations within and eight of 37 samples at concentrations greater than the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

Potential exposure to soil at Area C results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations and estimated cancer risks that exceed the USEPA acceptable risk range for the future scenario site worker, resident adult, and resident child. The predominant contributors to hazard indices are arsenic and antimony, at the maximum detected concentrations. Manganese, cobalt (at the maximum detected

concentration), and silver (at the maximum detected concentration) contribute to the hazard index for inhalation by the future scenario construction worker. The predominant contributor to cancer risks is arsenic. In addition, while not evaluated quantitatively, lead was detected in nine of 15 samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in five of 15 samples at concentrations within and four of 15 samples at concentrations greater than the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

Potential exposure of an adolescent trespasser to surface water and sediment on Parcel B results in a hazard index for noncancer effects in excess of the USEPA acceptable level. The predominant contributors to the hazard index are antimony, arsenic, cadmium, aluminum, and nickel at the maximum detected concentrations in surface water. While the total hazard index for dermal contact with surface water is greater than the USEPA acceptable level, the hazard quotients for the individual chemicals are all equal to (antimony) or less than the USEPA acceptable level. Potential exposure of an adolescent trespasser to surface water and sediment on Parcel C results in a hazard index for noncancer effects in excess of the USEPA acceptable level. The predominant contributor to the hazard index is arsenic at the maximum detected concentration in sediment. In addition, while not evaluated quantitatively, lead was detected in both sediment samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in both sediment samples at concentrations greater than the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

Potential exposure of the future scenario site worker, resident adult, and resident child to groundwater underlying the site results in hazard indices for noncancer effects in excess of the USEPA acceptable level and estimated cancer risks that exceed the USEPA acceptable risk range. The predominant contributors to the hazard indices are 1,2-dichloroethene, arsenic, antimony, trichloroethene, and tetrachloroethene. The predominant contributors to the cancer risks are arsenic and vinyl chloride. While evaluated in the human health evaluation since groundwater is a sole source aquifer, potable use of the shallow groundwater underlying the site in the future is unlikely due to the availability of a municipal water supply. In addition, while not evaluated quantitatively, lead was detected in 46 of 60

groundwater samples in concentrations greater than the USEPA MCL action level for lead in drinking water.

Radiological and Chemical Risk - Despite the differences in the quantitative approach to assessing radiological and chemical carcinogenic risks, it is not inappropriate to sum the risks estimates for populations that may be exposed to both types of contaminants. The resultant combined risks provide the best estimate of the total estimated carcinogenic impact of site contaminants on potentially exposed populations. Potential exposures to the current scenario off-site resident adult, the current and future scenario adolescent trespasser at Area B&C, the future scenario construction worker at Area B&C, and the future scenario site worker, resident adult, and resident child at all areas result in estimated total cancer risks greater than the USEPA acceptable risk range. The predominant contributor (i.e., radiological or chemical) and the predominant environmental medium (i.e., air, soil, or groundwater) to the total estimated cancer risks varies.

Ecological Assessment

The objective of the ecological assessment is to evaluate environmental samples for site-related contaminants, and to estimate any potential risks these contaminants pose to the natural environment. The ecological assessment includes a risk characterization of chemical contaminants in surface water, sediment and surface soil for aquatic, semi-aquatic and terrestrial receptors. Also included is a separate risk characterization for radionuclides occurring in surface water, sediment and surface soil, for aquatic, semi-aquatic and terrestrial receptors.

Chemical stressors were identified within the Site and contaminants of potential concern (COPC) and radionuclides of potential concern (ROPC) were selected. Selection of COPC and ROPC for ecological receptors was based on screening criteria, including maximum site-specific background concentrations and ecological risk-based values derived or obtained from published sources.

Ecologically relevant exposure pathways were identified for the Site. Wildlife near the Site may have incidental contact with or ingest contaminants while foraging, nesting, or

engaging in other activities in the terrestrial portions of the Site. Chemical contaminants can also adversely affect plants and animals in surrounding habitats via the food chain. Contaminants in surface water may be taken up by aquatic life as well as semi-aquatic and terrestrial wildlife. Detrimental effects in vegetation, invertebrates, fish, small mammals, birds and carnivores were selected as the assessment endpoints for the ecological assessment. Receptor species chosen were considered representative of the local wildlife populations that would use and frequent the Site. The receptors chosen are as follows: aquatic invertebrates, fish, reptiles and amphibians; mallard; meadow vole; raccoon; herbaceous terrestrial vegetation; American robin; deer mouse and; red fox.

Exposure media of ecological concern include surface soils, surface water and sediment. Maximum exposure point concentrations were considered for terrestrial and semi-aquatic wildlife receptors, to provide a conservative estimate of exposure. A maximum exposure scenario was also considered for benthic invertebrates, other aquatic biota and terrestrial vegetation, because they are either immobile or have limited mobility.

Dietary exposure and exposure from ingestion of soil/sediment and water for each wildlife species were calculated using equations derived from USEPA's "Wildlife Exposure Factors Handbook". Radiological exposure for aquatic organisms was calculated based on methodology contained in "Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment". Separate calculations were performed for internal and external dose rates. Estimation of radiation doses to semi-aquatic and terrestrial ecological receptors were conducted using equations adapted from the Hanford Site Ecological Risk Assessment prepared for the U.S. Department of Energy.

Toxicity reference values (TRVs) were derived for aquatic life, plants and terrestrial invertebrates based on available criteria, guidelines and toxicity data. TRVs for mammals and birds were derived based on an accepted methodology in the scientific literature. This general method is based on USEPA methodology for deriving human toxicity values from animal data. In this method, experimentally derived No Observed Adverse Effect Levels (NOAELs) for Lowest Observed Adverse Effect Levels (LOAELs) are used to estimate NOAELs for wildlife by adjusting the dose according to differences in body size. Radiation doses to aquatic organisms for each of the ROPC were compared with the benchmark dose

of 1 rad/d suggested by the National Council on Radiation Protection and Measurements as protective of aquatic organisms. Radiation doses for each of the ROPC were compared with the benchmark dose of 0.1 rad/d suggested by the International Atomic Energy Agency as protective of terrestrial organisms.

The Hazard Quotient (HQ) method was used to characterize risks to receptor species. The HQ method characterizes possible ecological hazard as the ratio of the concentration in the environmental medium (or the total estimated exposure) to the corresponding TRV. If an HQ exceeds one, there is concern for possible adverse effects. If an HQ exceeds 10 (i.e., if the environmental concentration or estimated exposure concentration exceeds the TRV by more than an order of magnitude), a more definitive probability of risk is present.

For the chemical risk characterization, most of the COPC in surface water had HQs that exceeded ten. In sediment, HQs for acetone, PCBs and six inorganic COPC exceeded 10. HQs for the mallard were greater than 10 for 4,4'-DDE, 4,4'-DDD and eight inorganic COPC. HQs for the raccoon exceeded 10 for PCBs and 16 inorganic COPC. Terrestrial plant HQs were greater than 10 for 15 COPC and earthworm HQs were greater than 10 for seven inorganic COPC. For the American robin, HQs were greater than 10 for PCBs and 13 COPC. HQs for the deer mouse and the red fox were greater than 10 for PCBs and 18 inorganic COPC. Based on use of the 95% UCL soil concentrations, HQs for the robin exceeded 10 for seven inorganic COPC, HQs for the mouse exceeded 10 for PCBs and 12 inorganic COPC and HQs for the fox exceeded 10 for PCBs and 14 inorganic COPC.

Acetone, 4,4'-DDE, 4,4'-DDD and 4,4'-DDT are most likely not major contributors to the overall risk at the Site, since the HQs for these COPC only exceeded 10 in surface water and/or sediment. The remaining COPC, particularly arsenic, copper, lead, nickel, selenium and zinc, exhibit high HQs (> 10) for most of the receptors chosen for the Site.

With regard to the radiological risk characterization, none of the radionuclides evaluated in surface water, sediment or surface soil posed potential risks.

SUMMARY AND CONCLUSIONS

Nature and Extent

Many of the contaminants that were found occurred in areas that were known or suspected to have contamination. A recurring pattern is evident by examining where individual constituents in each of the five main analytical parameter groups (e.g., inorganics, radionuclides, SVOCs, VOCs and pesticides/PCBs) were detected at concentrations exceeding either USEPA soil screening values or NYSDEC guidance values. The pattern that recurs is that several of the same areas repeatedly show exceedances for more than one constituent group. For example, in the middle portion of Parcel B, the concentration of SVOCs, pesticides/PCBs, inorganics and radionuclides all exceed regulatory guidance levels; in the upper and lower portions of Parcel C, the concentration of SVOCs, inorganics and radionuclides exceed regulatory guidance levels. Other areas which also exhibit exceedances but for only one or two analytical groups include: the northwest corner of Parcel A (outside of the fence) near the intersection of Herb Hill Road and Dickson Lane (inorganics and radionuclides); the bulkhead area (radionuclides); and the area between the Dickson Warehouse and the Benbow Building (inorganics and radionuclides). VOCs were only found in very low concentrations in the soils along Herb Hill Road on Parcel A and the lower portions of Parcel B.

A similar distribution pattern was also seen in the groundwater. The areas where contamination was found included an area on Parcel C and C′ north of the Mattiace Petrochemical Site (VOCs, SVOCs, pesticides/PCBs and inorganics); the lower portion of Parcel C in the vicinity of the 500,000-gallon aboveground fuel oil tank, Mud Pond and the two Mud Holes (VOCs, SVOCs, pesticides/PCBs, inorganics and radionuclides); and the middle portion of Parcel A/lower portion of Parcel B (VOCs, inorganics and radionuclides). Other areas where contamination was found included the middle portion of Parcel B (VOCs); the bulkhead area (SVOCs); the upper portion of Parcel C (radionuclides).

Fate and Transport

Several processes appear to be responsible for the transport and fate of organic and inorganic compounds in the various environmental media at the Site. Evidence indicates that advection, dispersion and facilitated transport are major mechanism for transport of

compounds. Preferential flow along flow paths adjacent to man-made subsurface infrastructure such as storm sewer lines amplifies the affect of these mechanisms. Biodegradation of some organic compounds, and sorption of organic and inorganic compounds with affinity for the surfaces of immobile soil particles seem to be important mechanisms for their attenuation.

The low frequency of detection of VOCs indicates that their transport and degradation are likely. Many of the VOCs detected were found at low concentration, and given the general biodegradability of these compounds, it is likely that biodegradation is a major mechanism for their removal. The data on SVOCs indicate that lower molecular weight compounds are transported and biodegraded, but higher molecular weight compounds are sorbed and subsequently attenuated on immobile soil particles.

A comparison of data from filtered and unfiltered groundwater samples indicate that facilitated transport is a major mechanism for transport of metals. Complexation and solubilization leading to transport of metals by advection and dispersion appears to occur but to a lesser degree than facilitated transport. The transport mechanism affecting metals will also influence radionuclides but to a lesser extent due to the low solubility of the radionuclides.

Recommendations for Future Work

The quality of the data collected during the RI at the Site is sufficient to have characterized the Site for the purposes of preparing a FS which will identify an environmentally sound and cost-effective Remedial Alternative(s). Additional studies may be necessary as part of the FS in order to properly Remedial Alternatives including:

- Additional soil and groundwater sampling to evaluate natural attenuation of contaminants at the site;
- Treatability studies for chemically- and/or biologically-based remedial technologies;
- Treatability studies for solidification/stabilization of soil contaminated with hazardous or radiological waste, or residual tungsten ore prior to land disposal;

- Groundwater modeling to delineate groundwater contaminant plumes, and to predict fate and transport of contaminant plumes.

Following completion of the FS for this Site, is may be necessary to collect additional pre-design data to design and implement the selected Remedial Alternative(s). The information which will be required will vary, based on the nature of the selected Remedial Alternative(s). Depending on the selected Remedial Alternative, the following pre-design activities may be required:

- Sampling from selected perimeter wells to confirm the horizontal extent of the groundwater contaminant plume immediately prior to application of a remedy;
- Installation and sampling of additional monitoring wells to confirm the vertical extent of the contaminant plume immediately prior to application of a remedy;
- Installation of interceptor trenches or other passive collection systems.

Preliminary Remedial Action Objectives

As stated in the NCP, the selected Remedial Alternative should be protective of human health and the environment, maintain the protection over time, and minimize the amount of untreated waste (40 CFR, Part 300.430). CERCLA, Section 121, includes a preference for remedial actions that permanently and significantly reduce the volume, toxicity, or mobility of the hazardous substances, pollutants and contaminants as a principal element. CERCLA, Section 121, also requires that remedial actions meet any federal standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate requirements (ARARs). If state ARARs are more stringent than federal ARARs, then the state ARARs must be met. CERCLA, Section 121, also identifies six circumstances in which ARARs can be waived. ARARs can be contaminant-specific, action-specific, or location-specific.

As outlined in the Work Plan (Malcolm Pirnie, 1993), the FS for the Site will evaluate a range of appropriate remedial alternatives for the Site. The first step of the FS will be to develop Remedial Action Objectives for the Site based on ARARs; non-ARARs which

are to be considered materials (TBCs), including NYSDEC TAGMs; and the potential risks to human health and the environment posed by the Site. The Remedial Action Objectives will be as specific as possible without limiting the range of Remedial Alternatives which can be developed during the FS. Remedial Action Objectives will be developed for each media of concern, including surface and subsurface soils, groundwater, surface water and sediment.

Based on the nature of the Site, Remedial Action Objectives are likely to include the items listed in the conclusions and recommendations section above.

- Excavation and disposal of ore residues on Parcels B and C;
- Removal and disposal of ore residues being stored in the Dickson Warehouse;
- Excavation of contaminated soils;
- Monitoring of natural attenuation of contaminants in soil and groundwater;
- Application of an in-situ remedy for soil and groundwater contamination to meet ARARs and to be protective of the human health and the environment.

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1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

The purpose of this Draft Final Remedial Investigation (RI) Report is to present and evaluate the results of the RI performed at the Li Tungsten Superfund Site (hereinafter referred to as the Site), Glen Cove, New York. The RI was performed by Malcolm Pirnie, Inc. (Malcolm Pirnie) on behalf of the United States Environmental Protection Agency (USEPA), Region II under the Alternative Remedial Contracting Strategy (ARCS), Contract Number 68-W9-0051, Work Assignment Number 025-2L4L. The RI was performed in accordance with the approved RI/FS Work Plan (Malcolm Pirnie, 1993) to characterize the nature and extent of contamination associated with the Site and to assess the risks posed to human health and the environment by the presence of that contamination. In addition, the RI provides sufficient information to subsequently perform a Feasibility Study (FS).

1.2 SITE BACKGROUND

1.2.1 Site Description

The Site is located at 63 Herb Hill Road in the City of Glen Cove, Nassau County, Long Island, New York. A regional map and a Site location map are provided in Figures 1-1 and 1-2, respectively. The geographic coordinates of the Site are latitude 40^0 51' 36" North and longitude 73^0 38' 25" West. Also located on Figure 1-2 is several other hazardous wastes sites including the Mattiace Petrochemical National Priorities List (NPL) site, the Konica Imaging, USA, Inc., property (formerly known as both the Powers Chemco and the Columbia Ribbon and Carbon Company) and the Crown Dykman site. Another hazardous waste site, the Captain's Cove site, is located 0.5 miles to the west but is not shown in the area depicted on Figure 1-2. The current status of the investigations or remediation at each of these sites is described in more detail in Section 1.4

The Site is approximately 26 acres and consists of four parcels designated A, B, C and C'. For the purpose of this Report, the study area is defined as the entire 26 acres. The location of

Parcels A, B, C and C' and the significant Site features on each parcel are shown on the site plan, Figure 1-3. A larger size drawing of the Site plan is also presented on Plate 1.

Parcel A is approximately seven acres and served as the main operations center when the Site was active. Parcel A is bounded by Herb Hill Road on the north, Garvies Point Road on the west, an adjoining property on the east, and Glen Cove Creek on the south. Historically, Parcel A contained the majority of buildings and structures (mostly aboveground tanks). Until 1995, Parcel A contained numerous drums and crates of processed tungsten ore residues. The ore residues were relocated in 1995 -1996 to the Dickson Warehouse on Parcel C as part of a second set of interim remedial actions (IRAs) conducted at the Site. A discussion of completed IRAs and ongoing removal actions at the Site is presented in Section 1.3.

Parcel B is approximately six acres and is located north of Parcel A across Herb Hill Road. Parcel B is bounded by Herb Hill Road on the south, Dickson Lane on the west, The Place on the north, and an adjoining property (Konica Imaging USA, Inc., formerly Powers Chemco) on the east. Parcel B is undeveloped but contains a small pond, an intermittent stream and a small wetland. Two separate areas on Parcel B, south of the pond and directly opposite the Benbow Building were used as parking areas when the Site was active. The northernmost area of Parcel B was used an employee picnic area (Personal communication, 1996). The area between the two parking areas was used for disposal of ore residue. This disposal area has been referred to in previous reports (Hart, 1990; NUS, 1989, 1990a, 1990b) as a "landfill". Observations of partially buried drums and mounds of ore residue made during the field investigation confirmed that disposal activities have taken place in this portion of Parcel B.

Parcel C is the largest of the three parcels, approximately 10 acres. It is bounded by Dickson Lane on the east, Garvies Point Road on the south, an adjoining property to the southwest, and Parcel C' to the northwest and north. Parcel C contains two buildings (the Dickson Warehouse and the Benbow Building), a 500,000 gallon aboveground fuel oil tank, two additional aboveground storage tanks (one hydrogen tank that was reportedly never placed into service and a propane tank), and three surface impoundments (one lined impoundment called Mud Pond and two unlined structures called "Mud Holes". All of the tanks currently on Parcel C are scheduled for removal by the end of the Summer 1998 as part of the USEPA's ongoing removal action at the Site (refer to discussion in Section 1.3.5).

The present Site owners, the Glen Cove Development Corporation (GCDC), acquired approximately four acres of undeveloped property adjacent to Parcel C sometime after 1984. This area has been designated Parcel C′. It is bounded in part by Dickson Lane and Parcel C on the east, two adjoining properties (including the Mattiace Petrochemical site) on the south, Garvies Point Preserve on the west, and a housing complex and another private property on the north. Parcel C′ was not part of the Site during active operations.

1.2.2 Site History

This Site has a complex history of name and ownership changes. Beginning in 1988 and continuing through the present, the Site has been the subject of several environmental site assessments, investigations and removal actions. Specific details are discussed in the paragraphs below. The chronological history of Site ownership, operations, previous investigations, interim remedial actions and removal actions is summarized in Table 1-1.

Early in the 1940's the National Reconditioning Company (NRC) was formed by Kuo Ching (K. C.) Li. NRC was operated and managed by the Wah Chang Trading Corporation, a company which K.C. Li had formed in New York in 1916. In addition to being the chairman and chief engineer of Wah Chang Trading Corporation, K. C. Li was also a distinguished mining engineer, who was credited with the discovery of tungsten in China, and as being the first to import tungsten into the United States. The initial purpose of NRC was to act as Wah Chang Trading Corporation's "operating affiliate" in purifying through smelting, refining, or other treatment off-grade tungsten ores under tolling arrangements with the U.S. Government to support the nation's defense needs. Following World War II, ores were processed at the Site through tolling agreements with both U.S. government entities and private companies (see below for more on tolling agreements).

The Site facility, which became substantially operational in October 1942, was primarily built on land acquired by the Defense Plant Corporation (a World Was II-era agency of the U.S. Government) from Wah Chang Trading Corporation in August 1942. The facility's operation initially consisted of processing of tungsten ore and scrap tungsten to produce ammonium paratungstate (APT) and the formulating of APT into metal tungsten powder and tungsten carbide powder. Other specialty products that were produced included: tungsten carbide powder for plasma spraying; tungsten titanium carbide powder; tantalum carbide powder; tungsten spray

powder; crystalline tungsten powder; and molybdenum spray powder. Beginning in 1945, the facility's capacity was expanded through the direct efforts of the Defense Plant Corporation to provide for processing of antimony (sulfide) ore concentrates into pure antimony metal.

Based on available information, a variety of extraction processes (or treatments) were used to separate the various accessory metals (or other impurities) from the tungsten or antimony depending upon the specific type of ore or concentrate. The smelting or refining was generally conducted in relatively small batches, to permit any individual or combination of extraction treatments. Typical treatments in the smelting process included physical, chemical and mechanical processes such as: sizing and crushing; gravity, magnetic and electrostatic separation; roasting; leaching; floatation; and fusion.

Numerous aboveground wooden, steel, or fiberglass tanks were used in performing some of these treatments and to store reactants (e.g., hydrochloric acid, ammonia, *sodium hydroxide*) and/or intermediate compounds (e.g., APT). As the ore concentrates moved through its various processing stages, radioactive isotopes of thorium, uranium, and radium naturally-occurring in the ore became more concentrated in the residue or slag. Accessory metals which constitute the impurities that were removed during the extraction process included: antimony, arsenic, barium, bismuth, copper, cobalt, chromium, lead, manganese, mercury, molybdenum, nickel, thorium, uranium, vanadium and zinc.

In 1948 the National Reconditioning Company changed its name to Wah Chang Smelting and Refining Corporation (WCSRC), and in 1949, its affiliate Wah Chang Trading Corporation changed its name to Wah Chang Corporation (WCC). WCSRC continued to operate the Site until 1964 when it fully leased the Site equipment and real property to WCC. WCC may have leased equipment and real property from WCSRC for purposes of operating at the Site as early as 1951. In 1967, WCC was acquired by and made a wholly-owned subsidiary of Teledyne, Inc., and in 1969 WCC was merged into Teledyne. From 1969 to December 1971 when Teledyne terminated its lease with WCSRC for the Site, the Site was operated by Teledyne as the Teledyne Wah Chang Glen Cove Tungsten Chemicals & Reduction Plant.

In 1972, after termination of its lease with Teledyne, WCSRC formed a wholly-owned subsidiary, Li Tungsten Corporation, which continued to operate the facility. In 1984, the Site property was acquired by the Glen Cove Development Company (GCDC). GCDC continued to lease the Site to Li Tungsten Corporation until 1985 when Li Tungsten Corporation ceased

operations at the Site and filed for bankruptcy. There are indications that Li Tungsten Corporation may have reconstituted itself as Buffalo Tungsten, Inc. In Depew, New York in 1986. In addition to sharing common ownership and management with WCSRC, Buffalo Tungsten (a subsidiary of Cleveland Tungsten, Inc. from 1987 to 1997) purchased and removed from the Site facility in 1987 certain equipment and inventory needed for the processing of tungsten ore.

Under a typical tolling agreement, throughout the treatment process carried out at the Site facility the supplier of the tungsten or antimony ore retained ownership of the ore, including its refined concentrates and residual waste. Through such an arrangement, the supplier of ore would receive the refined tungsten or antimony product, and the Site facility operators would dispose of the waste constituents on behalf of the supplier. In addition to tungsten and antimony ore that they may have themselves owned, NRC/WCSRC/Li Tungsten Corporation or Wah Chang Trading Corporation/WCC processed tungsten or antimony ore through tolling agreements with a number of U.S. Government and non-U.S. Government entities, including among potentially others: Metals Reserve Company of the Defense Plant Corporation (later Office of Metals Reserve of the Reconstruction Finance Corporation, General Services Administration); Department of Defense; W.R. Grace & Company; Kennametal, Inc.; China National Metals and Minerals Import and Export Corporation (Minmetals); Chi Mei Corporation (Chi Mei Metals Corporation); American National Carbide; and H.R. Taylor Company, Inc.

Specific information regarding waste volumes generated or waste disposal practices at the Site is still being developed by the USEPA, particularly with regard to tolling arrangements. It is known, however, that some waste from the Site, including radioactive waste, was taken to a nearby municipal dump that later began to be developed as the Captain's Cove Condominium project (Hart, 1989). Drummed waste was reported to have been buried on-site in a portion of Parcel B (NUS, 1989, 1990). Numerous partially buried drums are visible at the ground surface on Parcel B. Liquid wastes are believed to have been disposed of through numerous subsurface drainage pipes that have been noted in the bulkhead and empty directly into Glen Cove Creek. SPDES permits allowed for up to as many as 250,000 gallons per day of discharge to Glen Cove Creek. The Mud Pond and the two Mud Holes were also reportedly used to dispose of liquid wastes.

On April 14, 1989 the USEPA received a request from the NYSDEC to use its Superfund authority to respond to threats posed by hazardous materials at the Site. USEPA's preliminary

assessment and site inspection (NUS, 1989; 1990), revealed a large quantity of ore residues that were the source of low-level beta-gamma radiation. In addition, large quantities of laboratory reagents, various hazardous materials in drums and tanks, asbestos, transformers, and cylinders containing compressed liquids and gases were found in several buildings. Air monitoring showed no dangerous levels of organic compounds either on-site or off-site. As a result of the conditions identified at the Site, the USEPA issued an Administrative Order on Consent (AOC) to GCDC in July 1989 to address some of the most serious chemical and radiological hazards at the Site and to stabilize all potential threats to the public and the environment.

The results of Preliminary Assessment (PA) and Site Inspection (SI), conducted by the USEPA (NUS, 1989; 1990), indicated continued possible human health and environmental threats from the radioactive and chemical sources and potential soil, groundwater, and Glen Cove Creek sediment contamination with organic and inorganic hazardous substances.

In July 1991, USEPA proposed that Li Tungsten be included on the NPL after the Site scored a 50 in the hazard ranking score (HRS) (NUS, 1991). A score of 50 is above the threshold value of 28.5 needed for eligibility for NPL listing.

1.2.3 Production Processes

Early Operations - Antimony Smelting and Extraction of Tungsten

Early site operations included antimony smelting, and several processes for the extraction of tungsten from various concentrates. The processes included magnetic separation, floatation and roasting. Waste residues from the antimony smelting included an iron sulfide material (commonly referred to as matte) that also contained unreduced antimony, lead and arsenic. The matte material was dumped on the lower portion of Parcel C where is was readily disintegrated by weathering yielding very corrosive by-products. These corrosive by-products may have ultimately caused failure of the City's water main under Garvies Point Road. The antimony smelting operation ended in the late 1940's.

Magnetic separation was used to process ore concentrates containing mixtures of wolframite, scheelite and cassiterite. A low intensity magnetic separator (called a Bings-Norton machine or BN separator) was used to remove the highly magnetic tungsten ores. The residue left over consisted of mixed iron oxides and sulfides, occluded amounts of wolframite and scheelite, and some arsenic. The BN residue material was disposed of on the upper portion of

Parcel C, west of the Benbow Building. Floatation was used to remove sulfides from the tungsten concentrates that could not be removed by roasting. Waste residues which contained sulfides were dumped on the lower portion of Parcel C, at Captain's Cove and on Parcel B. The entire floatation operation was dismantled sometime during the 1960's. Roasting operations were conducted in the Herreshoff furnaces in the Benbow Building. Use of the furnaces was intermittent to correspond with the supply of feed material. Maintenance was both extensive and expensive. Gases, dust (arsenic oxide) and fumes were exhausted through a cyclone collector for recovery in a bag house dust collector. The arsenic oxide was collected in drums for off-site disposal.

Processing of Tungsten Concentrates for Government Stockpile

When the Korean War began, the site began processing off-grade tungsten concentrates for government stockpile. The scheelite tungsten concentrates originated from Kings Island, Australia and contained 1 - 1.5% of molybdenum; government stockpile specifications called for less than 0.5% molybdenum. The molybdenum could only be removed by chemically precipitating molybdenum trisulfide from a sodium tungstate solution. Hot concentrated hydrochloric acid was used to convert the scheelite to insoluble tungstic acid. The soluble calcium chloride was removed by washing. The washed tungstic acid was then dissolved with caustic soda to form sodium tungstate. Hydrochloric acid was then added in a closed agitated wooden tank to precipitate the molybdenum as molybdenum trisulfide. The molybdenum trisulfide was removed by filtration and then it was dumped at Captain's Cove. At some later time, the precipitate was drummed and stored in the warehouse for possible reclamation of molybdenum. The tungsten filtrate was pH adjusted with caustic acid to precipitate artificial scheelite. The artificial scheelite was placed in a kiln to produce scheelite nodules.

Bismuth Smelting

Some of the scheelite concentrates received from South Korea also contained bismuth. The smelting process for bismuth was similar to antimony, therefore, the idle antimony equipment was reactivitated. The first step was an iron precipitation process where bismuth sulfide reacts in the molten state with metallic iron to produce iron sulfide or matte. The matte was collected, solidified and dumped in the lower portion of Parcel C where it rapidly disintegrated. The crude

bismuth metal was transferred to a large heated cast iron kettle with a cast iron agitator. Zinc pellets were added to collect gold and silver that was present in the concentrates. After several hours of agitation a zinc dross was removed which contained the gold and silver. The excess zinc was removed by injecting gaseous chlorine into the hot agitated molten bismuth. A chloride dross formed at the surface and was removed which contained zinc chloride and some lead chloride. The refined bismuth was pumped to cast iron molds, weighed, sampled and assayed.

Sodium Tungstate Crystals

Sodium tungstate crystals were produced in an evaporator-centrifuge system located in the western end of the Loung Building. A large state-of-the-art evaporator was capable of producing one ton of crystals per hour. In addition, many tanks were needed to store solutions. Sodium tungstate solution was produced from both wolframite and scheelite; wolframite was caustic pressure digested, scheelite was digested using hot concentrated hydrochloric acid. Evaporation was rapid and the crystals were air-dried in a stainless steel drier also located in the Loung Building. Residues were either dumped at Captain's Cove or saved if the tungsten content was high.

Processing of Scrap Military Ordnance

The testing laboratory at the Site developed a method to reclaim tungsten and cobalt from military ordnance scrap (the core of armor piercing projectiles). Initially, the core of these projectiles was heated to 1,600°C. When cooled, the resultant material was crushed with a 3,000 pound drop hammer that was specifically constructed for this process. The crushed material was then amenable to leaching with hydrochloric acid and yielded a crystalline tungsten carbide. The cobalt precipitate was filtered, dried and sold. The crystalline tungsten carbide was dried and ground in a ball mill to produce a minus 325 mesh powder. The ground tungsten carbide powder was not generally accepted by the carbide industry and the project was abandoned. Later a new approach was adopted for processing this scrap material and is described below.

After World War II, even more sources of cemented tungsten carbide became available as scrap (e.g., cutting tools, dies, aircraft counterweights and ordnance rejects). It is estimated that over one million pounds of scrap were accumulated at the site. German documents obtained during the post war period were translated by the Director of Research, Dr. P. Y. Loung. The

documents referred to the dissolution of heavy tungsten materials by fusion with a molten bath of sodium sulfate at temperatures of about 1,000°C. The molten bath reaction converted the tungsten into sodium tungstate and the base metals into their sulfides. At the completion of the reaction, the molten material was cooled and then crushed for dissolution in water. The resultant slurry was allowed to settle and the clear solution was treated with calcium chloride to precipitate artificial scheelite. The insoluble base metal sulfides were washed to removed the soluble tungstate and the cobalt. Segregation of scrap that did not contain cobalt had little value and was discarded on Parcel B.

Residues that contained cobalt were recovered by treating the produced cobalt sulfide with a controlled oxidizing roast that produced a water soluble cobalt sulfate. The sulfated residue was then subjected to a water leach with the addition of hydrochloric acid. The leached slurry was pressure filtered and the cobalt solution accumulated in rubber lined tanks for precipitation as cobalt hydrates using sodium carbonate and caustic. Several decantation rinses removed the soluble salts and the cobalt hydrate solids were filtered in a large wooden box vacuum filter. The filtered solids were dried and calcined. Additional cobalt was recovered from carbide tool grindings which were extracted by hydrochloric acid leach.

Manufacture of Tungsten Welding Rod and Tungsten Wire

The production of tungsten welding rod and tungsten wire required many steps. The manufacturing method was developed by powder metallurgy. This involved combining additives with a very pure tungsten metal powder so that the final rod or powder would have the desired properties. After the powder was prepared, it was pressed into a bar, placed on an aluminum oxide surface supported by a graphite plate and sintered in a hydrogen atmosphere furnace at 1,500°C. After cooling, tungsten contacts were added to each end of the bar in a hydrogen atmosphere vertical chamber where it was heated to 95% of its melting point. The high temperature volatilized various additives and removed trace impurities. After careful cooling to avoid shrinkage, the untreated contact ends were broken off, the rods were reheated to 1,500°C, and fed into a swagging machine. Repeated swagging resulted in a smaller diameter and longer rod. Once the rod reached the desired thickness, it was subjected to a centerless grind. Thorium oxide was added for welding applications by applying a soluble thorium nitrate. Untreated rod was further swagged until it could be fed through a series of successively smaller diameter dies

to form a tungsten wire. The final steps prior to winding onto spools included chemical cleaning and annealing by reheating.

Production of Tungsten Metal Powder

The production of tungsten metal powder was a labor intensive and repetitive process. Tungsten metal powder was produced from a very pure form of ammonium paratungstate (APT). The APT was converted to a blue tungstic oxide by heating in hydrogen atmosphere at a temperature of 400 - 450°C. The tube furnaces used were designed by Mr. B. L. Benbow. The furnaces were made from a heat resistant alloy and heated externally by gas burners. The furnaces consisted of 12 parallel tubes supported on refractory brick. A recycling system was developed to recover hydrogen which consisted of a low pressure compression followed by heat exchanger cooling and chemical drying.

Production of Tungsten Carbide Powder

Tungsten carbide powder was manufactured by mixing tungsten metal powder with high quality carbon black. Each ingredient was carefully weighed. The mixing was completed in rubber lined batch ball mills with alloy grinding balls for a period of 8-10 hours. After milling, the mixture was placed in covered graphite boats and stoked through molybdenum resistant heated furnaces under a hydrogen protected atmosphere at temperatures ranging from 1,425 - 1,450°C for about two hours. At this temperature the mixture fully reacted to form tungsten carbide. The material was placed in a ball mill to produce a uniform powder. The carbide powder was primarily used for cutting tools and dies after being mixed with cobalt, pressed and sintered.

Production of Tungsten Titanium Powder

Eventually, superior cutting and machining qualities were being obtained from a cemented tungsten-titanium carbide so the facility began a manufacturing process for this product. This process was both very difficult and expensive. It involved an application known as forming a solid solution of the two carbides (e.g., dissolving the carbides in one another). Ingredients included a high quality (in terms of purity and crystal character) titanium oxide, tungsten and high quality carbon black. Weighing of the ingredients was one of the most critical steps. Mixing was

done over a 16-18 hour period in a water cooled rubber lined ball mill using alloy balls. The milled mixture was then charged into graphite crucibles that held 200 pounds of packed mix. The cruicible had screw-on covers that fitted inside a graphite crucible that retained the insulation grade carbon black. High-frequency heating was done at 1,900-2,000°C; cooling took 24-30 hours. The double carbide was then placed in a grind mill to generate a fine powder.

Production of Tantalum and Niobium Metal

Tantalum and niobium metals were produced in high temperature furnaces. Thorium oxide was used as refractory material to pack a one-inch gap between the crucible and fiberglass covered furnace coils. After high temperature vacuum heating, the thorium oxide would shrink and crack into metalized chunks that would have to be replaced. Oftentimes some of the metalized chunks of thorium oxide would fuse to the coils. Sometimes it could be removed in the maintenance shop; other times the coils would be damaged during the cleaning process and were stored in an out-of-the-way location. Later a concrete lined pit was dug for the storage of the thorium oxide material. This pit was located outside the southeast corner of the Office/Laboratory Building.

Swarf Processing

Grindings produced from the finishing of tungsten carbide cutting tools were processed to recover tungsten, cobalt and grinding wheel material (e.g., industrial diamonds). Centerless grindings from thoriated tungsten welding rods were also processed in a similar manner. The material was first dried to burn off cutting oils. The powder was then oxidized to convert the tungsten carbide and other metals to oxides. The oxidized powder was then leached with hot caustic to dissolve the tungstic oxide and form a sodium tungstate residue. The residues were then leached with hot 10% hydrochloric acid. The acid solution contained dissolved iron, cobalt and other acid solubles. The acid solutions were then neutralized with sodium carbonate and caustic to precipitate the cobalt and iron. The solids were then passed through a vacuum box filter, dried and calcined. The solids were then submitted to a violent attriter machine to liberate a slime consisting of titanium and silica oxides. Frequent decanting of the slime left a residue consisting mostly of aluminum oxide, silicon carbide and the fine diamonds. This material was

then sold to a specialist to recover the diamonds. The thorium oxide, however, most likely ended up in the attriter slimes which were discarded on Parcel B.

1.3 Previous Investigations, Interim Remedial Actions and Removal Actions at the Li Tungsten Superfund Site

1.3.1 Environmental Investigations

As discussed in Section 1.2, previous environmental investigations were performed at the Site by the Nassau County Department of Health (NCDOH), the New York State Department of Environmental Conservation (NYSDEC), the potentially responsible parties (PRPs), and the United States Environmental Protection Agency (USEPA). Results of these sampling activities indicated the presence of heavy metals, radioactive isotopes of uranium (^{238}U), thorium (^{230}Th and ^{232}Th) and radium (^{226}Ra and ^{228}Ra), fuel oil constituents, and volatile organics in the groundwater, surface water, sediments and soils. In addition to these previous investigations, removal actions and interim remedial actions (IRAs) were also performed. A summary of these activities is presented below.

1.3.2 First Removal Action: 1990

In response to the USEPA's Order of July 1989, GCDC performed nine actions including: removal of approximately 9,000 lbs. of anhydrous ammonia; removal of 26 gas cylinders; removal of 244 drums of materials including 12 drums containing 113 cubic feet of radioactive thorium metal and other materials; overpacking and removal of 2,500 laboratory containers; draining and removal of 38 PCB transformers; cleanup of a mercury spill in the laboratory building; characterization of various tanks; and other sampling and analyses (asbestos, radiological, creek sediments); and providing 24-hour mobile security patrols of the Site. In compliance with the AOC, GCDC completed the actions in 1990.

1.3.3 Interim Remedial Action: 1995 - 1996

During initial planning activities for this RI, it was determined that existing Site conditions would preclude or make it difficult and unsafe to proceed with the planned field investigation. As a result, the concept of an IRA was developed to stabilize the Site. An IRA

Work Plan (Malcolm Pirnie, 1994) was submitted to the USEPA and approved. The IRA was initiated in August 1995 in two phases. Phase I consisted of the removal of non-hazardous debris and vegetation to allow access to Site areas either during the IRA or the RI, removal of debris from the Dickson Warehouse, and limited exterior asbestos abatement. Phase I was completed in October 1995 and was followed immediately with the start of Phase II. Phase II consisted of structural repairs (roof drainage, barricading or replacing windows and doors) to the Dickson Warehouse, relocation of approximately 3,000-4,000 cubic yards of tungsten ore residue from various locations on Parcels A and C to the Dickson Warehouse, and repair or replacement of approximately 800 linear feet of the Glen Cove Creek bulkhead. Phase II was completed in March 1996.

1.3.4 Subsequent Removal Actions

On January 4, 1996, a leak from a sodium hydroxide (NaOH) aboveground tank on Parcel A overflowed the tank's containment berm and spread in a southerly direction over the asphalt-paved western section of Parcel A. Responders included the Nassau County Fire Marshall, the U.S. Coast Guard, the U. S. Coast Guard Atlantic Strike Team, and a representative from the NYSDEC Spill Response Team. The spill was immediately contained before any liquid reached Glen Cove Creek. The Coast Guard's contractor pumped approximately 5,000 gallons from the tank and disposed of the liquid off-site. Subsequent accumulations in low-lying areas around the tank were collected and disposed of by Malcolm Pirnie as part of the Phase II IRA.

On April 4, 1996, USEPA discovered a leaking above ground wooden storage tank, containing approximately 20,000 gallons of hydrochloric acid (pH = 1.0). The acid from the leaking tank was pumped into four 5,000-gallon holding tanks. Following sampling and analysis of the liquids, the acid was transferred into tanker trucks for disposal. In addition, two nearby wooden tanks were evacuated of approximately 56,000 gallons of acidic liquids and transported off-site for disposal.

1.3.5 Current Removal Activities

The USEPA Removal Action Branch (RAB) initiated a series of removal actions in September 1996. Removal actions have included consolidation and disposal of lab packs containing unknown solid and liquid materials, solidification of radioactive liquid wastes,

disposal of PCB liquids and transformer cases, removal and disposal of approximately 10,000-gallons of an oil/water mixture from the 500,000-gallon aboveground tank on Parcel C, salvage of scrap metal generated from the dismantling of steel tanks, neutralization, removal and disposal of corrosive liquids and residues from tanks, asbestos abatement, and removal and disposal of other hazardous waste and debris. Continued deterioration of the Dice Complex and structural damage as a result of a fire in a portion of the building complex on February 27, 1998 led to the demolition of the Dice Complex by RAB in the Spring of 1998. In addition, the East Building has also been demolished to gain access to the tanks. USEPA removal activities at the Site are expected to be completed in the Summer 1998.

1.3.6 Captain's Cove Focussed Feasibility Study

The USEPA is currently conducting a Focussed Feasibility Study (FFS) to address the radiological contamination at Captain's Cove pursuant to the NPL listing of the Site. The link between the two sites was made based on evidence obtained by the USEPA in 1995 that the previous owners/operators of the Site disposed of tungsten ore residue at Captain's Cove. The Captain's Cove property is considered an adjunct to the Site. A draft FFS Work Plan was submitted the USEPA on June 27, 1997. (Malcolm Pirnie, 1997); field investigation activities were initiated on April 20, 1998.

1.4 Previous Investigations at Nearby Hazardous Waste Sites

1.4.1 Mattiace Petrochemical Superfund Site

The Mattiace Petrochemical Site, is a federal Superfund site located on Garvies Point Road. The northern boundary of the Mattiace site borders the southwest portion of Parcel C'. While operational from the 1960s until September 1987, activities at the Mattiace site included bulking, blending and packaging and distribution of organic solvents. Chemicals of concern at the site include several volatile organic compounds (VOCs). For the purposes of remediation, the USEPA divided the site into a total of six operable units (OU-I - excavation of pesticide hot-spots; OU-II: excavation, off-site treatment and disposal of buried drums; OU-III - extraction/treatment/reinjection of contaminated groundwater; OU-IV - in-situ soil vapor extraction; OU-V - demolition/disposal of existing site structures including aboveground and

below ground storage tanks; OU-VI - pumping/disposal of floating product layer). Remediation has been completed on OU-I, OU-II and OU-V. Remediation on OU-VI was suspended during the construction of OU-III and OU-IV facilities after failing to pump any significant amounts of product.

1.4.2 Captain's Cove Site

The Captain's Cove site, a New York State Superfund site, is located at the western end of Garvies Point Road, approximately 0.5 miles from the western boundary of Parcel A. The Captain's Cove site served as a municipal dump from the early 1960s until the early 1980s. The site has been the focus of several investigations starting in 1981 (LKB, 1984, 1981; CDM, 1985; FPM, 1987; Hart, 1990, 1989; Ebasco, 1995; NYSDEC, 1997; Roux Associates, 1998) to characterize both chemical and radiological contamination present at the site. Radiological contamination at Captain's Cove originated from the (Li Tungsten) Site (Ebasco, 1995) and is, therefore, being investigated by the USEPA as a second operable unit of the Li Tungsten site. An RI to investigate chemical contamination at the Captain's Cove site is being performed through a Consent Order between the State and the City of Glen Cove under the State Superfund program. A Focussed Feasibility Study (FFS) to address the radiological contamination at the Captain's Cove site is being performed by the USEPA as part of the second operable unit of the Li Tungsten site (Malcolm Pirnie, 1997).

1.4.3 Konica Imaging, USA, Inc. Site

The Konica Imaging, USA, Inc. (Konica) site, formerly known as both the Powers Chemco and the Columbia Ribbon and Carbon Company site, is a state Superfund site located at 71 Charles Street. Chemicals of concern at the site include: VOCs including toluene, xylenes, benzene, ethylbenzene in addition to several other VOCs. The southern portion of the site borders on Herb Hill Road and is directly across the street from the eastern end of Parcel A and directly east of Parcel B. Remediation activities in the northern portion of the site (0.8 acres) have included groundwater recovery and treatment, soil vapor collection and treatment, and removal of contaminated soil.

1.4.4 Crown-Dykman Site

The Crown Dykman site, a state Superfund site, is located at 66 Herb Hill Road, directly across the street from the main gate to Parcel A. Dykman Laundry and Cleaners occupied the property from 1932 to 1975. Crown Uniform Service used the premises from 1975 to 1983 to dry clean and service uniforms. Crown Uniform originally used stoddard solvent and later switched to tetrachloroethylene (PCE). Subsequently, other occupants of the property included a wood working company and various automotive companies including an autobody shop. Several underground solvent and gasoline storage tanks and contaminated soils were removed from the property between 1990 and 1994. Remedial investigation activities are presently being conducted at the site by the site owners under an order with the NYSDEC.

1.5 Draft Final RI Report Organization

This Draft RI Report is organized into four volumes. Volume I includes ten (10) sections of text including references and glossaries of abbreviations and acronyms, radiological terms and risk assessment terms. Volume II includes all tables, figures and large plates. Volumes III and IV include all appendices. A brief description of each section of text in Volume I follows.

Section 1.0, **INTRODUCTION,** presents a generalized overview of the Site (i.e., background, description, history, previous investigations) as well as a description of the purpose, objectives and organization of this Draft RI Report.

Section 2.0, **STUDY AREA INVESTIGATIONS**, describes each major area of investigation including surface features, surface and subsurface soils, surface water/sediment, groundwater, radiological, ecological and cultural resources that was performed as part of this RI. Most of the field screening data (e.g., soil gas survey, geophysical survey, exposure rate measurements) that was collected during the initial phases of the field investigation and which guided subsequent activities (e.g., location of test pits, soil borings and monitoring wells) is described in this section.

Section 3.0, **PHYSICAL CHARACTERISTICS OF THE STUDY AREA**, utilizes historical data and information gathered during this RI to provide a general description of the physical characteristics of the surface features, meteorology, geology, soil, hydrogeology, demography and ecology (wetlands, fauna and flora).

Section 4.0, **IONIZING RADIATION**, introduces basic radiation facts and describes the biological effects of ionizing radiation relative to natural background radiation levels.

Section 5.0, **NATURE AND EXTENT OF CONTAMINATION**, provides a summary and interpretation of the analytical results obtained during the RI.

Section 6.0, **CONTAMINANT FATE AND TRANSPORT**, provides a general and site-specific discussion of contaminant fate and transport processes.

Section 7.0, **RISK ASSESSMENT**, presents assessments of potential human and environmental health risks associated with the chemicals and radionuclides detected at the Site.

Section 8.0, **SUMMARY AND CONCLUSIONS**, summarizes the discussions provided in previous sections and provides the foundation for future work as preliminary remedial action objectives.

Section 9.0, **REFERENCES,** provides a listing of the references cited in this report.

Section 10.0, **GLOSSARY,** provides a glossary of abbreviation and acronyms, radiological terms and risk assessment terms.

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2.0 STUDY AREA INVESTIGATIONS

2.1 SURFACE FEATURES INVESTIGATION

2.1.1 Topographic Mapping

Aerial photographs were used to prepare a topographic base map of the Site at a scale one inch = 100 feet with a two-foot contour interval. The base map, presented in Figure 2-1, was prepared using existing aerial photographs (1995 series at one-inch = 1,000 feet). Location of horizonal and vertical control points and the elevations of plotted contours were verified in the field in October 1996. The base map shows significant physical features such as surface water bodies, wetlands, roads, buildings, fence lines, and existing utilities. The base map was used in preparing the Site maps presented in this Report.

2.1.2 Surveying

Surveying of new and existing monitoring wells, soil borings, radiological borings, test pits, surface soil, surface water and sediment sample points, and wetland areas was performed in October 1996. Horizontal control points are based on New York State Plane Coordinates (NAD 1983) using horizontal control points KU4736 and KU4756 as shown on the existing base map. Vertical control is based on National Geodetic Vertical Datum (NGVD) 1929 using vertical control KU4736 located at the Glen Cove Fire Department Building. Vertical accuracies are ±0.01 foot for well casings (inner and outer) and ±0.1 foot for ground surface elevations.

2.1.3 Site Clearing

Site clearing activities were performed from August 1 through August 13, 1996 to allow access to sampling locations by truck-mounted and all-terrain vehicle (ATV) mounted drill rigs and support vehicles. Site clearing activities included clearing of small-diameter trees and brush to create access roads and paths around and to the proposed location of decontamination pads, test pits, soil borings and monitoring wells. Location of the major roads and paths are shown on the base map. Selective clearing continued at various times

during the field investigation due to changes in proposed sampling locations that were necessitated by field conditions.

The majority of clearing was required in the northern and central portions of Parcel B and the northern portions of Parcels C and C′. Clearing was performed primarily with chain saws, axes and sledgehammers. All brush and cuttings were left on-site. Front-end loaders and backhoes were also used in areas of dense brush to expedite clearing activities. The removal of trees was avoided whenever possible by diverting the roadways and access routes. All work was performed with protective health and safety OSHA approved equipment including safety goggles, hard-hats, Kevlar chaps and gloves. Power tree pruners were used to obtain the necessary overhead clearance for drill rigs. To gain access to sampling points on Parcels C and C′, a gravel roadway was constructed from a gate on Dickson Lane to the top of Parcel C. The gravel roadway is approximately 12 inches thick and underlain by filter fabric for erosion control and drainage control.

A health physicist or technician monitored both off-site (outside the perimeter fence) and on-site exposure rates with a Ludlum Model 12 ratemeter coupled to a gamma scintillation detector (one-inch by one-inch Sodium Iodide detector) during the clearing activities. Areas exhibiting elevated exposure rates were identified and flagged prior to clearing, and avoided by workers during clearing activities.

2.2 SURFACE AND SUBSURFACE SOIL INVESTIGATION

2.2.1 Geophysical Surveys

An electromagnetic (EM) and a magnetometer survey were performed between April 30 and May 3, 1996 using a Geonics EM-34-3 and a GeoMatrix G-856 survey instrument, respectively. The purpose of the geophysical surveys was to determine the presence and distribution of buried metallic objects (e.g., drums of ore residue) on the Site and to assist in the selection of test pit locations. The EM survey was conducted along three transects between buildings on Parcel A, four north-south trending transects on Parcel B, two transects on Parcel C, and six transects on Parcel C′. The magnetometer survey was only conducted along the four transect lines on Parcel B.

The EM survey was conducted in both the horizontal and vertical modes of operation. The depth of penetration using the vertical mode was approximately 7.5 meters (24.6 feet) and only a few meters (6-10 feet) in the horizontal mode. EM survey measurements were collected at 10 meter (32.8 feet) intervals corresponding to the largest coil spacing. Magnetometer measurements were collected at five meter intervals (16.4 feet). The end of all transect lines were located on a map of the Site by measuring the distance to two established landmarks. Geophysical survey results for each of the four areas surveyed are discussed below. The results of the EM and magnetometer surveys including the location of the transect lines, anomalies and preliminary test pit designations are provided on three plates in Appendix A.

PARCEL A. EM survey data collected on Parcel A indicates that measurements ranged from 33 to 300^{+} millimohs/meter. No anomalies were identified along the three transects. The variability in measurements is attributed to interference caused by the metal tanks and buildings on Parcel A.

PARCEL B. EM survey data collected on Parcel B identified five anomalies (shown on Plates A-1 and A-2 in Appendix A). One anomaly in the southeast corner of Parcel B was reflected in both the vertical and horizontal modes; the other four anomalies were detected on the vertical mode only. Each of the five anomalies were further explored with test pits (TP-1, TP-2, TP-3, TP-6 and TP-7). The results of the test pit excavations are described in Section 2.2.2

The magnetometer survey identified two anomalies: one anomaly occurred near the aboveground tanks in the southwest portion of Parcel B; the second anomaly was located in the central portion of Parcel B near the gate on Dickson Lane. The magnetic anomaly in the central portion of Parcel B (which also coincided with a electromagnetic anomaly) was further investigated with a test pit (TP-3), but the anomaly near the aboveground tanks was attributed to the tanks themselves and, therefore, was not investigated further.

PARCEL C. EM survey data on Parcel C were collected in the vertical mode only. Interference caused by the close proximity of the Dickson Warehouse resulted in survey measurements ranging from 240 to over 300 millimohs/m. The survey was not conducted in the horizontal mode due to the interference induced by the proximity to the building.

PARCEL C'. EM survey data collected on Parcel C' identified two anomalies. One anomaly coincided with a mound of ore residue and could not be investigated further with a test pit because the location was inaccessible. The second anomaly (over 300 millimohs/meter) and did not have any topographic expression, was investigated with a test pit (TP-8).

2.2.2 Test Pits

Seven test pits (TP-1 through TP-7) were excavated on Parcel B and one test pit (TP-8) was excavated on Parcel C between August 13-20, 1996. The location of the test pits were selected to investigate anomalies measured during the electromagnetic and magnetometer surveys (TP-1 through TP-4 and TP-6 through TP-8), and to investigate the vertical limits of a radiological anomaly identified during the exposure rate scanning (TP-5). In the Work Plan, six test pits were estimated, however, a total of eight anomalies were identified in accessible locations from the geophysical surveys and exposure rate scanning. The objectives of the test pit excavations were to determine vertical boundaries of buried wastes (ore residues) or metallic debris, assess changes in soils and aid in the location of radiological soil borings. The location of all test pits are shown in Figure 2-2.

In general, test pits were excavated to the water table or until the maximum allowable extension of the backhoe was reached, whichever came first. Prior to excavation, both the backhoe and backhoe bucket were decontaminated. Test pit excavations measured approximately 10 feet long and two feet wide; depths ranged from 2.5 feet (TP-5) to 13.5 feet (TP-6). Test pits were excavated in one foot increments. Each one foot increment of excavated soil was field screened for volatiles with a HNu photoionization detector (PID) and for radioactivity with a GM pancake detector[1]. A stainless steel bowl and trowel was used to collect the soil sample directly from the backhoe bucket. Samples exhibiting the highest field screening readings or samples containing visible evidence of contamination were selected for laboratory analyses. Test pit samples were analyzed for TAL/TCL compounds, cyanide, radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th and ^{238}U), pH and total organic

[1]The GM pancake detector responds to alpha, beta, and gamma radiation. The background response ranges from 10-50 counts per minute (cpm).

carbon (TOC). In addition, two test pit samples (TP-5 and TP-7) were analyzed for TCLP Parameters.

After sampling was completed, all test pits were backfilled with excavated material. Test pit analytical data are discussed in Section 5.2.1. Test pit logs are formulated in tabular form and presented in Appendix B. Test pit logs include a description of the soils or fill materials encountered with depth, radiological field measurements/soil screening data, samples selected for analysis and general comments. Fill materials were observed in four test pits: TP-1, TP-3, TP-5 and TP-7. No fill materials or debris were observed in TP-2, TP-4, TP-6 or TP-8. An asphalt layer (0.5-inch thick) was observed in TP-3 approximately 4.5 feet below grade and may represent a former employee parking area. TP-1 was located adjacent to a mound (approximately 2.5 feet high) of dark grey ore residue. Fill materials in TP-1 were encountered from the ground surface to approximately three feet below ground surface and included plastic, glass fragments, fiberglass, bricks, wood and charcoal. A steel automotive wheel drum and brake pad that was observed in the wall of the test pit, approximately two to three feet below ground surface, is likely to have generated the geophysical anomaly identified in the EM and magnetometer surveys.

TP-5 was excavated to determine the depth, extent and limit of an area with surface exposure rates up to a maximum of 800 μR/h. Fill materials, observed in the top one foot in TP-5, included glass bottles and metal fragments. In addition, GM pancake measurements were approximately 2,000 cpm within the 0-1 foot depth interval and 1,000 cpm within the 1-2 foot interval. TP-5 was terminated after encountering native material at a depth of approximately 2.5 feet.

The topography of the area near TP-7 indicated probable disposal activities because the area rises approximately four feet above the surrounding grade. Fill materials observed to approximately three to four feet below grade included asphalt pavement, bricks, glass fragments, rubber tires and porcelain dishware. The asphalt pavement (0.5-inch thick) may correspond to the former employee parking lot.

Other significant fill areas were observed during the drilling of radiological borings RT-6 and RT-8. Visual observations indicated that the filled area extends 20 feet further east and to a depth of eight feet (just above the water table). Fill materials encountered included wood, bricks, deteriorated drums and a hot water heater.

Two separate drum disposal areas were also observed west of TP-4 and north of TP-7. Due to inaccessibility, however, a test pit could not be located north of TP-7. A surface exposure rate of approximately 20-50 μR/h was measured at TP-4 and may have been caused by the adjacent drums which exhibited surface exposure rates of 200-400 μR/h.

2.2.3 Surface Soil Samples

Eighteen surface soil samples (SS-1 through SS-18) were collected from September 4-26, 1996 from locations on Parcels A, B, C and off-site. The location of all on-site surface soil samples are shown on Figure 2-3; the location of off-site sample locations are described in Table 2-1. Twelve surface soil samples (SS-1 through SS-12) were collected and analyzed for TAL/TCL compounds, cyanide and radiological parameters. Six surface soil samples (SS-13 through SS-18) were collected from off-site areas and analyzed for radiological parameters. The purpose of surface soil sampling was to determine the risk to plants and terrestrial receptors through ingestion, assess the dermal/inhalation pathway associated with surface soil contaminants (SS-1 through SS-12) and to determine site-specific background radionuclide concentrations (SS-13 through SS-18).

Surface soil samples were collected in accordance with sampling procedures described in the FSP. Surface soil samples were collected using a combination of sampling tools including stainless-steel hand-augers, stainless steel trowels, scoops and scoopulas. The sample fraction for the volatile organics was collected first followed by the fraction for extractable organics, metals, cyanide and radionuclides. The air was monitored using a PID and a GM pancake detector and ratemeter. A summary of all radiological field screening measurements at each surface soil sample location is presented in Table 2-1. All hand-augered sampling locations were backfilled with native materials. Laboratory analytical results of the surface soil sampling are described in Section 5.2.1.

2.2.4 Source Area Borings

Twenty-six source area soil borings were drilled between August 21 and September 25, 1996. The purpose of the source area soil borings was to provide additional information on the vertical limits of buried waste and to reassess the presence, nature and extent of

contamination in the vadose zone that was detected in previous investigations (NUS, 1990). Eight source area borings (SB-1 through SB-8) were drilled on Parcel A; 12 source area soil borings (SB-9 through SB-20) were drilled on Parcel B; and six source area borings (SB-23 through SB-28) were drilled on Parcel C. Of the six borings on Parcel C, three were located in the northwest corner in the area of "scarred vegetation" (NUS, 1990). Three source area borings were located in the southern portion of Parcel C adjacent to the 500,000-gallon aboveground fuel oil tank. The locations of all source area soil borings on Parcels A, B and C are shown on Figures 2-4, 2-5 and 2-6, respectively. A more detailed description of the source area soil borings for each individual parcel is provided below.

Continuous split-spoon soil samples were collected from the ground surface to the water table in two foot intervals. Two soil samples per boring were selected based on field screening results for laboratory analysis. In areas where the water table was within three feet of the ground surface, one sample was collected for analysis. Analytical parameters included TAL/TCL compounds, cyanide, radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th and ^{238}U), pH and TOC. Soil samples (SB-3 and SB-17) were also analyzed for TCLP Parameters. Sample collection procedures were consistent with those presented in the FSP.

Source Area Soil Borings - Parcel A (SB-1 through SB-8)

Source area soil borings (SB-1 through SB-8) were located beneath the paved areas in Parcel A. In general, due to a shallow water table (three to five feet below grade), the borings were drilled to a maximum depth of seven feet. The initial soil sample was collected at variable depths within the upper three feet, depending upon the thickness of the surface cover (asphalt, concrete slab or both) and submitted for laboratory analysis. A second soil sample was collected at SB-2, SB-3, SB-5 and SB-7. The only visible evidence of contamination was found in SB-7 (southeast corner of Parcel A). A thin layer of oil was observed in this sample with a corresponding PID reading of 40-80 ppm at a depth of 3.5-4.0 feet. The geoprobe/soil gas survey also detected petroleum-based constituents at two sampling locations (WS-22 and WS-23) near SB-7. Soil samples collected from all other source area borings (SB-1 through SB-6 and SB-8) exhibited background readings for volatiles (0-5 ppm) and radiation (20-40 cpm).

Source Area Soil Borings - Parcel B (SB-9 through SB-20)

Eight of the 12 source area borings (SB-9, SB-10, SB-11, SB-12, SB-14, SB-15, SB-16 and SB-17) were located on or adjacent to mounds of ore residue that exhibited above background exposure rates in the middle portion of Parcel B. Three source area borings (SB-18, SB-19 and SB-20) were located near the empty aboveground tanks on lower Parcel B. Samples collected from SB-13 at the northern boundary of Parcel B were used to determine site-specific background concentrations.

In general, the highest radiological field screening results observed in soil samples collected on Parcel B were located at the surface (0-2 feet) and near surface (2-4 feet) depths. For example, elevated screening measurements were observed within the upper four feet (e.g., 400 cpm from 0-1 feet in SB-10; 50-100 cpm from 0-4 feet in SB-11; and 500-600 cpm from 0-1.4 feet in SB-15). Surface exposure rate measurements ranged from 25 μR/h in SB-16 to 400 μR/h in SB-17. The highest field sample scan was 500-600 cpm in SB-15, from 0 to 1.4 feet below ground surface.

Soil samples collected from SB-14 and SB-17, exhibited consistently elevated count rate measurements to the bottom (10 feet) of each borehole. Soil samples from SB-14, which was located in an area where drums are visible at the surface, exhibited count rates from 60-100 cpm at each depth interval (0-2 feet, 2-4 feet, etc.). SB-17, which was located in a mound (four feet high) of ore residue, had a 400 μR/h exposure rate at the surface. The highest GM pancake measurement was 500 cpm in the 0-0.5 foot layer. The soil layers from 2-3 feet and 3-4 feet had readings between 200-300 cpm and 400 cpm, respectively. All other soil layers exhibited 60-100 cpm when scanned with the GM pancake detector.

A thin layer of black clay encountered in SB-18 from 0-1 foot, exhibited a count rate of 400 cpm. In SB-19, the soil from 0-0.5 feet exhibited a count rate of 150 cpm. SB-20, had a surface exposure rate of 25 μR/h; the soil from 2-6 feet exhibited 50-100 cpm when scanned with the GM pancake detector.

Source Area Soil Borings - Lower Parcel C (SB-23, SB-24 and SB-25)

Three source area borings were drilled to a maximum depth of six feet inside the berm area around the 500,000 gallon aboveground fuel oil tank. Samples were submitted for laboratory analysis from the 0-2 foot and 2-4 foot intervals in each boring. Radiological and

volatile scanning of soil samples exhibited background conditions (e.g., 20 cpm and 0-5ppm, respectively).

Source Area Soil Borings - Upper Parcel C (SB-26, SB-27 and SB-28)

Three source area borings were drilled to depths ranging from eight feet (SB 27 and SB-28) to 12 feet (SB-26) in the area of "scarred vegetation" on Upper Parcel C. Samples for submitted for laboratory analysis were collected from 0-2 feet (SB-26 and -27); 2-4 feet (SB-28); 4-6 feet (SB-27); and 10-12 feet (SB-26). The soil sample from SB-27 (0-2 feet) was also submitted for TCLP analysis. Slightly elevated volatile readings (10 ppm) were detected in SB-28 at 2-4 feet. Two elevated GM pancake detector readings were recorded in SB-26 from 0-2 feet (80 cpm) and from 10-12 feet (90-100 cpm). Elevated radiological readings were observed in SB-27 (60-70 cpm from 0-2 feet and 50-60 cpm from 2-8 feet).

2.2.5 Storm Sewer Borings

Eleven storm sewer soil borings (SB-29, SB-31, SB-32, SB-33, SB-34, SB-35, SB-36 and SB-37 on Parcel A and SB-40, SB-41 and SB-42 on Parcel C) were drilled between August 27 and September 23, 1996. The purpose of these borings was to assess the extent and potential that storm sewer piping is functioning as a conduit and continued contaminant source to the groundwater and Glen Cove Creek. Originally 15 storm sewer soil borings were planned; however only 11 locations were accessible. The locations of the borings and the associated existing storm sewer pipe locations on Parcels A and C are shown in Figures 2-7 and 2-8, respectively.

Soil sampling procedures were consistent with those presented in the FSP. Continuous split-spoon samples were collected from ground surface to the bottom of the borehole. Each sample was field screened for volatiles and radioactivity. An inspection was performed in the field prior to drilling to determine invert elevation of the pipe and to select the target sampling depth. One sample was collected from each boring at a depth approximately one-foot below the invert elevation of the pipe. Due to a shallow water table on Parcel A, saturated soil samples were collected at some locations. Soil samples were collected and analyzed for TAL/TCL compounds, cyanide, radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th,

^{232}Th and ^{238}U), pH and TOC. Soil samples from SB-40 and SB-41 were analyzed for TCLP Parameters.

Storm Sewer Borings - Parcel A (SB-29 and SB-31 through SB-37)

SB-29 and SB-31 through SB-37 were drilled to a maximum depth of five feet below grade. Soil samples were collected from four soil borings (SB-34 through 37) at 1-3 feet below grade and from three soil borings (SB-29, SB-31, and SB-32) at 3-5 feet below grade. SB-29 is associated with a 12-inch diameter pipe which flows from the southeast portion of Parcel A to Glen Cove Creek. SB-36 and SB-37 are associated with another 12-inch diameter pipe which originates on Parcel B and runs in a southerly direction to Glen Cove Creek. SB-33, SB-34 and SB-35 are associated with a 12-inch diameter pipe that originates near the Office/Laboratory Building and ends at Glen Cove Creek. SB-31 and SB-32 are associated with a 15-inch diameter pipe that runs between the East Dice Building and the Loung Building and terminates at Glen Cove Creek.

The results of field screening for volatiles and radioactivity indicate that all soil samples collected from SB-29 and SB-31 through SB-37 exhibited background conditions. The volatile readings ranged from 0.8 ppm (SB-36) to 12.8 ppm (SB-33). GM pancake detector readings ranged from 10-40 cpm.

Storm Sewer Borings - Parcel C (SB-40, -41, and -42)

SB-40, SB-41 and SB-42 were drilled to a maximum depth of eight feet and are associated with a 24-inch diameter pipe that originates near the Benbow Building on Parcel C and runs south under Garvies Point Road to an outfall at Glen Cove Creek. The results of field screening for volatiles and radioactivity indicate that all soil samples exhibited background conditions. The volatile readings ranged from 0 ppm (SB-40 and SB-41) to 0.2 ppm (SB-40). GM pancake detector screening of soil samples ranged from 20-40 cpm.

2.2.6 Monitoring Well Borings

Fifteen new monitoring wells were installed between August 18, 1996 and October 9, 1996. New monitoring wells were designated "MP" to distinguish them from the existing monitoring wells which were designated either "EMW", "GM" or "MW". The location of

all new and existing monitoring wells are shown on Figure 2-9. The Work Plan called for the installation of up to 16 monitoring wells (10 new locations and 6 replacement locations). Based upon our evaluation of the existing wells and the results of the geoprobe/soil gas survey, the locations of new and replacement monitoring wells were adjusted to maximize coverage across the Site. The rationale for the monitoring well placement is provided in Table 2-2.

All monitoring well borings were drilled using hollow stem augers. Continuous split-spoon samples were collected from the ground surface to bottom of the borehole. In general, the two vadose zone samples from each monitoring well borehole that displayed the highest field screening results were collected for subsequent laboratory analysis. The sample fraction for volatile analysis was collected first. Then the contents of each split-spoon collected from the unsaturated zone were transferred to a stainless steel bowl, homogenized and covered with foil. Each sample was field screened for volatile organics and radioactivity. No samples were collected from either MP-17D or MP-21D, and only one sample was collected at MP-2 and MP-18, because of the high water table. At monitoring well cluster MP-16/MP-16D, two samples were collected from MP-16; no samples were collected from MP-16D.

Split-spoon soil samples submitted for laboratory analysis were analyzed for TAL/TCL compounds, cyanide, radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th and ^{238}U), pH and TOC.

2.3 SURFACE WATER/SEDIMENT INVESTIGATION

2.3.1 Surface Water Investigation

Seven surface water samples (SW-1, SW-4, SW-5, SW-8, SW-9, SW-10 and SW-11) were collected between October 16 and 17, 1996 from surface drainage areas and retainage structures on Parcels A, B and C. The purpose of surface water sampling was to verify previously collected data (NUS, 1990) and to characterize areas not previously sampled (e.g., the intermittent stream and unnamed pond on Parcel C).

Two previous surface water sample locations (SW-2 and SW-3) at the Mud Holes on Parcel C were dry and, therefore, could not be sampled as part of this RI. Previous sample locations designated SW-6 and SW-7 were located in Glen Cove Creek. Sampling of the

creek was beyond the scope of this investigation, therefore, these locations were not resampled either. To avoid confusion with previous sample station designations, sample numbers SW-6 and SW-7 were not reassigned to a new sampling location. Surface water sample numbers SW-2, SW-3, SW-6 and SW-7, therefore, do not appear in any of the figures or summary tables.

SW-1 was collected from an open-topped concrete tank on Parcel A, and SW-5 was collected from the oil/water separator located along the western boundary of Parcel A. Two samples (SW-8 and SW-9) were collected from drainage areas in Parcel B: SW-8 from the unnamed pond in the middle of Parcel B and SW-9 from the swale north of the pond. Two samples (SW-10 and SW-11) were collected from an intermittent stream (drainage ditch) and unnamed pond on Parcel C, and one sample (SW-4) was collected from Mud Pond on lower Parcel C. All surface water sampling locations are shown on Figure 2-10. Surface water sampling procedures were consistent with procedures presented in the FSP. Samples were analyzed for TAL/TCL compounds, cyanide and radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th and ^{238}U).

Field measurements for the surface water investigation are summarized in Table 2-3. The pH ranged from 3.0 to 9.0 in the seven surface water samples measured. The maximum pH (9.0 at SW-1) was recorded from standing water in the open concrete retention tank on Parcel A (Note: the standing water in this tank has since been disposed of by the USEPA-RAB). A pH of 3.0 was measured in the drainage ditch in Upper Parcel C (SW-10 and SW-11). The temperature of the samples ranged from 12°C (SW-1) to 19°C (SW-9). Conductivity ranged from 350 umhos/cm (SW-9) to 2,350 umhos/cm (SW-4).

Two rounds of surface water samples have been collected from Glen Cove Creek as part of the Mattiace investigation. The first round was collected at three locations late in 1990; the second round was collected at four locations in 1995. All samples were analyzed for TAL/TCL compounds; the Glen Cove Creek surface water data is presented in Appendix Q.

2.3.2 Sediment Investigation

Eight sediment samples (SED-2 through SED-5 and SED-8 through SED-11) were collected between October 17-18, 1996. The purpose of the sediment sampling was to confirm previously collected data (NUS, 1990) and to characterize areas not previously sampled. In general, sediment samples were collected from the same locations as the surface water samples, however, samples SED-2 and SED-3 were collected at the two Mud Holes where surface water was not present at the time of sampling. Sediment samples were analyzed for TAL/TCL compounds, cyanide, radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th and ^{238}U), pH and TOC. Sediment sampling locations are also presented on Figure 2-10. Laboratory results of the sediments are discussed in Section 5.3.4.

Two rounds of sediment samples have been collected from Glen Cove Creek as part of the Mattiace investigation. The first round was collected at three locations late in 1990; the second round was collected at four locations in 1995. All samples were analyzed for TAL/TCL compounds; the Glen Cove Creek sediment data is presented in Appendix Q.

2.3.3 Storm Sewer Sediment

Four sediment samples (SED-DP-1, SED-DP-2, SED-DP-3, SED-DP-5, and SED-DP-29) were collected on October 18-22, 1996 from manholes grates in the existing storm sewer system on Parcel A. SED-DP-1 was located in a existing manhole on the 12-inch diameter line near the south-west corner of Parcel A. SED-DP-2 was located at a steel grate location on a 12-inch diameter pipe. SED-DP-3 was located in a steel grate access location upstream of SED-DP-2. SED-DP-5 was located upstream of SED-DP-1 on the same storm sewer discharge line near the above ground open sump tanks of Parcel A. SED-DP-29 was located in an existing manhole on a 12-inch diameter pipe. Storm sewer sediment sample locations are shown in Figure 2-11. Laboratory analytical results of storm sewer sampling are discussed in Section 5.3.4.

2.4 GROUNDWATER INVESTIGATION

2.4.1 Geoprobe/Soil Gas Survey

A geoprobe/soil gas survey was performed between April 30 and May 2, 1996. The purpose of the geoprobe/soil gas screening data was twofold: (1) verify the presence and extent of the volatile organic compounds that were previously detected (NUS, 1990) in the groundwater in four areas of the Site and; (2) assist in the selection of monitoring well locations. The four areas of the Site where volatile organics or petroleum constituents were detected previously correspond to a former dry cleaning service on the north side of Herb Hill Road opposite the main gate to Parcel A and adjacent to the southeast corner of Parcel B (Area 1 on Figure 2-12); the southwest corner of Parcel A (Area 2 on Figure 2-12); the 500,000-gallon aboveground fuel oil tank on Parcel C (Area 3 on Figure 2-12) and the "scarred vegetation" area on Parcel C (Area 4 on Figure 2-12).

A total of 56 samples (49 aqueous and seven soil gas) were collected in the four areas. Due to the shallow water table (e.g, less than three feet below grade on Parcel A), it was impossible to achieve the necessary seal in the borehole to collect soil gas. At these locations, a geoprobe sample of groundwater was obtained in lieu of a soil gas sample (soil gas samples are designated SG; aqueous or water samples are designated WS). A total of seven soil gas samples were collected; aqueous samples were collected at all other locations. Twenty-eight samples collected in Area 1 (WS-1 through WS-11, WS-13 through WS-18, and WS-24 through WS-31) were located in the northeast portion of Parcel A. Six samples (WS-12 and WS-19 through WS-23) were collected in the southwest corner of Parcel A. Eleven samples (WS-32 through WS-42) were collected from lower Parcel C; eight samples (SG-43, SG-44, SG-46 through SG-50 and WS-45) were collected from the "scarred vegetation area, and three samples (WS-53 through WS-55) were collected between Areas 3 and 4. The location of all sampling points and the four study areas are shown on Figure 2-12. All samples were analyzed for eight target compounds: trichloroethene (TCE), trans-1,2-dichloroethene (trans-1,2 DCE), tetrachloroethene (PCE), 1,1,1-tetrachloroethane (1,1,1-TCA), benzene, toluene, ethylbenzene and (total) xylene.

At some locations it was necessary to core through concrete and/or asphalt. Generally, paved areas were cored in Parcel A and included concrete and/or asphalt subgrade

of varying thickness. At some locations (SG-43, SG-44, WS-45 and SG-46 through SG-50) manual sampling methods and portable sampling equipment were used due to inaccessibility. Decontamination of soil gas sampling equipment was performed in accordance with the procedures outlined in the FSP. The open holes generated by the geoprobe/soil gas survey were backfilled with bentonite and a concrete patch was used to cap holes through paved areas. Geoprobe/soil gas sampling results are described below.

Trichloroethene (TCE)

TCE was detected in 44 of 49 aqueous samples and three of the seven soil gas samples. In the aqueous samples TCE ranged in concentration from 0.02 µg/L (WS-32) to 198.76 µg/L (WS-5). In the soil gas samples, TCE detected ranged in concentration from 0.02 µg/Kg (SG-48) to 0.08 µg/Kg (SG-44). The largest areal extent and highest concentrations were detected in the northeast portion of Parcel A centered around sampling location WS-5 (198.76 µg/L). The affected area extends to the west and north of WS-5. The measured concentration of TCE decreases to the south (in the direction of Glen Cove Creek); toward the southwest corner of Parcel A (WS-22); and toward the southwest corner of Parcel B. Isoconcentration lines for TCE are presented in Figure 2-13. These data confirms previous findings by others (G&M, 1988, NUS, 1990) regarding high VOC concentrations in the shallow groundwater in the southern part of Parcel B the northern portion of Parcel A.

Tetrachloroethene (PCE)

PCE was detected in 43 of the 49 aqueous samples and six of seven soil gas samples. In the aqueous samples, PCE ranged in concentration from 0.03 µg/L (WS-39 on Parcel C) to 189.30 µg/L (WS-5 on Parcel A). In the soil gas samples, PCE ranged in concentration from 0.04 µg/Kg (SG-50) to 0.33 µg/Kg (SG-44). Concentrations of PCE occur in three areas: the northeast section of Parcel A around WS-5 (189.30 µg/L); in the southeast corner of Parcel A at WS-22; and in the southwestern corner of Parcel B at WS-24 (59.26 µg/L). Isoconcentration lines for PCE are presented in Figure 2-14.

Benzene, Toluene, Ethylbenzene and Xylene (BTEX)

BTEX compounds (benzene, toluene, ethylbenzene and total xylene) were detected in 5 of 49 aqueous samples. BTEX concentrations were calculated by summing the measured concentrations of the four constituents. The highest total BTEX concentration (77.55 µg/L) was detected at WS-40 near the 500,000-gallon aboveground fuel oil tank. Lower BTEX concentrations (10.69 µg/L) were also detected at WS-23 in the southwest corner of Parcel A and at WS-28 in the southwest corner of Parcel B (2.45 µg/L xylene). The distribution of BTEX compounds is presented in Figure 2-15. BTEX concentration data observed at WS-23 and WS-22 (free product) support previous reports of petroleum constituents detected in the southeast portion of Parcel A (G&M, 1988).

1,1,1-Trichloroethane/trans-1,2-Dichloroethene

1,1,1-TCA was detected in 2 of the 49 aqueous samples: WS-5 (10.04 µg/L) and WS-3 (0.38 µg/L) on Parcel A. Trans-1,2-DCE was detected in 3 of 49 aqueous samples: WS-14 (2.97 µg/L) and WS-20 (0.63 µg/L) on Parcel A and WS-54 (1.73 µg/L) on Parcel C. The distribution of 1,1,1-TCA/trans-1,2-DCE is presented in Figure 2-16.

2.4.2 Evaluation of Existing Monitoring Wells

During February and March 1996, the condition of 26 existing monitoring wells was evaluated. Existing monitoring wells were installed as part of at least three earlier investigations and, therefore, had been designated "GM", "EMW" or "MW".

The evaluation process consisted of three general tasks: locate the wells; inspect the physical condition; and perform a slug test to evaluate the condition of the bentonite seal. Three wells (EMW-2, GM-6 and GM-16) could not be located or were known to have been irreparably damaged. The physical condition of the remaining 23 wells was then evaluated based on the condition of the cement apron, the PVC riser, the protective steel casing or flush mount curb box, and the expansion cap and lock. Based upon the physical inspection, five wells (EMW-3, EMW-5, GM-3D, GM-5 and GM-17) were abandoned. The reasons the wells were abandoned included: unsuitability for sampling (1.5-inch diameter); damage to the cement apron from frost heave; or damage to the flush-mount housing. Existing well GM-4, constructed with 1.5-inch diameter PVC, was in good condition and maintained for

use as a piezometer. Six wells (GM-1, EMW-1, GM-2, EMW-4, GM-14A and GM-14B) required rehabilitation (e.g., replacing the protective steel casing or flush mount covers, extending the PVC risers, replacing the expanding caps, and reconstructing the concrete apron). New locks were placed on all of the monitoring wells remaining in use.

Rising head slug tests were performed on 18 monitoring wells to determine the condition of the bentonite seal around the well casing. The rising head test consisted of inserting a slug (sand filled PVC pipe) into the water column of the test well and allowing the water level to return to equilibrium. Once the initial water level was reached, the slug was removed from the water column causing the water level to drop. The rate of the subsequent rise of the water level as it approached equilibrium was measured. These data were analyzed to evaluate the integrity of the seal above the gravel pack.

Based upon the slug test data, the integrity of the bentonite seal in 12 monitoring wells was not compromised. Slug test data was not evaluated on six wells for the following reasons: the water level recovered too quickly (GM-8 and GM-11); a strong hydrocarbon odor indicated the possibility of free product (MW-8D, MW-10 and GM-14B); and insufficient water in the well (MW-8S). Observations made during the performance of the slug tests such as slow recovery rates and a build-up of fine material at the bottom of several wells, however, suggested that all of the wells should be redeveloped. Redevelopment procedures are discussed in Section 2.4.5. Slug test data collected during the evaluation of existing monitor wells are provided in Appendix C.

2.4.3 Ammonia Headspace Measurements

Ammonia headspace measurements were collected from 28 monitoring wells. Monitoring wells MP-5, GM-12, GM-11 and MP-11D were not tested because they were far removed from the location of a former source of ammonia (aboveground anhydrous ammonia tank on Parcel A). Headspace readings were collected using a Draeger tube and pump. After the expansion cap was removed, the Draeger tube was placed at the top of the well casing and the required amount of air was pumped through the tube. Results of the headspace analysis indicated that ammonia was detected in 10 monitoring wells (MP-22D, MP-4, GM-4, GM-2, MP-17, GM-15, GM-14B, GM-9, MP-16D, GM-13) at concentrations ranging from 0.1 ppm (MP-4, GM-1 and MP-16D) to 1.6 ppm (GM-9).

2.4.4 Installation of New Monitoring Wells

Prior to the start of the RI, the thickness of the Upper Glacial Aquifer, the depth to the top of the underlying confining layer (Port Washington Clay) and the water quality in the deeper zones of the Upper Glacial Aquifer at the Site were unknown. Shallow and deep monitoring well clusters were proposed in the Work Plan to address these three conditions. In the context of this Report, therefore, the term "shallow" is defined as a monitoring well that bridges the water table; the term "deep" is applied to a monitoring well that (if clustered with a shallow well) is at least ten feet below the zone screened by the "shallow" monitoring well and is screened immediately above the confining layer, or if located by itself (MP-19D and MP-21D are not clustered next to a shallow monitoring well), is screened immediately above the confining layer. Because of the variability in the thickness of the Upper Glacial Aquifer, the completed depths of the "deep" monitoring wells range from 25 feet below ground surface (MW-2D) to 112 feet below ground surface (MP-11D).

Drilling for the installation of new monitoring wells was completed using truck-mounted or ATV-mounted drilling rigs equipped with hollow-stem augers. Seven borings were completed as "shallow" monitoring wells (MP-4, MP-5, MP-6, MP-16, MP-18, MP-20 and MP-22) and eight as "deep" monitoring wells (MP-2D, MP-11D, MP-16D, MP-17D, MP-18D, MP-19D, MP-21D and MP-22D). A ten-foot well screen was installed in the shallow wells to bridge the water table facilitating the detection (if any) of light non-aqueous phase liquids (LNAPLs) that may be floating on the water table. Due to high water table conditions on portions of Parcel A and lower Parcel C, it was necessary to place the top of the well screen at or below the water table for three monitoring wells (MP-4, MP-17D, and MP-18).

Monitoring well design and installation procedures were consistent with those presented in the Work Plan and FSP. The monitoring wells were constructed from four-inch diameter PVC casing and 10-slot size well screen. Morie sand (#0) was placed in the annular space around the well screen to a height of approximately two feet above the top of the screen. A two-foot thick bentonite pellet seal was placed above the sand pack. The thickness of the sand pack and the bentonite seal was reduced in the field, if the water table was near the ground surface. A cement/bentonite grout seal was placed over the bentonite seal. The surface was sealed with expanding cement. A locking eight-inch diameter steel

protective casing or a flush mount cover was placed over the PVC riser pipe and seated into the cement. The cement well apron was constructed so as to slope away from the well. The PVC riser pipe was topped with an expansion cap and a permanent surveyor's mark was placed on the lip of PVC riser pipe.

The shallow monitoring wells were drilled to a depth corresponding to six to nine feet below the water table. Groundwater was encountered at depths ranging from 1.5 feet (MP-4, MP-17 and MP-18) to approximately 20 feet below grade (MP-5).

The deep monitoring wells, in addition to providing data on groundwater quality in the deeper zone of the Upper Glacial Aquifer at the site, also helped to define the top of the Port Washington Clay. Once the top of the clay was encountered, the boring was extended approximately ten feet into the clay (this was used to confirm that the clay was a significant confining layer and not a thin clay lens). Selected Shelby tube samples of the clay were collected at four locations (MP-22D, MP-17, MP-19 and MP-2D). Shelby tube samples were shipped to the laboratory for hydraulic conductivity testing, average hydraulic gradient and effective consolidation stress. Before the well was installed, the ten-foot open hole into the clay was backfilled with cement/bentonite grout to the top of the clay. A minimum of two feet of packed sand was then placed into the borehole before the well screen was inserted. A complete summary of well construction details and groundwater elevation measurements for both existing and new monitoring wells is presented in Table 2-3.

2.4.5 Well Development

From September 26, 1996 to October 28, 1996, all of the existing and newly installed monitoring wells were developed using either a decontaminated, two-inch diameter, stainless steel submersible pump or a centrifugal pump with dedicated discharge hose. The monitoring wells were developed in an effort to remove fine-grained material from the formation and the filter pack and to increase the hydraulic connection between the well and the formation. In general, the wells were developed for up to three hours, or until a turbidity measurement of 50 nephelometric turbidity units (NTUs) or less was reached, whichever came first. During development, the discharge water was regularly tested for turbidity, pH, and specific conductivity.

Of the 32 wells that were developed or redeveloped, a turbidity value of 50 NTUs or less was achieved in 18 wells. Six of the remaining 14 wells yield turbidity values greater than 1,000 NTUs. Monitoring well development logs, summarizing the volume removed, elapsed time, temperature, pH, conductivity and turbidity are provided in Appendix D. No evidence of free product was found in wells MW-8D, MW-10 or GM-14B during redevelopment.

2.4.6 Collection of Groundwater Samples

Two rounds of groundwater samples were collected from a total of 32 monitoring wells (17 existing and 15 new). It became necessary to resample nine monitoring wells (EMW-1, MP-4, MP-5, GM-7, GM-9, GM-13, MP-16, MP-16D and MP-19D) during the first round because the laboratory performing the TAL/TCL analyses was unable to complete all analyses. The first round of groundwater sampling was conducted from December 3-18, 1996. The resampling of the nine wells was conducted from January 6-8, 1997. Samples collected during resampling have been designated with an "R" (e.g., MP-4R). The second round of groundwater sampling was conducted from January 20-31, 1997.

2.4.6.1 Sample Collection Method

Prior to the collection of groundwater samples, a minimum of three well volumes were purged from each well. The depth to groundwater and the anticipated yield of the well, based on well development observations determined which type of purging method was used. In general, if the depth to groundwater was greater than 20 feet, a submersible pump was used. If the anticipated yield was low, the well was purged by bailing, to avoid pumping the well to dryness. In all other cases, a centrifugal pump was used.

Upon completion of the purging, groundwater samples were collected from each well. Dedicated, decontaminated stainless steel bailers attached to Teflon coated stainless steel leaders were used to collect each groundwater sample. Groundwater samples were analyzed for TAL/TCL compounds, cyanide, radionuclides (^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th and ^{238}U), total dissolved solids (TDS), and both filtered and unfiltered metals. The filtered samples were passed through dedicated 45-micron filters in the field. Samples for volatiles, metals and cyanide were preserved in the field and placed in the appropriate containers in accordance

with procedures outlined in the FSP. Groundwater samples collected during the resampling round were analyzed for volatile and semi-volatile organic compounds and cyanide.

2.4.6.2 Field Measurements

The temperature, specific conductivity, pH, dissolved oxygen and turbidity of the purged water was tested in the field after each well volume was removed. These data are summarized on the sample collection logs provided in Appendix E. A strong organic odor was again detected in MW-8S and MW-8D, north of the Mattiace Petrochemical NPL site, however, no evidence of free product was observed during sampling.. The groundwater sample collected from GM-14B, located southwest of the 500,000-gallon aboveground fuel oil tank, was black and had a petroleum odor, but no free product was observed.

2.4.6.3 Groundwater Elevation Measurements

Two synoptic rounds of groundwater elevations were collected on November 18, 1996 and January 15, 1997. Depth to groundwater was obtained using an electronic water level indicator relative to the permanent marking on the top of the PVC casing. Groundwater elevation data are presented in Table 2-3. Groundwater elevation contour maps with flow directions were constructed for both the shallow and deep monitoring wells on both days. The groundwater elevation contour maps and flow direction are presented and discussed in Section 3.5.2.2.

2.4.6.4 Aquifer Testing

Slug tests were performed to provide hydraulic characteristics of the Upper Glacial Aquifer. Falling head and rising head slug tests were performed. The construction of the well relative to the depth to the water table and the response to the insertion of the slug determined which type of test was performed. Slug tests were performed on 32 monitoring wells, however, only slug test data from 18 wells are considered representative of hydraulic conductivity because of various interferences including slow recovery, rapid recovery, and the inability to measure accurate water levels due to the presence of floating product. Rising and falling head test data was analyzed from the following wells: GM-1, GM-2, GM-5, GM-

7, GM-9, GM-12, GM-14A, GM-15 and MP-4, MP-6, MP-18, MP-19D, MP-20, and MP-21D (Rising Head); and MP-5, MP-16D, MP-18D, and MP-19D (Falling Head).

The falling head test consisted of inserting a slug into the water column of the test well causing the water level to rise. The rate of the subsequent fall of the water level as it approaches equilibrium was measured using an electronic water level meter and a stop watch. In general, the falling head tests were aborted if the water level in the well did not approach equilibrium (at least 50 percent) within one hour.

The rising head test consisted of inserting a slug into the water column of the test well and allowing the water level to return to equilibrium. Once the initial water level was reached, the slug was removed from the water column causing the water level to drop. The rate of the subsequent rise of the water level as it approaches equilibrium was measured. In general, the rising head test was aborted if the water level in the well did not approach equilibrium (at least 50%) within one hour.

As described in the Work Plan, the aquifer testing program included both slug tests and a continuous 72-hour pumping test. The fluctuation in water levels in response to pumping and purging during well development and sampling suggested that only one monitoring well (MP-19D) could sustain a yield sufficient for a pumping test. The estimated yield for all other wells was approximately one gallon per minute (gpm). Although it was estimated that MP-19D could sustain a pumping rate of 20 gpm, MP-19D was much deeper than most other monitoring wells on the Site. In addition, there were no other nearby wells at similar depths that could be used for observations wells. Hydrogeologic data from this deeper zone would not be representative of hydrogeological conditions at the shallow depths where most of the volatile and petroleum compounds were found. Subsequently, the pumping test was canceled.

2.5 RADIOLOGICAL INVESTIGATION

2.5.1 Surface Exposure Rate Measurements

Prior to clearing activities (described previously in Section 2.1.3), baseline background and on-site radiological exposure rate data were collected. Average background radiological exposure rates observed outside the fence on Parcel B were approximately 6-10

μR/h. Radiological exposure rates observed during clearing activities inside the fence on Parcel B ranged from approximately 20-30 μR/h. Radiological exposure rates ranged from background to as high as 2.5 milliroentgen per hour (mR/h). Some of the mounds of ore residue on Parcel B exhibited elevated exposure rates ranging from 20 to several hundred μR/h. Elevated radiological exposure rates were also identified along the Dickson Lane fence on Parcel B. Deteriorated drums and ore residues were the source of exposure rates ranging from 100-200 μR/h in TP-4. On August 1, 1996, a rock with a surface exposure rate of 1.5 mR/hr that was found near a crushed drum on Parcel B, was removed from the work area and taken to the Dickson Warehouse for interim storage.

2.5.2 Radiological Borings

Twenty radiological soil borings (RT-1 through RT-20) were completed on Parcels B and C from September 4-19, 1996 to a depth of approximately 15 feet. The purpose of the radiological soil borings was to define the extent (depth and volume) of radiological contamination. Soil borings were drilled at biased locations to collect soil samples based on field screening data and to collect downhole gamma logging data. Two samples per boring were selected and analyzed for radiological parameters. Generally, the two samples obtained from each boring were taken: 1) at the ground surface of the boring and 2) at the highest gamma reading in the boring above the water table.

Five radiological borings (RT-11, RT-12, RT-13, RT-14 and RT-15) were drilled in an open area on Parcel C between the Benbow Building and the Dickson Warehouse (designated Area 1 on Figure 2-17). Three radiological borings (RT-18, RT-19 and RT-20) were located on lower Parcel C (designated Area 2 on Figure 2-17). RT-18 and RT-19 were drilled into the berm surrounding the 500,000-gallon aboveground fuel oil tank. RT-20 was drilled through the lining of Mud Pond. Radiological borings (RT-1, RT-2, RT-3, RT-4, RT-5, RT-7, RT-8, RT-9, RT-10, RT-16 and RT-17) were drilled in elevated radiological exposure rate areas on Parcel B (designated Area 3 on Figure 2-17).

2.5.3 Downhole Gamma Logging

Boreholes were drilled using the hollow-stem augering method. Soils samples were collected continuously from grade to approximately 15 feet below grade with two-inch diameter split spoon samples. Soil collected in each split-spoon was scanned with a GM pancake detector to identify segments which exhibited elevated radioactivity. After completion of the boreholes, a three-inch inside diameter (ID) PVC pipe capped at the bottom, was placed in the open borehole. Gamma logging data was collected over thirty-second intervals within the PVC pipe at six-inch increments from the ground surface to the bottom of each radiological soil boring with a Ludlum Model 44-10 2"x 2" NaI scintillation detector coupled to a portable Ludlum Model 2221 ratemeter/scaler. Downhole gamma logging data are presented in Appendix F.

Gamma logging data has been plotted with depth for each of the three areas. In general, elevated gamma logging measurements were observed in soil horizons from grade to approximately four feet below grade. Gamma logging measurements generally decreased with depth and field screening results were generally consistent with the downhole gamma logging data. Results of the downhole gamma logging, are discussed below, presented graphically in Figures 2-18, 2-19 and 2-20 and in tabular form in Tables 2-4, 2-5 and 2-6 for each of the three areas, respectively.

Area 1 RT Borings (RT-11, RT-12, RT-13, RT-14, and RT-15)

Gamma logging data for Area 1 is presented in Table 2-4 and Figure 2-18. RT-13, located 10 feet west of a 300-gallon aboveground tank near the Dickson Warehouse, had a surface exposure rate of 2.5 mR/h, (the highest exposure rate recorded on the Site). Maximum counts were recorded in the 0-1-foot depth interval, with 219,230 counts at the surface, 250,607 counts at 0.5 feet, and 214,583 counts at one foot. Throughout the Site, at borings containing radiologically contaminated materials in the first few feet below ground surface (bgs), the counts recorded dropped significantly with depth, from maximum values in the first few feet to numbers in the range of background (approximately 4,000-8,000 counts in 30 seconds). At RT-13, the number of counts dropped to 4,214 counts at 15 feet bgs.

RT-11 and RT-12 also exhibited elevated gamma measurements in the 0-4 foot depth interval. RT-11, approximately 50 feet south of the entrance to the Benbow Building, was in an area with surface exposure rates ranging from 250-1,000 μR/h. Based on the soil screening data, the contaminated material was limited to the upper three feet of soil. At 0-6 inches, the soil exhibited 900-1,000 cpm when scanned with the GM pancake detector. The GM response to soil collected from 2.5 feet below grade dropped to 150 cpm. Slightly elevated radioactivity was observed in the 4-6 foot (50-60 cpm) interval. The downhole gamma data ranged from 108,943 counts (0.5 feet bgs) to 4,321 counts (14 feet bgs). The exposure rate at the surface of RT-12, adjacent to the 300-gallon aboveground tank, was approximately 300-400 μR/h. The highest soil screening result was 500-600 cpm within the 0-4 inch dark black layer. Elevated field screening measurements (200-400 cpm) were also observed at 6-7 feet bgs, which consisted of "blue" fine-to-medium silty-sand material. The downhole gamma data ranged from 119,433 counts (0.5 foot) to 4,367 counts (14 feet bgs).

Gamma logging and soil screening measurements at RT-14 and RT-15 were in the background range. RT-14, located approximately 50 feet north of the northeast corner of the Dickson Warehouse, had a 12 μR/h surface exposure rate. Field screening of soil ranged from 30-50 cpm. Gamma logging data increased with depth from 5,452 counts (at the surface) to 9,874 counts (at 14.5 feet). The surface exposure rate at RT-15, located 20 feet south of MP-16S and 16D, was approximately 700 μR/h (at a 1 foot offset from a 1.2 mR/h maximum surface reading). Despite the high surface exposure rate readings, the gamma logging and soil screening data throughout the boring were in the background range.

Area 2: RT Borings (RT-18, RT-19, and RT-20)

Gamma logging data from Area 2 borings were generally lower than those from Area 1 and are presented in Table 2-5 and Figure 2-19. RT-19 exhibited the highest surface exposure rate (150 μR/h) and the highest gamma logging measurement (85,202 counts at the 0.5 foot depth). The highest field screening result was 200 cpm in the 0-2 foot depth interval. Gamma logging and soil screening data from RT-18 and RT-20 were in the background range. RT-18 was located in the south berm area. RT-20 penetrated the existing liner in Mud Pond.

Area 3: RT Borings (RT-1, RT-2, RT-3, RT-4, RT-5, RT-6, RT-7, RT-9, RT-10, RT-16 and RT-17)

As depicted in Table 2-6 and Figure 2-20, gamma logging data were higher in radiological borings RT-1, RT-2, RT-3, RT-5, RT-7 and RT-8 in the upper soil layers compared to other borings in Area 3. In particular, RT-3 and RT-7 had the highest downhole gamma measurements. RT-7 was located near a mound of black ore residue on Parcel B. It had a 250 μR/hr surface exposure rate and had a maximum gamma logging measurement in the one foot soil layer of 220,131 counts. Slightly elevated gamma logging measurements were recorded from 8.5 feet (17,918 counts) to 12.5 feet (11,900 counts). Field screening of soil with the GM pancake detector was consistent with downhole gamma measurements (GM detector readings and downhole gamma measurements were generally elevated in the same depth intervals). Screening data were as high as 1,000 cpm in the 0 - 3.5 foot layer. RT-3, located in an elevated mound of black ore residues approximately 30 feet west of RT-1, exhibited a surface exposure measurement of 150-200 μR/h. Gamma logging data ranged from 202,321 counts (1.5 feet) to 6,684 counts (12.5 feet) in RT-3. Field screening measurements were highest in the 1-2 foot soil horizon (300-400 cpm) and were also elevated in the 3-4 foot interval (90-100 cpm).

RT-1 was located in the middle of Parcel B at a location with a surface exposure rate of 200-250 μR/hr. Gamma logging data ranged from 39,200 counts (1 foot) to 4,928 counts (15 feet) and generally decreased with depth. Field screening measurements were elevated on soil collected from 0-2 feet (120 cpm) and 2-4 feet (280 cpm).

RT-2, located in a 3-foot high mound of gray ore residues on Parcel B, had a surface exposure rate of 100 μR/h. The highest field screening measurements were recorded in the 0-1 foot sample (500 cpm) and 2-4 foot sample (250 cpm). Gamma logging data ranged from 37,853 counts (0.5 foot) to 7,098 counts (6 feet). The highest readings corresponded to the field screening results in the zero to one foot layer.

RT-5, located adjacent to TP-4 on the east side of a swale on Parcel B, had a surface exposure rate of 700 μR/hr. Field screening of soil samples indicated 600 cpm emanating from a dark black clayey layer or ore residue at 0-1.5 feet bgs. Gamma logging measurements were consistent with the field screening data, ranging from 97,835 counts (1 foot depth) to 2,827 counts (13.5 feet depth).

RT-8, located in Parcel B, had downhole gamma measurements ranging from 21,463 counts at the ground surface to 13,220 counts at the termination depth (4 feet). Five borings (RT-4, RT-9, RT-10, RT-16 and RT-17) had downhole gamma logging data and soil scanning results in the background range. Surface exposure rates at these locations ranged from 11-14 μR/h.

2.5.4 Building Material Sampling

Ten building material samples were collected from buildings on Parcel A in areas exhibiting elevated exposure rates. These areas included portions of the Dice Building (BM-1 through BM-7) and the northern portion of the East Building (BM-8, BM-9 and BM-10). Location of the building material samples are shown on Plate 1. Samples of wall and floor materials were collected with a hammer and chisel. Thorium-232 and ^{226}Ra concentrations were determined by counting their gamma-emitting decay products.

The majority of the building material sample data do not suggest contamination, however, several samples collected in the Dice Building did have elevated ^{232}Th concentrations. For example, samples BM-2 and BM-3 had 23 pCi/g and 7.4 pCi/g, respectively. Building material surfaces were scanned before and after sample collection with an alpha scintillation detector. At these locations, surface alpha count rates were elevated (100-200 cpm compared to 0 cpm background) prior to sample collection. Following removal of the surface layer, the newly exposed surfaces exhibited significantly lower counts (0-20 cpm), suggesting that in these areas, building material surfaces contained an outer layer of contamination. Building material sample results are summarized in Table 2-7.

2.6 POPULATION AND LAND USE INVESTIGATION

Glen Cove is located near the north shore of Long Island. The demographic study area is a 3-mile radius from the Site. As seen in Figure 2-21, the study area encompasses a large portion of Long Island Sound, as well as Glen Cove, and sections of Oyster Bay, Sea Cliff, Brookville, Glen Head, Locust Valley, Sands Point, Port Washington and Lattingtown.

Notable features within this area are Garvies Point Preserve, a community hospital, and several schools, country clubs and municipal parks.

The population within the study area (A_0) was estimated using 1990 U.S. Bureau of Census STF-1A and TIGER/Line files prepared by a speciality subcontractor. This data determined that A_0 is located partially in Census Block Group 36059 in Census Tracts 301, 302, and 517. For each census block group, the total population and area were used to determine the population density (persons/square mile). The study area was subdivided into five tiers with distance "rings" at 0.25, 0.5, 1, 2, and 3 miles from the site, as shown in Figure 2-21. The area of each census block group within each ring, known as the "partial area", was multiplied by the corresponding population density to estimate the population within A_0. It was estimated that approximately 43,823 persons reside within a 3-mile radius of the Site in 1990, as shown in Table 2-8.

Land use classification within a 3 kilometer radius of the Site was assessed according to the Auer methodology (Auer, 1978). A local zoning map was used to identify properties within 3 kilometers of the Site as either urban (I1, I2, C1, R2, and R3) or rural (R1, R4, A1, A2, A3, A4, and A5). These land use areas were then plotted on a base map derived from USGS quadrangle maps. The rural and urban areas were calculated using a planimeter and their percentage of the total area were calculated. Rural land use categories accounted for more than 50% of the area around the Site as shown on Table 2-9, therefore, a rural land use classification was selected.

2.7 ECOLOGICAL INVESTIGATION

2.7.1 Wetlands Delineation

Wetland-nonwetland boundaries were identified using the Corps of Engineers Wetlands Delineation Manual (Dept. of the Army, 1987) and the Memorandum on Clarification and Interpretation of the 1987 Manual (Dept. of the Army, March 1992). The routine determination method was applied for the collection of data, since wetland areas delineated were small and had little vegetation diversity. Application of this procedure required identification of plant community types and characterization of vegetation, soils and

hydrology using established criteria. Data were collected at the sampling stations (designated as "SS") noted on the forms in the Wetland Delineation Report (Appendix G).

Within sample quadrants and along transects, dominant plant species for each vegetative stratum were classified using the National List of Plant Species That Occur in Wetlands: Northeast (Region 1) (US Fish and Wildlife Service, 1988). On-site soil series were identified from mapping provided in the Soil Survey of Nassau County New York (USDA Soil Conservation Service, 1987). Soil boreholes along transects were augered to a depth of 12 to 18 inches and observed for hydric soil characteristics and ground water levels. Soils sampled at these locations were characterized for hydric indicators using Munsell Soil Color Charts (Munsell Color, 1990). Wetland hydrology was determined by the presence of saturated soils, and the depth to water as observed in unlined, hand-augered boreholes.

The following is an outline of the steps taken to determine the presence of wetlands in accordance with the 1987 federal guidelines for a routine determination with on-site inspection.

Steps 1-3: Locate the Project Area. Determine Whether an Atypical Situation Exists. Determine the Field Characterization Approach to be Used.

Because the delineated wetland areas occurred in small discrete pockets less than one acre in area and the vegetation, soils, and/or hydrologic regime appeared relatively homogenous throughout the Site, routine wetland delineation procedures were applied.

Steps 4-9: Determine Whether Normal Environmental Conditions are Present. Characterize Plant Community Types. Classify Dominant Vegetation Species. Determine the Presence of Hydrophytic Vegetation.

The delineation was conducted in late fall 1996 following a wet summer and early fall. Normal environmental conditions were present within the plant communities observed. All of the wetland areas have been affected by human activity whether recent or past. Data forms were completed for each of the wetland areas identified, and short transects of sampling points were run across the wetland-nonwetland boundaries to establish the wetland line

At least one set of data sheets were compiled for each wetland; more than one set was recorded for larger areas or those with more than two distinct vegetative communities. A summary of the dominant vegetation, the primary soil and hydrology indicators for each sample location, and complete Routine Wetland Determination data forms are included in Appendix G.

Wetland vegetation communities on Parcels B and C are relatively homogenous. Because it was late in the growing season at the time of the delineation, some dominant herbaceous species may not have been present or identifiable. Conclusions were drawn on the existing vegetation and the other two criteria (soil and hydrology). More than 50 percent of the vegetative communities were comprised of Facultative (FAC) to Obligate (OBL) plant species which fulfills the hydrophytic vegetation criterion for the federal methodology.

Nonwetland vegetation communities on Parcels B and C are relatively homogenous. The plant community types in nonwetland areas contain less than 50 percent OBL, Facultative Wetland Plants (FACW) and/or FAC plants, which does not fulfill the hydrophytic vegetation criterion (facultative wetland).

Steps 10-11: Apply Wetland Hydrologic Indicators. Determine the Presence of Wetland Hydrology.

Positive wetland hydrology indicators for the federal methodology were present in each of the wetland areas on-site. The main wetland hydrologic indicators were saturated soils and inundation. All four wetland areas had impounded water on some portion. All wetland areas had saturated soils within 12 inches of the soil surface. According to the ACOE methodology, primary indicators of wetland hydrology include inundation or saturation within 12 inches of the soil surface. All wetland borings fulfilled this criterion.

Steps 12-15: Characterize Wetland Soils. Apply Hydric Soil Indicators. Determine the Presence of Hydric Soils.

Since much of the soil at the Site contains fill material and the soil is somewhat sandy, low chroma could not be relied on as a hydric indicator. An aquic moisture regime provided the most immediate evidence of hydric soil conditions. In most cases, soils with

high organic content or high organic content of the surface layer also provided evidence of hydric soil conditions. Soil at one area was fill material with a red/orange color. In this instance, it can be assumed that the soils are functioning as hydric soils if positive indicators of hydrophytic vegetation and wetland hydrology are found (ACOE, 1987).

Step 16: Make Wetland Determination.

The wetland areas as shown in Appendix G support the federal criteria for hydrophytic vegetation, wetland hydrology and hydric soils. Since wetland indicators for the ACOE methodology were present during the October 14-15 and November 28-30, 1996 field investigation, the areas delineated meet the multi-parameter criteria established for determination of ACOE jurisdictional wetlands. Photographs of the wetland systems are also presented in Appendix G.

2.7.2 Flora and Fauna Inventory

As part of the RI/FS process and in support of the Ecological Assessment presented in Section 7.5), ecological investigations were performed at the Site. Vegetation patterns were mapped within the site boundaries, based on observations made during field surveys conducted in September through November 1996. Since considerable tree cover was disturbed due to interim remedial measures and site clearing, the percent areal cover for the Site was estimated based on aerial photography taken in 1995. Vegetational communities providing wildlife habitat were noted and indicated on a Site map. Wildlife species likely to utilize specific area vegetational communities were identified based on New York Fish and Wildlife data for the area. Wildlife observations were recorded and observations were made concerning the ability of habitat to support Federal or State threatened or endangered species, if present. Data collected include the numbers of individuals observed, species utilization of the site (i.e., foraging, nesting, migratory stopover) and species utilization of vegetation stratum (i.e., open field, shrub/scrub, wooded). In addition, data supplied by New York State Natural Heritage Program were used to identify possible habitat for documented threatened or endangered species utilizing the area. The results of these investigations are included in Section 3.7.2.

2.8 CULTURAL RESOURCES INVESTIGATION

2.8.1 Stage 1a Survey

A Stage 1a Archaeological Survey of the Site was conducted in February 1995 before the 1995-1996 IRAs were initiated. The objectives of the Stage 1a Survey were to determine whether: 1) portions of the Site were sensitive for the presence of potentially significant archaeological resources; 2) a preliminary evaluation of the architectural and historical significance of Site buildings was warranted; and 3) further archaeological investigations at the Site were warranted and, if warranted, make recommendations on the scope of that work.

The results and analysis of the Stage Ia Archeological Survey indicated the following:

- Some of the existing structures within Parcel A may be associated with the early twentieth century Ladew Leather Belting Works and may possess architectural and/or historical value;
- Parcel B is sensitive for the presence of possibly significant prehistoric period and historic period archaeological resources; and
- The artificially filled area behind the bulkhead along Glen Cove Creek (Parcel A) may possibly constitute an historic period cultural resource.

Subsurface testing was recommended for Parcel B and the area behind the bulkhead along Glen Cove Creek on Parcel A. It was also recommended that an industrial archaeologist evaluate the potential significance of the buildings on Parcel A that may have been associated with the Ladew Leather Belting Works. The full text of the Stage 1a Report is presented in Appendix H.

2.8.2 Stage 1b Survey

Once the IRA was initiated, it became apparent that repair to the bulkhead would necessitate disturbance to the artificially filled areas behind the bulkhead. In addition, test pit excavations on Parcel B, planned during the RI field investigation would also cause ground disturbance. To determine whether possibly significant archeological resources were

present at the Site which would be impacted by the RI field activities, a Stage 1b Survey was conducted.

Testing determined that the area in the immediate vicinity of the bulkhead on Parcel A consisted of at least two episodes of fill deposited over the former shoreline of Glen Cove Creek. Both fill episodes consisted primarily of redeposited glacial soils. Construction related materials were the predominant class of artifacts recovered from the upper fill layers. Analysis suggested that the artifacts and associated fill dated to the late nineteenth or early twentieth century and were probably associated with the industrial activities occurring on the Site during that period. The lower fill layers were found to contain little cultural material. It was determined that these layers probably date to the period prior to 1890 when only limited industrial and commercial activity occurred at the Site.

No domestic deposits were encountered on Parcel A nor were any fill retaining structures or other features observed. A Native American flake was encountered beneath the fill in the uppermost creek bank layer in one portion of the tested area. Additional tests in that vicinity did not encounter other indications of Native American activity.

Subsurface investigations of the area in the vicinity of the Glen Cove Creek bulkhead did not reveal the presence of fill layers or other archaeological deposits that are potentially eligible for listing on the New York State or National Registers of Historic Places. It was concluded, therefore, that further archaeological investigations on this portion of Parcel A were not warranted. The full text of the Stage 1b Survey is presented in Appendix I (1).

A Stage 1b investigation was not conducted on Parcel B, however, due to the archaeological sensitivity of that parcel, test pits excavated during the RI were monitored by Malcolm Pirnie's archaeologist. Test pit excavations did not encounter any Native American or Historic Period deposits of potential significance. Test pits in the middle and southern portions of Parcel B revealed recent fill deposits overlying former ground surface layers and sequentially, glacial deposits and/or wetland associated deposits. The former ground surfaces were not archaeologically sampled. Only the natural soil sequence was observed in the test pits excavated in the northern portion of Parcel B. The text of monitoring observations made during test pit excavation on Parcel B is provided in Appendix I (2).

2.8.3 Architectural Assessment

The architectural assessment on Parcel A determined that the Loung Building and parts of the East Building were associated with the early twentieth century Ladew Leather Belting Works. The assessment concluded that the Loung Building and the East Building were unspectacular vernacular examples of early twentieth century industrial/commercial architecture.

Exterior and interior portions of both structures were modified by owners or operators of the facility. It was also concluded that these structures did not have potential architectural or historical significance and no further recordation was warranted. The architectural assessment also concluded that the facility on Parcel A could not provide information on the industrial processing of tungsten ore or on the role of the tungsten industry during World War II that was not available from other sources. No further investigation of the facility was recommended. The full text of the architectural assessment is presented in Appendix J.

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3.0 PHYSICAL CHARACTERISTICS OF STUDY AREA

3.1 SURFACE FEATURES

Surface elevations at the Site range from approximately 70 feet above MSL at the northern boundary of Parcel C′ to approximately 5 feet above MSL at the bulkhead on Glen Cove Creek which forms the southern boundary of Parcel A. Parcel A is relatively flat with a gentle uniform slope of approximately two percent from its northern boundary at Herb Hill Road, toward its Glen Cove Creek. Approximately 95 percent of Parcel A is covered with buildings, aboveground tanks, asphalt pavement or concrete slab. Parcel B is completely vegetated, contains a small surface water body, an intermittent stream and a wetland. Several empty aboveground tanks are on the ground in the southwest portion of the parcel. Parcel B has a steeper slope of approximately six percent from its northern boundary at The Place to its southern boundary at Herb Hill Road. The middle portion of the parcel features several deep gullies.

Parcels C and C′ are contiguous and, therefore, are described in this section of the Report as one section. Parcel C/C′ exhibits the most variable topography. The northwest corner of Parcel C/C′, near Janet Lane, slopes steeply (40 percent) to the southeast. The area west of the Benbow Building slopes (15 percent) towards a wetland area located west of the Dickson Warehouse. A steep escarpment is present along the northern boundary of the Mattaice site and Parcel C/C′. The southern portion of Parcel C, near the Dickson Warehouse and the 500,000-gallon aboveground fuel oil tank, is relatively flat. A small wetland area is present within the bermed area around the tank. Standing water is present in the Mud Pond.

Surface water run-off is controlled by Dickson Lane's paved surface and catch-basins between Parcel B and C/C′. Surface water exiting Parcel B at Herb Hill Road enters a catch-basin located in the south-east corner of Parcel B and Herb Hill Road. The crest line of the roadway of Herb Hill Road and catch-basins minimize surface runoff flowing onto Parcel A. Lower Parcel C surface runoff collects in the bermed area around the 500,000-gallon aboveground fuel oil tank and in Mud Pond.

3.2 METEOROLOGY

The Site is located along the north shore of Long Island, NY on the Atlantic Coastal Plain. The region is predominantly affected by cold, dry air masses from the northern interior of the continent and warm, humid air masses from the south. In addition, the region is greatly affected by a third air mass that typically flows inland from the North Atlantic Ocean, providing cool, cloudy and damp conditions. During the winter months, the Atlantic Ocean provides moderating influences on Long Island, with average temperatures around freezing. During the summer months, prevailing southerly winds and maritime flows often provide hot and uncomfortably humid conditions.

The mean annual temperature measured at Mineola (approximately 10 miles south of the Site) is 53.3° F. The maximum and minimum mean monthly temperatures are 75.2°F (July) and 31.8°F (January), respectively. Precipitation totals are almost the same in the cool season as in the warm season. The mean annual precipitation is 42.45 inches. Monthly averages range from 2.68 inches in January to 4.30 inches in March. A summary table of temperature and precipitation data collected at Mineola from 1951-1973 is presented in Table 3-1. The predominant wind flow is from the west-northwest at a mean velocity of 12.4 mph (NOAA, 1974).

3.3 GEOLOGY

3.3.1 Regional Geology

The geology of northwestern Long Island is discussed below with emphasis on the Glen Cove region. The Glen Cove region for the purpose of this discussion is defined as the area surrounding the Site for a distance approximately one mile to the north, east and south, and bounded by Hempstead Harbor to the west. A more detailed discussion regarding regional geology is discussed in several USGS publications. Information presented in the earlier publications (Swarzenski, 1963; USGS, 1946) is superseded by the information presented in the more recent publications (Smolensky et. al., 1989; Kilburn and Krulikas, 1987).

Long Island is the northern most extension of the Atlantic Coastal Plain. The Island is composed of terrestrial deposits of Cretaceous age and Quaternary deposits primarily of glacial

origin (Pleistocene). These deposits form a southeastward thickening wedge of sediments which overlie either Paleozoic or Precambrian crystalline bedrock. The bedrock surface and the overlying strata generally dip to the southeast, with the unconsolidated strata thickening in the down-dip direction. In the Glen Cove region, the unconsolidated sediments are 400 to 600 feet thick. The stratigraphic column underlying the northern part of the Town of Oyster Bay, Long Island, which includes the Glen Cove region is presented in Table 3-2.

The Site is located about four miles north of the Harbor Hill terminal moraine, a series of coalescing irregular hills (kames) which form a pronounced ridge trending north-northeast across Long Island. This moraine marks the terminal position of the most recent Pleistocene (late Wisconsin) ice sheet to reach Long Island. The deposits which formed during the glacial recession include outwash sand and gravel deposits, till or ground moraine (a heterogenous mixture of clay, silt, sand and boulders) interlayered with gray clay lenses and delta deposits. Earlier glacial deposits associated with the Ronkonkoma glaciation underlie the Harbor Hill drift. These deposits are collectively designated as the upper Pleistocene deposits. Older inter-glacial deposits include lacustrine, estuarine and marine sediments.

The predominant surficial deposit in the Glen Cove region is a veneer of Harbor Hill ground moraine, which is a heterogeneous mixture of clay, silt, sand and boulders typically 5 to 10 feet thick although locally, the thickness is as much as 40 feet. Beneath the ground moraine lies another sequence of older (Ronkonkoma) drift containing interlayered glacial till and outwash deposits. The glacial sediments range in thickness from less than 10 to over 200 feet in the northern part of Long Island (Kilburn and Krulikas, 1987).

On most of Long Island, the glacial deposits lie uncomfortably on the Mattawan Group (Magothy Formation - undifferentiated), a Cretaceous age sedimentary sequence of discontinuous sand, gravel and clay lenses. In the Glen Cove region, however, the Magothy Formation is absent. The absence of the Magothy is attributed to channel cutting during a pre-Wisconsin stage of the Pleistocene epoch (Smolensky, et. al 1989). Post Cretaceous erosion was the major contributing factor in producing more than 400 feet of relief on the Cretaceous surface along the north shore of Long Island.

In the Glen Cove region, the upper Pleistocene deposits are underlain by an extensive unit comprised of clay, silt and a few layers of sand. This unit was believed by some researchers to be equivalent to the Gardiners Clay, which is a shallow marine sequence deposited during an

interglacial period (Swarzenski, 1963; Isbister, 1966). A more recent publication (Kilburn, 1972) refers to this stratum as the Port Washington confining unit and identifies it as Pleistocene and Holocene age.

In the Glen Cove region, that sequence rests unconformably on the unnamed clay member of the Raritan Formation. The surface of the clay member is about 200 feet below sea level (Smolensky et al., 1989). The clay member and the Port Washington clay deposits are in direct contact and differentiation between the two is sometimes difficult (Smolensky, 1989). Together these strata comprise a contiguous unit at least 75 feet thick in the Glen Cove region.

The lower unit of the Raritan Formation is the Lloyd Sand Member which is approximately 125 feet thick in the Glen Cove region. The Lloyd Sand Member rests on bedrock at depths of approximately 400 to 500 feet below MSL (Smolensky et. al., 1989).

A geologic log of a water supply well (N1917) drilled on the Site for Wah Chang Trading Corporation provides the only information on the deep subsurface geology in the region. Table 3-3 presents a geologic log of Water Supply Well N1917. The well was drilled in 1943, probably by the cable tool method, and the geologic samples were examined, described and logged by the USGS. The well was drilled to a depth of 311 feet and terminated in the Lloyd Sand Member. Well N1917 is located on the western portion of Parcel A and is shown on Figure 1-3.

3.3.2 Site Geology

The discussion regarding Site geology is based on previous geologic investigations (G&M, 1988), information collected during this field investigation, and the Mattiace RI/FS Report (Ebasco, 1991). A total of 23 borings were drilled during a previous hydrogeologic investigation at the Site (G&M, 1988). Boring logs from the soil borings and monitoring wells that were drilled as part of this RI are presented in Appendix K. The boring logs indicate unsorted deposits of sand, silt, clay and gravel interbedded with lenses of moderately-to-well sorted sand, silt and clay. This stratigraphic profile is consistent with published sources that describe the regional area as underlain by interlayered Pleistocene deposits of till, outwash and lacustrine sediments (Swarzenski, 1963; Kilburn and Krulikas, 1987).

The monitoring wells that were initially installed on the Site were used primarily to assessing shallow groundwater quality. Three wells were drilled to a depth greater than 20 feet,

and only one well to more than 25 feet. As a result, except for the boring log of supply well N1917, little information was available on the deeper Site geology.

Boring logs and physical soil properties measured from samples collected during the drilling of soil borings and monitoring well borings as part of this RI were consistent with the previous investigation and published sources. Generalized geologic cross-sections of the Site are presented on Plate 2. The shallow deposits consist of well to poorly sorted sands, silt, clay, and gravel. Till deposits were observed in three monitoring well borings (MP-11D, MP-16D, and MP-4D) located on Parcel C. The shallow deposits are underlain by the Port Washington Clay. The shallow groundwater table appears to mimic the topography and does not appear to be influenced by the deeper Port Washington Clay.

3.4 SOIL CHARACTERISTICS

Soil samples that were collected during each phase of the soil investigation were analyzed for physical properties (e.g., grain size, bulk density, moisture content, atterberg limit and hydraulic conductivity). The soil samples were collected from both the saturated and unsaturated zones.

Grain size data suggest that the soil consists of poorly sorted sand, gravel, silt and clay. The average grain size distribution estimated from 16 soil samples collected throughout the Site consisted of approximately 17% gravel, 60% sand, and 23% silt and clay. This composition is similar to the regional description of the Upper Pleistocene deposits as poorly sorted sand, silt and gravel.

The average soil bulk density estimated from 14 soil samples was 1.34 grams per cubic centimeter (g/cc). This value falls within the expected range of bulk density values for poorly sorted silty sands (Maidment, 1993).

During the drilling of the monitoring well borings, Shelby tube samples of the Port Washington Clay were collected. Four Shelby tubes were submitted for hydraulic conductivity analyses. Analytical results indicate average hydraulic conductivity value of 3.02×10^{-07} cm/sec. This value falls within the expected range of hydraulic conductivity valves for fine silt and clay (Freeze and Cherry, 1979). Copies of all results from the physical property testing are presented in Appendix L.

3.5 HYDROGEOLOGICAL CHARACTERISTICS

3.5.1 Regional Hydrogeology

There are two discrete aquifers in the Glen Cove region and they are designated the Upper Glacial and the Lloyd aquifers. In addition to these aquifers, local bodies of perched groundwater occur above the water table. Long Island was declared a sole source aquifer by USEPA on June 29, 1978.

Bodies of perched groundwater are found in several parts of the Glen Cove region. Perched groundwater occurs where the downward migration of water in the vadose zone is impeded by a layer of relatively low permeability which results in a local zone of saturation above and unrelated to the main water table. In the Glen Cove region, perched water occurs close to the land surface in depressions that are underlain by clayey till and clay. Perched groundwater is prevalent in the area of ground moraine north of the Harbor Hill terminal moraine (which includes the Glen Cove region).

The Upper Glacial aquifer consists of permeable upper Pleistocene deposits that occur below the water table. The water table occurs from MSL to about 60 feet above MSL in the Glen Cove region. Recharge is entirely from precipitation occurring mostly during the late fall and winter when plant growth is dormant. Under natural conditions, shallow groundwater discharges to streams, springs and Long Island Sound and its harbors by evapotranspiration and by downward leakage to the underlying aquifer. Previous investigations have indicated that groundwater movement in the Upper Glacial aquifer is generally to the south in the vicinity of the Site, with shallow discharge to Glen Cove Creek. Groundwater movement in the deeper zones of the Upper Glacial aquifer may pass under the creek. In the Glen Cove region, discontinuous beds of low permeability sediments limit the amount of water which can be pumped from the Upper Glacial aquifer; hence several supply wells in the area tap the deeper Lloyd aquifer.

The Magothy aquifer is not present in the Glen Cove region. However, groundwater likely moves into the Upper Glacial aquifer where it is in contact with the subcrop of the Magothy formation to the west and south.

The clay member of the Raritan Formation is a confining unit that overlies the Lloyd aquifer. The Port Washington confining unit occurs above, and is contiguous with, the clay

member in many places. Together, these strata form an effective confining unit separating the Lloyd aquifer from the Upper Glacial aquifer in the Glen Cove region. The thickness of the confining unit is about 112 feet beneath the Site based on the log of well N1917. In places where the Cretaceous deposits have been completely eroded, the Port Washington confining unit lies on a sequence of deposits of Pleistocene and (or) Late Cretaceous Age called the Port Washington aquifer. It is not known if the Port Washington aquifer extends onto the Site.

The lower limit of the Lloyd aquifer and the Port Washington aquifer is the Precambrian bedrock surface; the upper limit is the clay member of the Raritan formation or the Port Washington confining unit. The Lloyd aquifer is the most confined of the water bearing units, as demonstrated by minimal interference effects between pumping wells tapping the different aquifers. Hydraulic heads in the Lloyd aquifer are generally lower than those in the Upper Glacial aquifer resulting in downward leakage of water through the clay unit. The Lloyd aquifer is replenished entirely by downward percolation of water from the overlying aquifers through the more permeable zones of the confining unit and, directly but slowly, through the clay itself. The primary recharge area of the Lloyd aquifer is in eastern Nassau County. Groundwater movement in the Lloyd aquifer is generally westward, away from the recharge area. Groundwater moves laterally into the Port Washington aquifer from the Lloyd aquifer where the two units are contiguous. Water discharges by submarine leakage and through pumping wells.

3.5.2 Site Hydrogeology

The uppermost hydrostratigraphic unit on the Site is the Upper Glacial aquifer which is comprised of outwash and lacustrine deposits of Quaternary Age. Immediately beneath this aquifer lies the Port Washington confining unit, an aerially continuous clay sequence. The clay member of the Raritan Formation may also be present. These clay units impede downward groundwater movement, thereby inhibiting contaminant migration from the Upper Glacial aquifer to the underlying Lloyd aquifer. For this reason, hydrogeologic investigations of industrial sites in the area have focused almost exclusively on shallow groundwater in the Upper Glacial aquifer. Consequently, little information is available on the deeper glacial sediments and Cretaceous strata (Raritan Formation) at the Site.

3.5.2.1 Clay Topography

A contour map of the Cretaceous clay surface was prepared for the Mattiace RI/FS (Ebasco, 1991). This map showed that the elevation of the upper clay surface varies dramatically over a short distance (e.g., the clay surface was found to have over 65 feet of relief across a 350 foot horizontal transect). The clay surface and the abundance of non-horizontal beds observed in the clay was attributed to deformation by the moving ice sheet (Ebasco, 1991).

Observations made during the drilling of the deep monitoring wells at the Site, indicated that the clay surface elevation ranged from approximately four feet below MSL near the southeastern corner of Parcel A (MP-17) to approximately 48 feet below MSL near the northwest corner of Parcel C′ (MP-11D). The elevation of the top of the clay surface is presented in Figure 3-1. The clay layer is believed to be at least ten feet thick (borings did not extend beyond ten feet into the clay. The presence and direction of this downward trend in the clay surface is consistent with the results of the Mattiace site investigation (Ebasco, 1991) and a regional dip of the clay surface to the west, beneath the Hempstead Harbor (Swarzenski, 1963).

3.5.2.2 Groundwater Flow Direction

In the context of this Report, the term "shallow" is defined as a monitoring well that bridges the water table; the term "deep" is applied to a monitoring well that (if clustered with a shallow well) is at least ten feet below the zone screened by the "shallow" monitoring well and is screened immediately above the confining layer, or if located by itself (MP-19D and MP-21D are not clustered next to a shallow monitoring well), is screened immediately above the confining layer. Because of the variability in the thickness of the Upper Glacial Aquifer, the completed depths of the "deep" monitoring wells range from 25 feet below ground surface (MW-2D) to 112 feet below ground surface (MP-11D).

Groundwater elevation data collected from the shallow monitoring wells located on Parcels A, B, and C indicate a fairly uniform hydraulic gradient ranging from 0.015 feet/foot (Parcel A) to 0.046 (Parcel B). The direction of groundwater flow beneath these Parcels is to the south, toward Glen Cove Creek. The hydraulic gradient beneath Parcel C′ was nearly one order of magnitude steeper (0.109 feet/foot). This gradient appears to mimic the steeper topographic gradients in the vicinity of Parcel C′. The direction of groundwater flow beneath

Parcel C′ is also to the south, although there is a eastern flow component near the northern portion of Parcel C′. Groundwater elevations and flow direction have been plotted for both the shallow and deep wells. Figures 3-2 through 3-5 present the groundwater elevations and flow directions for November 1996 and January 1997.

The hydraulic gradients calculated using the groundwater elevations in the deep monitoring wells are fairly uniform and range from 0.031 feet/foot (on Parcel B) to 0.039 feet/foot (on Parcels A and C). The direction of the deep groundwater flow beneath these parcels is to the south. The hydraulic gradient beneath Parcel C′ was approximately twice as steep (0.075 feet/foot). The direction of the deep groundwater flow in the Upper Glacial aquifer on Parcel C′ is also to the south.

Groundwater elevations in the deep and shallow monitoring wells indicate a downward vertical gradient throughout most of the Site. This trend was anticipated near areas of probable groundwater recharge, such as the higher elevation portions of Parcel C′. However, an upward vertical gradient was expected near the groundwater discharge area (i.e., Glen Cove Creek). One possible explanation for the downward vertical gradients near Glen Cove Creek is the presence of the bulkhead which may be impeding groundwater recharge to the creek.

3.5.2.3 Hydraulic Conductivity

Data collected from the slug tests was analyzed using the procedures developed by Bouwer and Rice 1976). Results of the slug test analyses are summarized in Table 3-4. Hydraulic conductivity values ranged from 2.2×10^{-2} cm/sec (MP-19D) to 9.9×10^{-6} cm/sec (MP-16D) with an average value of 3.1×10^{-3} cm/sec. The range of hydraulic conductivity values reflect the heterogenic nature of the Upper Glacial deposits. Upon review of the geologic logs, it appears that the hydraulic conductivity values are within the expected range for the materials that were encountered. The slug test data and semi-logarithm plots of time versus displacement are provided in Appendix M.

3.5.2.4 Groundwater Use

The municipal water supply for the City of Glen Cove is provided from the following three wells:

Number	Aquifer	Address	Capacity (gpm)	Depth (feet)
N-09210	Magothy	Duck Pond Road	1400	275
N-09211	Magothy	Duck Pond Road	1400	269
N-09334	Magothy	Kelly Street	1200	298

Five additional wells formerly provided water to the City of Glen Cove, however, these wells have either been abandoned or taken off-line. The active and inactive municipal water supply wells are presented on Figure 3-6.

3.6 DEMOGRAPHY

The Site is located in an industrial area on Herb Hill Road, Dickson Lane and Garvies Point Road in Glen Cove, Nassau County, New York. The 26-acre property contains office, laboratory, manufacturing and storage buildings which have been closed since operations ceased in 1985. The Site is bordered by light and heavy industry to the north, east, west and by Glen Cove Creek to the south.

The Glen Cove commercial base includes several manufacturing plants, distribution facilities, warehouses and auto service centers. In addition, there are a number of large estates which have been adapted for use as the Harrison Conference Center, a Russian consulate, the Webb Institute of Naval Architecture and the GEO Company. The commercial center of Glen Cove, located approximately 0.25 miles east of the Site, includes numerous shops and restaurants.

The nearest residence to the Site is located approximately 200 feet to the north on Janet Lane and The Place. Additional residential developments are located within 0.5 mile of the Site. The nearest water body, Glen Cove Creek, forms the southern boundary of Parcel A. Hempstead Harbor and the Long Island Sound are approximately 0.5 mile west of the Site. There are no agricultural activities within three miles of the Site.

3.7 ECOLOGICAL CHARACTERISTICS

3.7.1 Wetlands Delineation

There are no large freshwater streams in the Glen Cove area. The Site is located on the north side of Glen Cove Creek, a saltwater tidal channel. Approximately 3,000 feet southwest of the Site, Glen Cove Creek empties into Hempstead Harbor. Surface drainage from the Site is generally southward toward Glen Cove Creek. Since the area is developed, much of the surface water runoff is collected in storm drains that discharge directly into Glen Cove Creek. Total relief ranges from 10 to 96 feet above MSL. Wetlands on-site appear to be associated with natural drainage patterns and impoundments due to human activity. No wetland areas are depicted on either the National Wetlands Inventory Map (Sea Cliff, NY quadrangle) prepared by the U.S. Fish and Wildlife Service (USFWS) or the NYSDEC Freshwater Wetland Map (Sea Cliff, NY quadrangle). These maps are shown as Figures 3-7 and 3-8, respectively.

The Site has been altered in the past and to a lesser extent recently due to the clearing activities before the beginning of the field investigation. Much of the vegetation on the western portion of Parcel B was removed. A road was also constructed on Parcel C north of the Benbow Building. Given these factors, on-site drainage and vegetation have been disturbed. Two areas of impounded water have resulted from human activity which provided suitable conditions for the establishment of wetland communities. These areas are discussed below.

There are two surface water systems on-site. A drainage ditch located on the eastern half of Parcel B runs south approximately two-thirds the length of the parcel. A small pond approximately 15 feet wide by 25 feet long is located approximately midway along the drainage ditch. The most northerly section of the ditch was dry during the October-November 1996 field visits. Common reed (*Phragmites australis*) is the dominant species growing around the pond. Significant shrub and overstory species include northern spicebush (*Lindera benzoin*), northern arrowwood (*Viburnum recognitum*) and poison ivy (*Toxicodendron radicans*). The drainage becomes undefined in lower Parcel B. Dominant wetland species growing in and around the remaining drainage include jewelweed species (*Impatiens* spp.), common reed, poison ivy and pussy willow (*Salix discolor*). Dominant upland herbaceous vegetation includes greenbriar species (*Smilax* spp.). The dominant shrub species was black cherry (*Prunus serotina*).

A series of drainages running south on the western portion of middle Parcel C end in a pond. The area is forested and the pond is only very sparsely vegetated by emergent sedges. The northern portion of the largest drainage appears to be affected by silt from an upgradient unvegetated area. Vegetation is relatively homogeneous. Dominant wetland vegetation includes northern spicebush, northern arrowwood and common reed. In the drainages and at the north end of the pond, dominant wetland herbaceous vegetation includes jewelweed (*Impatiens capensis*), royal fern (*Osmunda regalis*) and skunk cabbage (*Symplocarpus foetidus*). Dominant upland herbaceous vegetation includes striped wintergreen (*Chimaphila maculata*), smooth solomon's seal (*Polygonum biflorum*) and goldenrod species (*Solidago* spp.). Dominant upland shrub and overstory species include gray birch (*Betula populifolia*), red oak (*Quercus rubra*), red maple (*Acer rubrum*) and sassafras (*Sassafras albidum*).

Two areas of impounded water exist on Parcel C that contain wetland vegetation. An area along the north side of the Benbow building measures approximately 20 feet by 160 feet. Dominant wetland vegetation includes jewelweed species, common reed and northern arrowwood. Dominant upland vegetation includes red oak, black cherry, gray birch and Japanese honeysuckle (*Lonicera japonica*). An area along the western boundary and within the berm around the 500,00-gallon aboveground fuel oil tank on lower Parcel C, measures approximately 15 feet by 25 feet in size. Dominant wetland vegetation includes pussy willow, wool grass (*Scirpus cyperinus*), sedge (*Carex scoparia*) and tussock sedge (*Carex stricta*). Dominant upland species include gray birch and common reed.

Based on field investigations of vegetation, soils and hydrology, and the data recorded on the wetland delineation forms (Appendix G), four delineated areas (Wetlands B, C1, C2 and C3) meet the federal criteria for wetland designation based on the application of the Corps of Engineers Wetland Delineation Manual (Dept. of the Army, 1987). Wetland B, situated on Parcel B, is approximately 25,246 square feet in size. Wetlands C1, C2 and C3 are approximately 2,867 square feet, 3,246 square feet and 11,376 square feet, respectively. Cumulatively, the wetland areas occupy approximately 1.0 acre of the Site. Wetland B can be classified as a palustrine emergent persistent and scrub-shrub broad-leaved deciduous wetland (PEM1/SS1), based on the Cowardin system (USFWS, 1979) of wetland classification. Wetlands C1 and C2 can also be classified as PEM1/SS1. Wetland C3 contains a mixture of wetland types and can best be classified as PSS1/PFO1 (palustrine scrub-shrub broad-leaved

deciduous/palustrine forested broad-leaved deciduous) and PEM2/PEM1 (palustrine emergent nonpersistent and persistent). The delineated boundaries of the on-site wetlands are depicted in Figure 3-9 and Plate 1 of Appendix G. Although Parcel A is predominantly paved, a small strip approximately 2 feet wide by 50 feet long (Area A) supports wetland vegetation. Upon investigation, it was discovered that while inundated, this vegetation was growing on approximately 1/2 inch of silt on top of pavement. The three surface impoundments (Mud Pond and the two Mud Holes) on lower Parcel C historically were used to dispose of process water were not delineated as wetlands. The Mud Holes have been altered during the field investigation and no longer exist as recognizable features. They are relatively level and while saturated, do not contain standing water. There is no vegetation and the soil consists of fill material. Mud Pond contains a dense stand of common reed in the southwestern half of the pond. The 'soil' on top of the liner consisted of a red clay/sand and dense root mat. More detailed results of the wetland delineation can be found in Appendix G.

3.7.2 Flora and Fauna Inventory

The Site lies in an area characterized as "successional maritime forest" according to the NYSDEC (Reschke, 1990). This community type is:

> "a successional hardwood forest that occurs in low areas near the seacoast. It is a variable type that develops after vegetation has burned or land cleared (such as pasture land or farm fields). The trees may be somewhat stunted and flat-topped because the canopies are pruned by salt spray. The forest may be dominated by a single species, or there may be two or three codominants. Characteristic canopy trees include black oak (*Quercus velutina*), post oak (*Quercus stellata*), shadbush (*Amelanchier canadensis*), white oak (*Quercus alba*), black cherry (*Prunus serotina*), black gum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), and red maple (*Acer rubrum*). A small number of eastern red cedar (*Juniperus virginiana*) may be present. Vines that are common in the understory and subcanopy include riverbank grape (*Vitis riparia*), poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and greenbriar (*Smilax spp.*)."

This community is distributed in the Coastal Lowlands ecozone, in low areas near the coast of Long Island. While Parcel A is mostly devoid of vegetation due to the presence of buildings and pavement, Parcels B and C consist mostly of this vegetative community type. Tree species are dominated by various oaks (Quercus spp.), with other species such as sassafras and black gum interspersed. Several invasive species, such as smooth sumac (Rhus typhina) and royal paulownia (Paulownia tomentosa) have also become integrated into this community.

As described above, poison ivy, Virginia creeper and greenbriar are dominant in the understory. The vegetation found on the Site during the September through November 1996 field surveys is listed in Table 3-5; the on-site vegetation patterns are illustrated on Figure 3-10. Since the Site vegetation had already been disturbed when the flora/fauna inventory took place, the percent aerial cover was estimated using aerial photography from a previous year (1995). This was done to give a better estimate of baseline conditions at the Site.

On Parcel A, the overstory percent coverage is approximately 2%. Scrub/shrub cover is approximately 3%. About 95% of this parcel consists of buildings and/or pavement. On Parcel B, the overstory percent coverage is approximately 70%, while the scrub/shrub cover is approximately 30%. On Parcel C and C', the overstory percent cover is approximately 40% and the scrub/shrub cover is approximately 15%. Buildings and pavement occupy approximately 45% of these parcels combined. The vegetative cover on each parcel is shown on Figure 3-10.

Wildlife observations were made during the September through November 1996 field surveys. A list of the birds, mammals and reptiles/amphibians observed on the Site during that time period is presented in Table 3-6. Small birds such as the American goldfinch (*Carduelis tristis*), common flicker (*Colaptes auratus*), blue jay (*Cyanocitta cristata*), gray catbird (*Dumetella carolinensis*), northern mockingbird (*Mimus polyglottos*), tufted titmouse (*Parus bicolor*), nuthatches (*Sitta* sp.), American robin (*Turdus migratorius*) and mourning dove (*Zenaida macroura*) were observed in the wooded areas of the Site. These wooded areas likely provide habitat for other small bird species as well, such as sparrows, starlings, grackles, cardinals and finches. American crows (*Corvus brachyrhynchos*) and killdeer (*Charadrius vociferus*) were also observed utilizing the Site. Many gulls (*Larus* spp.) were observed flying overhead and feeding or resting in the Glen Cove Creek area near the Site. A single osprey (*Pandion haliaetus*) was seen roosting on a telephone pole near the creek, as well as in the trees of Parcel B. An American bittern (*Botarus lentiginosus*) was observed feeding on the mudflats of Glen Cove Creek during low tide. It is likely that this area near the Site provides feeding and resting habitat for other waterfowl and wading birds as well.

Several small mammals were observed on the Site. A domestic cat (*Felis domestica*), several mice (*Mus musculus*) and rats (*Rattus norvegicus*) and a red fox (*Vulpes vulpes*) were seen at various points throughout the Site. The fox appeared quite unhealthy and had little fear of humans. One of the mice and one of the rats observed were dead. Raccoon (*Procyon lotor*)

tracks were observed on Parcel A near the warehouses, and this species is known to inhabit the warehouses on a long-term basis. A single common garter snake (*Thamnophis sirtalis*) was seen near the tank area on Parcel A. It is likely that other small mammals such as gray squirrels, chipmunks, rabbits, skunks, voles, moles and groundhogs may also utilize the wooded portions of the Site.

The New York State Natural Heritage Program was consulted with regard to the potential presence of threatened/endangered species on the Site. According to the Natural Heritage Program files, five sensitive species of vascular plants have been recorded within a one-mile radius of the Site (NYSDEC, 1997). These plants, along with species descriptions, are listed in Table 3-7. No threatened or endangered birds, mammals, reptiles, amphibians, fish or invertebrates were listed for this area. However, Hempstead Harbor is listed as a Waterfowl Nesting Area and is also a designated Significant Coastal Fish and Wildlife Habitat. This habitat is part of New York State's Coastal Management Program (CMP), which is administered by the NYS Department of State (DOS). Hempstead Harbor is also a known waterfowl wintering area most noted for scaup, canvasback and black ducks, and is a nursery/feeding habitat for shrimp, striped bass, bluefish, Atlantic silverside, menhaden, winter flounder and blackfish.

3.7.3 Floodplains

The southernmost portions of the site are located within both the 100-year and 500-year floodplains associated with Glen Cove Creek. As shown in Figure 3-11, most of Parcel A (south of Herb Hill Road) is within the 100-year floodplain, and the northernmost portion of Parcel A is within the 500-year floodplain. Only a small part of Parcel B (the southernmost portion of the parcel, just north of Herb Hill Road) is within the 500-year floodplain. Likewise, a small portion of the southern end of Parcel C (just north of Garvies Point Road) is located within both the 100-year and 500-year floodplains.

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4.0 IONIZING RADIATION

4.1 THE RADIOACTIVE ATOM

An atom is the smallest discrete unit of mass. It consists of a positively charged nucleus (made up of positively charged protons and electrically neutral neutrons) and a negatively charged cloud of orbiting electrons. The electrons move around the nucleus in paths which determine the amount of energy which the electrons possess.

A variety of forces exist within the atom. In a stable atom, all of the forces are balanced, indicating that the ratio of neutrons to protons falls within a target range. The actual range of nuclear stability varies with the atomic number of the element. All atoms with unstable nuclei strive to reach a stable configuration; this is achieved by releasing energy in the form of subatomic particles or electromagnetic rays by a process known as radioactive decay. The decay of an atom effectively alters the neutron to proton ratio, resulting in a more energetically stable atom.

There are approximately 1,700 different unstable atomic species, or radionuclides. They consist of both naturally occurring and man-made radionuclides. Each radionuclide has its own unique characteristic "fingerprint," consisting of three parameters: 1) The radioactive half-life describes the amount of time in which half of any given number of atoms of a radionuclide will decay. 2) The mode of decay refers to the type(s) of particles or electromagnetic rays emitted from the radionuclide as it decays. These types include alpha and beta particles and gamma rays, which will be described below. 3) The energy carried away from the atom by the particles or rays is radionuclide specific (i.e., radionuclides emit a range of energies upon decay; the magnitude of energy emitted is a characteristic of the radionuclide). It is the transfer of this energy to living tissue which may cause biological effects.

Following the decay of a radioactive atom, the resultant atom, and/or decay product, is often radioactive. It will decay with its own unique pattern. Its decay may also result in the formation of another radionuclide. This phenomenon describes the concept of a decay chain. The existence of these chains indicates that radioactive material is often

a mixture of the characteristic emissions of alpha, beta, and gamma radiation from the decay of several radionuclides. There are three naturally occurring decay chains, known as the uranium chain (of which ^{226}Ra is a member), the thorium chain, and the actinium chain. The radionuclides of concern present in the wastes which originated at the Site are members of the uranium and thorium chains.

The uranium chain is shown in Figure 4-1 and the thorium chain is shown in Figure 4-2. There are 14 unique radionuclides in the uranium chain and 11 unique radionuclides in the thorium chain which precede the formation of stable lead (^{206}Pb or ^{208}Pb). As can be seen in the figures, a plethora of alpha, beta, and gamma radiation are emitted from the various members of the two chains. One of the more prevalent contaminants is ^{226}Ra, the sixth member of the uranium chain. It emits alpha particles and gamma rays and has an approximate half-life of 1620 years. Its immediate decay product is gaseous radon (^{222}Rn; half-life of 3.8 days). The largest contribution to the background radiation dose received by most persons results from the decay of radon progeny, which can reach significant concentrations in indoor air where they may become electrostatically attracted to respirable dust particles. Once inhaled, the particles may deposit within the bronchial passages where the radon progeny will decay, irradiating nearby tissue primarily with alpha particles (and to a lesser extent with beta particles and gamma rays).

The thorium series radionuclides include a different gaseous isotope of the element radon (Rn). Radon-220, commonly known as thoron, is generally not a significant contributor to one's inhalation dose because the extremely short half-lives of thoron and its progeny usually preclude them from concentrating to any appreciable extent in indoor air. However, if a significant source of thoron exists beneath or adjacent to a structure (such as the thorium and ^{228}Ra found in tungsten ore residues), thoron progeny can reach concentrations resulting in dosimetric significance.

4.2 Modes of Decay

Excess energy may be emitted by radioactive atoms, or radionuclides, via several processes. The most common modes of radioactive decay are gamma rays, beta particles, and alpha particles.

Gamma rays consist of electromagnetic waves which are released from the nucleus of an atom at the speed of light. They have no mass and no net charge. Gamma rays travel as a series of propagating or oscillating waves. The greater the frequency of oscillation, the greater the energy of the gamma ray. They are physically identical to X-rays; however, the two possess differing points of origin. Unlike gamma rays, X-rays originate within the electron cloud following rearrangement of electrons between different energy levels.

Gamma rays (and X-rays) are often referred to as "penetrating" radiation. They can often pass through thick layers of lead, glass, concrete, and other absorbing media, as well as through human tissue. Gamma rays also travel relatively large distances through air and may, therefore, cause irradiation from sources outside of the body in a phenomenon known as external irradiation.

Beta radiation emission occurs when a neutron is converted into a proton and a beta particle. Physically identical to an electron, the beta particle is subsequently discharged from the nucleus at high speeds. A form of particle radiation, beta particles pose primarily an internal threat of biological damage. In most cases, for a beta particle emitter to deliver a significant radiation dose, it must be ingested, inhaled, or absorbed into the body, where it becomes a source of internal irradiation. There are some beta emitters, however, which may deliver a radiation dose to the skin from external sources. Beta particles are not highly penetrating; they will be stopped by a few centimeters of human skin.

Alpha particles consist of two protons and two neutrons (identical to the nucleus of a helium atom). They are the heaviest type of particle radiation and therefore are the slowest and least penetrating type of radiation. Alpha particles will only travel through a few centimeters in air and can be blocked by a single sheet of paper. When deposited within the body (such as on the surface of the lung), radionuclides that emit alpha particles

are the most effective type of radiation producing biological damage, since all of their energy is deposited in a small mass of tissue.

4.3 Units of Quantity, Exposure and Dose

The quantity of radioactive material may be measured in several different units. Like chemical (non-radioactive) materials, the mass of a radionuclide may be expressed in kilograms, pounds, etc. However, mass does not indicate the quantity of radiation emitted from the material being measured. When describing a quantity of a radionuclide, the unit must quantify the number of decaying atoms in a given time period. The Curie (Ci) is equal to 2.22×10^{12} decaying atoms per minute.[1] The concentration of a radionuclide in a solid matrix (e.g., the concentration of radium in a soil sample) would be expressed in picoCuries per gram (pCi/g). One pCi is equal to 10^{-12} Ci. Similarly, the concentration of a radionuclide in water would be expressed in pCi/L of water and in air, pCi/L of air.

The concentration of ^{222} Radon (radon) and ^{220} Radon (thoron) are gases and, therefore, are expressed in pCi/L of air. A special unit, known as Working Level (WL), was created to quantify the amount of alpha particle energy in air as a result of the decay of these gases and their two alpha particle emitting decay products. One WL is equal to 1.3×10^{5} Mega-electron Volts (MeV) of alpha particle energy in one liter of air.

Radiation exposure refers to the rate at which air molecules are ionized by incident gamma rays. The Roentgen (R) describes the amount of energy produced by ionized molecules and is equal to 86.9 ergs of energy per gram of air. [One erg is equal to 625,000 MeV.] In most cases, the exposure is shown as a rate and is expressed in micro-Roentgen per hour (μR/h). One μR is equal to 1×10^{-6} R.

A dose of ionizing radiation is defined as the quantity of energy absorbed per mass of tissue. The unit of dose is known as the "radiation absorbed dose," or rad, and is equal

[1]The international unit of radioactivity is the Becquerel (Bq), which is equal to one disintegrating atom per second.

to 100 ergs of energy per gram of tissue.[2] Therefore, a person who spends one hour in an exposure rate of 100 R/h will receive a radiation dose of 86.9 rads.

The biological hazards resulting from equal doses of differing modes of radiation are extremely variable. That is to say, the hazards posed by 100 rad doses of alpha, beta, and gamma radiation are not the same. Therefore, the unit of dose equivalent, measured in radiation equivalent man, or rem, has been defined to incorporate the type of radiation absorbed, the quantity of radiation, and other modifying factors.[3] Dose equivalent is calculated by multiplying the dose by the applicable quality factor (QF), which adjusts the dose to account for the relative biological effectiveness of the different types of radiation. Gamma rays and beta particles have a QF equal to one, and alpha particles have a QF equal to 20.

The committed dose equivalent is the dose equivalent averaged throughout any tissue or organ over a 50-year period following a known intake. It accounts for the fact that the radiation dose resulting from an intake may be delivered over many years. It will be affected by the biokinetics and decay characteristics of each individual radionuclide. Summing the committed dose equivalents for all tissues results in the committed effective dose equivalent value. It incorporates the dose from radionuclides decaying internal to the body as well as the dose from exposure to penetrating radiation (e.g., gamma rays and X-rays) whose source is external to the body.

The radiological parameters and their units are summarized in Table 4-1.

4.4 Biological Effects Of Ionizing Radiation

Radiation is known to cause biological effects in irradiated organisms. The actual effects resulting from a dose of radiation is a function of the magnitude of the dose, the dose rate, the type of radiation involved, the organs receiving the dose, and the age of the exposed individual.

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[2]The international unit of dose is the Gray (Gy), which is equal to 100 rads.

[3]The international unit of dose equivalent is the Sievert (Sv), which is equal to 100 rem.

The interaction of radiation with living tissue causes atoms in the tissue to become "ionized" or "excited." Ionizations occur when the energy of the incoming radioactive particle causes removal of electrons in the absorbing tissue from their orbital path. Therefore, radionuclides are said to emit "ionizing" radiation. The net charge of the ionized atom has been altered. In an excitation event, electrons remain in the affected atom, but are moved to a farther distance from the atom's nucleus. The charge of the atom remains the same. Ultimately, the electron returns to its original ground state with a subsequent release of the excess energy.

When atoms in a cell are ionized or excited, they may react with other atoms, disrupting the normal operations of organs. Some exposure scenarios will lead to organ-specific anomalies, while a whole body dose may result in deleterious effects in several organ systems.

Acute health effects will result following doses ranging from approximately 100 to several hundred rads. Symptoms include gastrointestinal disorders (e.g., nausea and vomiting), fever, loss of hair, diarrhea, hemorrhage, central nervous system disorders, and cardiovascular collapse. Acute radiation doses may be fatal; a median lethal dose of 450 rads has been established in humans.

Note that exposures resulting from waste materials originating at the Site do not result in acute exposures and therefore cannot cause the acute health effects described above. The materials of concern at this site are sometimes referred to as diffuse naturally occurring radioactive material (NORM). While this acronym is often used to classify the material for the purposes of handling and disposal, one should not lose sight of the fact that the materials are, for the most part, not in their natural state with regard to radionuclide concentrations. The processing of the tungsten ore caused the radionuclides to concentrate in many of the processed waste streams. Another acronym sometimes used to describe the material is technologically enhanced radioactive material (TERM), which incorporates the fact that the radionuclide content has been affected by human activity.

While incapable of causing acute health effects, exposure to these materials may increase the risk of developing a radiogenic cancer. This carcinogenic risk is a type of chronic, or long-term health risk. Chronic risks are best described as statistical

probabilities based on models and risk coefficients which have been derived from numerous studies of radiation effects on various populations (human, animal, and cellular).

Chronic exposure to radiation may increase the risk of cancer. There is no unique radiogenic cancer type, nor can a diagnosis of a cancer be shown to be the result of radiation exposure. However, some specific associations have been observed such as the increased risk of lung cancer due to exposure to radon decay products. There are several mechanisms which have been proposed describing the role of ionizing radiation in cancer development. These include damage to chromosomes, mutations in somatic cells affecting cellular activities, and free radical formation following irradiation of water molecules.

Other long-term effects from radiation exposure are cataract formation in the eye lens, teratogenic effects, and hereditary effects, such as genetic mutations.

4.5 Natural Background Radiation

The radioactive contaminants of concern at the Site are all naturally occurring constituents in most rocks and soils. Most soils and rocks indigenous to the northeast United States have thorium, radium, and uranium concentrations ranging from 0.5 - 1 pCi/g.

Background sources of radiation include terrestrial, cosmic, cosmogenic, and internally deposited radionuclides. The terrestrial component consists of several radionuclides including all members of the thorium and uranium series, which are the radionuclides of concern at the Site. Internal emitters include natural radionuclides which are ingested through normal dietary intake of meat, fruits, and vegetables, such as ^{40}K (a radioisotope of potassium) and ^{137}Cs, which was distributed in the environment during the atmospheric weapons testing conducted in the 1950s and early 1960s. The estimated average annual dose equivalent from these sources to an individual in the United States is approximately 100 mrem (NCRP, 1987). The majority of this dose is delivered via two pathways; (1) externally, from gamma emitters located in the earth's crust, and (2) internally, due to ingested radionuclides.

An estimated average of 200 mrem per year will result from the inhalation of the decay products of indoor ^{222}Rn gas where present in background concentrations. Radon-222 is produced by the decay of ^{226}Ra. Radon gas is mobile, i.e., it emanates from soil into structures. An elevated ^{226}Ra concentration in soil underlying and adjacent to a structure will often result in a high concentration of indoor radon, especially in the lowest level of the structure. Since radium is ubiquitous in soil, there will always be some level of radon in both outdoor and indoor air. The indoor radon concentration has been shown to average approximately 1.5 pCi/L in the absence of any enhanced sources of radium. Some geographic areas have been associated with a potential for elevated indoor radon. Levels as high as 1000 pCi/L have been measured due to natural sources. Thoron gas (^{220}Rn, a decay product of ^{232}Th) is generally not a major contributor to the inhalation dose due to the extremely short half-lives of thoron and its decay products. However, if there are elevated sources of thorium-bearing materials within, beneath, or adjacent to a structure, thoron gas and its decay products may contribute a significant radiation dose via the inhalation pathway.

Medical exposures constitute an additional source of radiation to members of the general public, although they are not a result of natural background radiation. On average, an individual receives approximately 55 mrem per year due to diagnostic x rays and nuclear medicine procedures. Other sources of radiation exposure are various consumer products and the nuclear fuel cycle, although the magnitude of exposure to the average member of the general public is less than 1 mrem per year.

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5.0 NATURE AND EXTENT OF CONTAMINATION

5.1 INTRODUCTION

5.1.1 General

The following discussion on the nature and extent of contamination at the Site is based on validated data obtained from the sampling events described in Section 2.0. These samples include surface and subsurface soil, surface water, sediment, groundwater and building materials. These samples were analyzed for a full range of TCL organics, TAL inorganics (including cyanide) and radionuclides (^{238}U, ^{230}Th, ^{232}Th, ^{226}Ra and ^{228}Ra). Selected soil samples were also analyzed for other chemical parameters such as total organic carbon (TOC), TCLP Parameters, and physical properties (grain size, moisture content, bulk density, atterberg limits and hydraulic conductivity). Selected aqueous samples were analyzed for pH and total dissolved solids (TDS). The complete results are summarized by the major analytical groups (e.g., volatiles, semi-volatiles, pesticide/PCBs, inorganics, radionuclides) in Appendix N. Soil chemistry data (e.g., total organic carbon and pH) are presented with the radionuclide data in Appendix N.

All laboratory analyses were performed by non-RAS laboratories procured under subcontract with Malcolm Pirnie. Laboratory analytical methodologies and data validation procedures were selected to meet the data quality objectives identified in the Work Plan. All samples were analyzed by non-RAS laboratories; CLP laboratories could not accept any samples from the Site due to the potential for radioactive contamination. The laboratory statement of work and analytical methodologies were developed to be consistent with the latest CLP methodology (ILM04.0 and OLM03.2 for TAL/TCL analyses) or USEPA approved analytical methods for non-RAS chemical and radiological parameters and to meet data quality objectives . A list of analytical parameters and methodologies are presented in Table 5-1.

All data were validated by USEPA Region II certified data validators according to USEPA validation guidelines. Validation procedures for the radiological data were developed specifically for this investigation and were contained in the FSP. The validation procedures were submitted to and approved by the USEPA.

Tentatively identified compounds (TICs) were found most commonly in the BNA analysis for soils; very few occurred in the VOA or pesticide/PCB analysis. Those compounds that could be presumptively identified, were flagged with a "N" (presumptively identified) and an "E" (estimated) qualifiers. A portion of these data, however, were ultimately rejected because the TICs also showed up in some of the blanks. All other TICs were identified as "unknown hydrocarbons". For these reasons, TICs have not been included in the summary tables and have been omitted in the discussion of the nature and extent and the risk assessment.

5.1.2 Comparison to ARARs and TBCs

The various media (soil, groundwater, surface water and sediment) are compared against ARARs and TBCs for volatiles, semi-volatiles, pesticide/PCBs, inorganics and radionuclides. The ARARs and TBCs included USEPA Generic Soil Screening Levels (SSLs) and Maximum Contaminant Levels (MCLs), NYSDEC standards and site-specific background concentrations.

The New York State standards for soils were derived based upon the NYSDEC Technical Administrative Guidance Memorandum (TAGM) HWR-94-4046 Determination of Soil Cleanup Objectives and Cleanup Levels (NYSDEC, 1994) and TAGM 4003 Cleanup Guideline for Soils Contaminated with Radioactive Materials. TAGMs 4046 and 4003 are guidance documents, therefore, TAGM values are treated as TBCs. The TAGM guidance values have been derived and corrected for the average site-specific TOC soil value of 0.55%. PCB guidance values have been corrected by a factor of 100 as required by TAGM 4046.

The New York State standards for groundwater are based on the New York Codes, Rules and Regulations (NYCRR) Title 6, Chapter X, Parts 700-705. The USEPA MCLs are based on the Federal Safe Drinking Water Act (40 CFR Part 141). Surface water contaminant concentrations were compared and screened against NYSDEC Surface Water Standards provided in Title 6, Chapter X, Parts 700-705. Sediment and storm sewer sediment contaminant concentrations were compared and screened against TAGM guidance values.

5.1.3 Determination of Site-Specific Background

Seven samples collected at four sample locations (MP-11D/11DB on Parcel C' and MP-5/5B, SB-13/13B and TP-6 on the northern portion of Parcel B) were selected as representing site-specific background for volatile organics, semi-volatile organics, pesticides/PCBs and

inorganics. These samples were chosen because the sample locations were in areas that are removed from known sources of contamination and in areas believed to be relatively undisturbed. Site-specific background concentrations in soils and groundwater are discussed in the respective sections below for each analytical group (e.g., volatiles, semi-volatiles, etc).

Site-specific radionuclide background concentrations were determined from the same four sample locations plus six off-site sampling locations. The location of the off-site locations were described in Table 2-1. The site-specific radionuclide background concentrations for groundwater are presented in Table 5-2. The site-specific background and 1.5X site-specific background for soils are presented in Table 5-3. No site-specific background was determined for surface water because no areas could be identified that were not potentially affected by operations at the Site; the TAGM guidance values for sediment is used to compare sediment and storm sewer sediment data.

5.1.4 Data Presentation Utilizing GIS/Key

GIS/Key™ is a environmental database management system that integrates data and graphics. Because of the extensive amount of chemical and radiological data collected and the overall size of the areas to be represented on maps, conventional methods of data management and graphical presentation were determined to be too cumbersome. GIS/Key™ has been used in a modified format in this Report to present the distribution of chemical and radiological constituents in the soils and groundwater. One limitation to the GIS/Key™ software is that only one data point at each sampling station can be plotted. At soil sampling stations (soil borings, monitoring well borings and clustered monitoring well borings), where more than one sample was collected, the highest detected value for that constituent was selected for graphical illustration (the lower value is not represented). For example, arsenic in soil samples collected from MW-5 at 0-2 feet (14.9 mg/Kg) and MW-5B at 2-4 feet (6.5 mg/Kg) - only the 14.9 mg/Kg value is represented graphically; for arsenic in groundwater samples from MW-18 (36.4 µg/L) and MW-18D (ND) - only the 36.4 µg/L value is represented graphically. The summary tables presented on the figures, therefore, represent the data set that was used to construct the drawing and does not reflect the total number of samples where each individual constituent was detected. In the case of groundwater samples, if the measured value of the particular constituent from the clustered wells are comparable, both values were used in construction of the figure and are

shown on the summary tables. The total number of times each constituent was detected is described in the text; the complete data set is provided in Appendix N.

A variety of contaminants were detected in both the soils and groundwater samples at a wide range of concentrations. The distribution pattern of many of the constituents in a particular group (e.g., volatiles, semi-volatiles, inorganics and radionuclides), however, often showed some similarities in the areas of the Site where they were detected. The selection of individual chemical or radiological constituents for graphical presentation was based on one of three primary criteria:

- represents that group of constituents (e.g, inorganics, volatiles, etc.,);
- represents a unique or particularly significant distribution for that group of constituents;
- represents a health-risk.

Based on one of these criteria, the constituents were selected. The selected constituents and the accompanying figure number for soils and groundwater were as follows:

Soils

- Volatiles - trichloroethene, tetrachloroethene and benzene (0-4 feet) in Figures 5-1 through 5-3;
- Semi-volatiles - benzo(a)anthracene (0-4 feet) in Figure 5-4;
- PCBs - total PCBs (0-4 feet) in Figure 5-5;
- Inorganics - arsenic, cobalt and manganese (0-4 feet and below 4 feet) in Figures 5-6 through 5-11;
- Radionuclides - ^{238}U, ^{232}Th and ^{226}Ra (0-4 feet and below 4 feet) in Figures 5-12 through 5-17.

Groundwater

- Volatiles - trichloroethene, tetrachloroethene and total BTEX (December 1996 and January 1997) in Figures 5-18 through 5-23;
- Semi-volatiles - no figure presented;
- PCBs - no figure presented;
- Inorganics - arsenic, antimony and manganese (December 1996 and January 1997) in Figures 5-24 through 5-29;

- Radionuclides - ^{238}U, ^{232}Th and ^{226}Ra (December 1996 and January 1997) in Figures 5-30 through 5-35.

5.2 NATURE AND EXTENT OF CONTAMINATION

The following section summarizes the nature and extent of contamination in each medium sampled. Based on the environmental sampling and historical information, the primary and secondary sources of contamination are identified as discussed. For purposes of understanding the general extent of contamination in surface and subsurface soils, laboratory analytical data from all sampling locations (monitoring wells, test pits, surface soils and soil borings) are presented together. Where applicable, the extent of contamination is further discussed by type of boring (i.e., storm sewer borings, source areas borings, etc.). The vertical extent of the selected contaminants in soils have been grouped into surface and near surface soils (0-4 feet) and subsurface soils (greater than 4 feet).

The source of much of the contamination at the Site is the tungsten ore residues that were previously left on-site or currently remain buried on-site. Prior to the start of this RI, approximately 3,000 - 4,000 cubic yards of the ore residues were present on the Site in drums, wooden crates and mounds both inside some of the buildings and outside on driveways and walkways, primarily on Parcel A, but also to a lesser extent on Parcel C. These ore residues were temporarily relocated to the Dickson Warehouse as part of the 1995-1996 IRAs described in Section 1.3.3. Other primary contaminant sources include an area in the center of Parcel B that is believed to have been used as a disposal area for ore residues; the "scarred" vegetation area in the northern portion of Parcel C that was also used as a disposal area for ore residues; the Mud Pond and two Mud Holes which were used for disposal of wastewater; underground storage tanks on Parcel A; and a 500,000-gallon aboveground fuel oil tank on Parcel C. Secondary sources of contamination include the on-site storm sewer lines and groundwater from three off-site sources: the Mattiace Petrochemical site, the Konica property (formerly Powers-Chemco) and the Crown Dykman site across Herb Hill Road from the main entrance to Parcel A.

5.2.1 Surface and Subsurface Soil

5.2.1.1 Volatile Organic Compounds (VOCs)

VOCs were detected in relatively few soil samples, at low concentrations (less than 5 µg/Kg) and at shallow depths (0-4 feet). The distribution of VOCs in the soils is limited to three areas: the northern portion of Parcel A; the southern portion of Parcel B; and the southern portion of Parcel C around the aboveground fuel oil tank and Mud Pond. The VOCs which exceeded their respective TAGM guidance value include acetone, 2-butanone, methylene chloride, benzene, toluene, trichloroethene and tetrachloroethene. The distribution of trichloroethene, tetrachloroethene and benzene are presented in Figures 5-1 through 5-3. The only VOC present in any of the site-specific background soil samples was methylene chloride. Methylene chloride was detected in MP-5B (3 J µg/Kg) and in two samples from monitoring well boring MP-11D (3 J and 5 J µg/Kg).

Trichloroethene (TCE) was detected in three samples at concentrations ranging from 2 J to 5 J µg/Kg. The USEPA SSL (3 µg/Kg) was equaled or exceeded twice. Two sample locations were on Parcel C in the vicinity of Mud Pond (5 J µg/Kg in SB-22 and 2 J µg/Kg in SB-4); the third location was near the main entrance to Parcel A (3 µg/Kg in MP-20). The distribution of TCE in soils from 0-4 feet is presented in Figure 5-1.

Tetrachloroethene (PCE) was detected in six samples and exceeded the USEPA SSL (6 µg/Kg) in the two samples from monitoring well boring MP-20 along the northern boundary of Parcel A (39 E µg/Kg in the 0-2 foot sample and 45 µg/Kg in the 2-3 foot sample). Other areas where PCE was detected but did not exceed the USEPA SSL included SB-36 (3 J µg/Kg), SS-2 (2 J µg/Kg) and SB-1 (1 J µg/Kg) on Parcel A and SB 40 (2 J µg/Kg) on the southern portion of Parcel C. The distribution of PCE in soils from 0-4 feet is presented in Figure 5-2.

Benzene was detected in three samples. The TAGM guidance value (3 µg/Kg) and the USEPA SSL (2 µg/Kg) for benzene was exceeded in one surface soil sample located in the southwest corner of Parcel B (4 µg/Kg in SS-8). Benzene was also detected in one monitoring well boring sample on Parcel C (2 J µg/Kg in MW-18) and one storm sewer soil boring sample on Parcel A (1 J µg/Kg in SB-35). The distribution of benzene in soils from 0-4 feet is presented in Figure 5-3.

Acetone, 2-butanone, and methylene chloride were detected in approximately 15-18% of the soil samples. The TAGM guidance value for acetone (10 g/Kg) was exceeded in 16

samples. The TAGM guidance value for methylene chloride (5 µg/Kg) was exceeded in two samples (7 J µg/Kg in MP-2D and 22 g/Kg in SB-5 on Parcel A), and one surface soil sample on Lower Parcel B (16 µg/Kg in SS-8). The TAGM guidance value for 2-Butanone (15 µg/Kg) was exceeded in three samples: MP-22 (52 µg/Kg); MP-22D (17 µg/Kg and 16 µg/Kg).

Toluene was detected in three samples. Toluene exceeded the TAGM guidance value (75 µg/Kg) in one sample at 0-2 feet (5 J mg/Kg in SB-5). The concentration of 1,1,2,2-tetrachloroethane (1,1,2,2-TCA) exceeded the USEPA SSL (2 µg/Kg) in one sample on Parcel C (4 J µg/Kg in SB-25), but did not exceed the TAGM guidance value (30 µg/Kg). 1,2 Dichloropropane was also detected in one sample from 0-2 feet in monitoring well boring MP-18 on Parcel C (3 J µg/Kg) above the USEPA SSL (1 µg/Kg), but below the TAGM guidance value (15 µg/Kg). Other VOCs detected were below their respective regulatory levels as follows: styrene (two samples), 2-hexanone (six samples), carbon disulfide (four samples), chloroform(two samples), 1,1,1 trichloroethane (both samples from SB-5), total 1,2-dichloroethene (four samples), 1 chlorobenzene (one sample), ethylbenzene (two samples), 4-methyl-2-pentanone (eight samples), and total xylenes (one sample).

5.2.1.2 Semi-Volatile Organic Compounds (SVOCs)

Soil background samples (MP-11D, MP-5B, SB-13 and TP-6) indicated no detectable levels of any semi-volatile organic compounds (SVOCs). Thirteen SVOCs were detected in the surface and subsurface soils at concentrations that exceeded the TAGM or USEPA SSL guidance values. The 13 SVOA compounds included benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, pentachlorophenol, fluoranthene, phenanthrene, pyrene, dibenz(a,h)anthracene, N-nitrosodiphenylamine, and carbozole.

Benzo(a)anthracene was detected in 33 samples and exceeded the USEPA SSL guidance value (80 µg/Kg) in 28 samples and the TAGM guidance value (112 µg/Kg) in 21 samples. In the 28 samples exceeding the more restrictive (lower) USEPA SSL guidance, the concentration ranged from 81 J µg/Kg (SS-2) to 9,900 µg/Kg (SB-31). Benzo(a)anthracene was detected mostly frequently in the soil samples collected on Parcel A, however, it was also detected in the central portion of Parcel B, and in the northern ("scarred vegetation area") and southern (Mud Pond) portions of Parcel C. Areas on Parcel A where the concentration exceeded the USEPA

SSL guidance included two surface soil samples: SS-2 (81 J µg/Kg) and SS-5R (3,100 µg/Kg); six storm sewer boring samples: SB-31 (9,900 µg/Kg), SB-32 (120 J, µg/Kg), SB-33R (460 E µg/Kg), SB-35R (220 J, µg/Kg), SB-36R (150 J µg/Kg) and SB-37R (110 J µg/Kg); five source area soil boring samples: SB-1R (570 µg/Kg), SB-3R (1,700, µg/Kg), SB-5 (540 E µg/Kg), SB-6R (200 J µg/Kg) and SB-7R (100 J µg/Kg); and six monitoring well boring samples MP-2 (280 J µg/Kg), MP-6 (170 J µg/Kg), MP-20 (99 J µg/Kg), MP-22 (310 J µg/Kg), MP-22BR (1,100 µg/Kg and MP-22D (440 µg/Kg). In the central portion of Parcel B, benzo(a)anthracene exceeded the USEPA SSL in two test pit samples (360 and 260 µg/Kg in TP-3R and TP-5, respectively), two source area soil boring samples (100 J and 270 J µg/Kg in SB-11 and SB-16R, respectively) and one surface soil sample (92 J µg/Kg in SS-9). The USEPA SSL was exceeded in three source area soil borings (260 J, 170 J and 110 J µg/Kg in SB-22, SB-26 (on Parcel C′) and SB-28, respectively) on Parcel C. The distribution of benzo(a) anthracene is shown in Figure 5-4.

Chrysene was detected in 47 samples at concentrations ranging from 220 J µg/Kg (SB-6) to 11,000 µg/Kg (SB-31). The concentration of chrysene exceeded the TAGM guidance value (200 µg/Kg) in 18 samples and the USEPA SSL (8,000 µg/Kg) in one sample. The distribution of chrysene was very similar to benzo(a)anthracene: throughout most of Parcel A, the middle of Parcel B and small areas in the upper and lower portions of Parcel C. On Parcel A, the TAGM guidance values were exceeded in two surface soil samples: SS-5R and SS-7 (4,000 and 440 E µg/Kg, respectively); five source area soil boring samples: SB-1R (580 µg/Kg), SB-3R (1,900 µg/Kg), SB-5 (860 µg/Kg), SB-6R (220 J µg/Kg), SB-7B (420 J µg/Kg); three storm sewer boring samples: SB-31 (11,000 µg/Kg), SB-33R (500 µg/Kg), SB-35R (220 µg/Kg); and three monitoring well soil boring samples: MP-2DR (500 µg/Kg), MP-22R (360 µg/Kg) and MP-22BR (450 µg/Kg). On Parcel B, two test pit samples (400 J and 330 J µg/kg in TP-3R and TP-5, respectively) and one source area soil boring sample (360 J µg/Kg in SB-16R) exceeded TAGM guidance value. On Parcel C and C′, two source area soil borings (310 J and 230 µg/Kg in SB-22 and SB-26, respectively) exceeded TAGM guidance value.

Benzo(b)fluoranthene was detected in 47 soil samples and exceeded the USEPA SSL (200 µg/Kg) in 28 samples and the TAGM guidance value (550 µg/Kg) in 13 samples. In the 28 samples exceeding the USEPA SSL guidance value (200 µg/Kg), the concentration of benzo(b)fluoranthene ranged from 220 J µg/Kg (in SB-35R) to 14,000 E µg/Kg (in SB-31). The

majority (20) of samples that exceeded the USEPA SSL were from various locations throughout Parcel A including: three surface soil samples: SS-2 (400 E µg/Kg), SS-5R (6,900 Y µg/Kg) and SS-7 (10,000 E µg/Kg); seven source area soil borings: SB-1R (1,000 Y µg/Kg), SB-2B (7,800 µg/Kg), SB-3R (1,600 µg/Kg), SB-5 (1300 E µg/Kg), SB-5B (500 E µg/Kg), SB-6R (290 µg/Kg), SB-7B (360 µg/Kg); six storm sewer soil boring samples: SB-31 (14,000 E µg/Kg), SB-32 (250 µg/Kg), SB-33R (390 J µg/Kg), SB-34R (820 J Y µg/Kg), SB-35R (220 J µg/Kg), SB-36R (260 Y J µg/Kg); and four monitoring well boring samples: MP-2DR (540 Y µg/Kg), MP-6B (360 J µg/Kg), MP-22BR (740 µg/Kg) and MP-22D (930 µg/Kg). Other locations where the USEPA SSL guidance value was exceeded included three test pit samples: TP-1 (510 µg/Kg), TP-3R (320 J µg/Kg) and TP-5 (1,000 E µg/Kg); one surface soil sample: SS-9 (500 µg/Kg); and two source area soil boring samples: SB-11 (360 µg/Kg) and SB-16R (550 Y J µg/Kg) on Parcel B; and two sources area soil borings: SB-22 (670 µg/Kg) and SB-26 (400 J µg/Kg) on Parcels C and C′.

Benzo(k)fluoranthene was detected in 13 samples. The TAGM guidance value (550 µg/Kg) was exceeded in two samples; the USEPA SSL guidance value (2,000 µg/Kg) was not exceeded in any sample. The two samples where the TAGM value was exceeded are located on Parcel A in one source area soil boring sample (1,500 µg/Kg in SB-3R) and in one monitoring well boring sample (710 µg/Kg in MP-22R).

Benzo(a)pyrene was detected in 36 soil samples at concentrations ranging from 38 J (MP-5) to 3,900 E µg/Kg (SS-7). The TAGM guidance value (30 µg/Kg) was exceeded in 35 samples and the USEPA SSL guidance value (400 µg/Kg) was exceeded in eight samples. Benzo(a)pyrene was mostly found on Parcel A in the same general locations as benzo(a)anthracene and benzo(b)fluoranthene. Parcel A locations where the TAGM guidance value was exceeded included three surface soil samples: SS-2 (43 J µg/Kg), SS-5R (3,600 µg/Kg), SS-7 (3,900 E µg/Kg); nine source area soil boring samples: SB-1R (620 µg/Kg), SB-2R (81 J µg/Kg), SB-2B (2,200 E µg/Kg), SB-3R (1,900 µg/Kg), SB-5 (480 µg/Kg), SB-5B (46 J µg/Kg), SB- 6R (230 J µg/Kg), SB-7R (130 µg/Kg), SB-7B (200 J µg/Kg); six storm sewer soil boring samples: SB-31 (2,900 µg/Kg), SB-32 (72 J µg/Kg), SB-33R (390 µg/Kg), SB-35R (220 J µg/Kg), SB-36R (170 µg/Kg), SB-37R (110 J µg/Kg); and eight monitoring well samples: MP-2DR (180 J µg/Kg), MP-6B (110 J µg/Kg), MP-20R (100 J µg/Kg), MP-20BR (77 J µg/Kg), MP-22R (280 J µg/Kg), MP-22BR (850 µg/Kg), MP-22D (460 µg/Kg), and MP-

22DB (60 J µg/Kg). Parcel B locations include two test pits samples: TP-3R (390 µg/Kg), TP-5 (200 J µg/Kg); two source area soil boring samples: SB-11 (75 J µg/Kg), SB-16R (320 J µg/Kg); one surface soil sample: SS-9 (120 µg/Kg); and one monitoring well boring sample: MP-5 (38 J µg/Kg). Parcel C and C′ locations included two source area soil boring samples: SB-22 (250 J µg/Kg), SB-26 (89 J µg/Kg) and one monitoring well boring sample: MP-16SB (130 J µg/Kg).

Indeno(1,2,3-cd)pyrene was detected in 33 soil samples and exceeded the USEPA SSL (700 µg/Kg) in five samples and the TAGM guidance value (3,200 µg/Kg) in three samples. The five locations where the USEPA SSL guidance value was exceeded were on Parcel A. The highest concentration (6,300 J µg/Kg) was detected in SB-31, a storm sewer soil boring at 3-5 feet below grade. Other samples exceeding the USEPA SSL included two source area soil boring samples: SB-2B (1,300 E µg/Kg) and SB-3 R (1,200 µg/Kg); one storm sewer soil boring sample: SB-31 (6,300 J µg/Kg); and two surface soil samples: SS-5R (3,800 µg/Kg) and SS-7 (2,200 µg/Kg).

Pentachlorophenol was detected in one surface soil sample (SS-3R) near the former sodium hydroxide tank on Parcel A at a concentration of 3,600 µg/Kg. This concentration exceeded both the TAGM guidance value (500 µg/Kg) and the USEPA SSL (300 µg/Kg).

The regulatory levels for fluoranthene, phenanthrene, and pyrene were also exceeded in storm sewer boring SB-31 on Parcel A (also the location of the highest concentration of indeno(1,2,3-cd)pyrene). Fluoranthene was detected in 45 samples, however, only one sample (26,000 µg/Kg in SB-31) exceeded the TAGM guidance value (25,000 µg/Kg). The same sample, however, was below the USEPA SSL (210,000 µg/Kg). Phenanthrene was detected in 34 soil samples and exceeded the TAGM guidance value (25,000 µg/Kg) in one sample (33,000 E µg/Kg in SB-31). Pyrene was detected in 51 samples, but exceeded the TAGM guidance value (25,000 µg/Kg) in one sample (28,000 E µg/Kg in SB-31) and was below the USEPA SSL (50,000 µg/Kg) in all samples.

Dibenz(a,h)anthracene was detected in ten samples and exceeded the TAGM guidance value (7 µg/Kg) in all ten samples; eight samples exceeded the USEPA SSL (80 µg/Kg). The locations that exceeded TAGM guidance values were all on Parcel A and included four source areas soil borings samples: SB-1R (170 J µg/Kg), SB-3R (420 µg/Kg), SB-5 (170 µg/Kg) and SB-6R (75 J µg/Kg); two storm sewer soil boring samples: SB-33R (110 µg/Kg) and SB-35R

(65 J µg/Kg),; two surface soil samples: SS-5R (1,300 J µg/Kg) and SS-07 (770 E µg/Kg); and two monitoring well soil borings: MP-6B (380 J µg/Kg), MP-22R (180 J µg/Kg).

N-nitrosodiphenylamine was detected in four samples above the USEPA SSL (60 µg/Kg). All four samples were collected from two source area soil borings on Parcel B near the 500,000-gallon aboveground fuel oil tank: SB-24 (5,300 J µg/Kg), SB-24B (530 E µg/Kg), SB-25 (10,000 J µg/Kg) and SB-25B (2,400 E µg/Kg). These samples were collected from 0-2 feet and 2-4 feet below grade.

Carbazole was detected in eight samples and exceeded the USEPA SSL (30 µg/Kg) in seven samples. Samples which exceeded the USEPA SSL guidance value were all on Parcel A and included one source area soil boring sample: SB-5 (90 J µg/Kg); one storm sewer soil boring sample: SB-33R (94 J µg/Kg); two surface soil samples: SS-5R (700 J µg/Kg) and SS-7(1,000 E µg/Kg); and three monitoring well soil boring samples: MP-2DR (490 µg/Kg), MP-6B (58 µg/Kg) and MP-22BR (310 J µg/Kg).

Other SVOCs were detected in the surface and subsurface soils, but at concentrations that were below their respective regulatory screening levels including: bis(2-ethylhexyl)phthalate - 17 samples below the TAGM guidance value (25,000 µg/Kg); benzo(g,h,i)perylene - 36 samples below the TAGM guidance value (25,000 µg/Kg); anthracene -15 samples below the TAGM guidance value and USEPA SSL (25,000 µg/Kg); diethylphthalate - two samples below the TAGM guidance value (3,550 µg/Kg); acenaphthene - nine samples below the TAGM guidance value (25,000 µg/Kg) and the USEPA SSL (29,000 µg/Kg); fluorene - 12 samples below the TAGM guidance value (25,000 µg/Kg) and the USEPA SSL (28,000 µg/Kg); naphthalene - eight samples below the TAGM guidance value (6,500 µg/Kg) and the USEPA SSL (4,000 µg/Kg); dibenzofuran - nine samples below the TAGM guidance value (3,100 µg/Kg); 2-methylnaphthalene - six samples below the TAGM guidance value (18,200 µg/Kg); dimethylphthalate - one sample below the TAGM guidance value (1,000 µg/Kg); acenaphthylene - one sample below the TAGM guidance (20,500 µg/Kg); di-n-butylphthalate - two samples below both the TAGM guidance value (4,050 µg/Kg) and the USEPA SSL (270,000 µg/Kg); and butylbenzylphthalate - two samples below the TAGM guidance value (25,000 µg/Kg) and the USEPA SSL (810,000 µg/Kg).

5.2.1.3 Pesticide/PCBs

Soil background samples (MP-11D, MP-5B, SB-13 and TP-6) indicated no detectable concentration of any pesticide or PCB compound. The pesticide/PCBs detected in the surface and subsurface which exceeded the TAGM guidance or the USEPA SSL values included total PCBs (the summation of Aroclor-1242, 1248, 1254, and 1260), Endrin, and 4-4-DDT.

PCBs:

Total PCBs exceeded the TAGM guidance value (1,000 µg/Kg) in four samples. Three samples were located near the mounds of ore residue in middle Parcel B: SB-14 (15,890 µg/Kg), SB-15 (2,110 µg/Kg) and TP-5 (1,170 µg/Kg). The fourth sample collected from a source area soil boring (1,020 µg/Kg in SB-6) near the former sodium hydroxide tank on Parcel A. The distribution of total PCBs is presented in Figure 5-5.

Looking at individual congeners: aroclor-1242 was detected in one sample on Parcel B (1,990 µg/Kg in TP-1). Aroclor-1248 was detected in one source area soil boring sample on Parcel A: SB-6 (890 µg/Kg); six source area soil boring samples on Parcel B: SB-9 (270 µg/Kg), SB-10 (56 µg/Kg), SB-12 (56 µg/Kg), SB-14 (11,500 E µg/Kg), SB-15 (1,500 µg/Kg) and SB-15B (210 E µg/Kg); and one source area soil boring sample: SB-21 (450 E µg/Kg) and one storm sewer soil boring sample: SB-41(28 J µg/Kg) on Parcel C. Aroclor-1254 was detected in one surface soil sample: SS-3 (150 J µg/Kg); and one source area soil boring sample: SB-6 (130 µg/Kg) on Parcel A; one surface soil sample: SS- 8(99 E µg/Kg); nine source area soil boring samples: SB-9 (73 µg/Kg), SB-10 (42 µg/Kg), SB-11 (180 E µg/Kg), SB-13 B (49 E µg/Kg), SB-14 (4,390 E µg/Kg), SB-15 (450 µg/Kg), SB-15B (74 E µg/Kg), SB-17 (555 E µg/Kg), SB-18 (41 J N µg/Kg); five test pit samples: TP-1 (5,500 D µg/Kg), TP-2 (37 µg/Kg), TP-3 (620 µg/Kg), TP-5 (11,00 E µg/Kg) and TP-7 (510 E µg/Kg) on Parcel B; and one source area soil boring: SB-21 (470 E µg/Kg) and one storm sewer soil boring sample: SB-41 (37 µg/Kg) on Parcel C. Aroclor-1260 was detected in five source area soil boring samples in the middle Parcel B: SB-9 (90 E µg/Kg), SB-10 (96 µg/Kg), SB-11 (170 E µg/Kg), SB-12 (96 µg/Kg) and SB-15 (160 E N µg/Kg); and one surface soil sample outside the fence on lower Parcel B: SS-8(180 E µg/Kg).

Pesticides:

Endrin was detected in three samples on Parcel B including one source area soil boring sample: SB-18 (5.3 E µg/Kg) and two test pit samples: TP-3 (37 µg/Kg), TP-5 (70 E µg/Kg). One sample (TP-5) exceeded both the USEPA SSL value and TAGM guidance value (50 µg/Kg). 4,4'-DDT was detected in one sample: TP-2 (10 µg/Kg) on Parcel B, but below the TAGM guidance value (1,050 µg/Kg).

5.2.1.4 Inorganics

The concentration of inorganics in the surface and subsurface soils were compared to average site-specific background and/or regulatory levels (e.g., USEPA SSLs or TAGM guidance values). Site-specific background concentrations for inorganics were obtained by averaging the concentration in the following samples (MP-11D, MP-11DB, MP-5, MP-5B, SB-13, SB-13B and TP-6). The average site-specific background concentration for each TAL metal is presented in Table 5-4.

Many of the inorganics present in the soils are the accessory metals naturally occurring in tungsten ore that were considered impurities during the tungsten extraction process and, therefore, were removed. The accessory metals include: antimony, arsenic, barium, copper, cobalt, chromium, lead, manganese, mercury, nickel, thorium, uranium, vanadium and zinc. All accessory metals except thorium and uranium are TAL metals. In addition, laboratory analysis of three ore residue samples from the Dickson Warehouse confirm the high concentration of accessory metals in the ore residues. The range and average concentration for each constituent is provided in Table 5-5. The horizontal and vertical distribution of many of these inorganics are very similar, therefore, only selected metals have been presented graphically. Three inorganics selected for graphical presentation and include arsenic, cobalt and manganese.

Aluminum, detected in all samples, exceeded average site-specific background concentration of 9,676 mg/Kg in 19 samples. The concentration of aluminum in the three ore samples ranged from 12,800 - 17,100 mg/Kg.

Antimony is one accessory metal commonly found in tungsten ore. Antimony was detected in only one of the seven site-specific background samples at a concentration of 1.6 mg/Kg (TP-6); the USEPA SSL for antimony is 0.3 mg/Kg. The analytical data for antimony in the three ore residue samples was rejected during data validation. Overall, antimony was

detected in 55 samples. The measured concentration of antimony exceeded site-specific background concentration (0.3 mg/Kg) and the USEPA SSL (0.3 mg/Kg) in all 55 samples. The highest concentrations of antimony in soils from 0-4 feet occurred in three areas: near a mound of ore residue in the middle of Parcel B (5,610 and 251 mg/Kg in SB-9 and TP-3, respectively); around the northern rim of Mud Pond on Parcel C (3,490 E and 1,710 E mg/Kg in SB-21 and SB-22, respectively); and in the bermed area around the 500,000-gallon aboveground fuel oil tank on Parcel C (2,430 E, 1,050 E, 1,920 E and 1,420 E mg/Kg in MP-18, SB-23, SB-24 and SB-25, respectively). In the soils below four feet, the highest concentrations of antimony occur in the northwest corner of Parcel C (1,230 E mg/Kg in SB-28) and the lower portion of Parcel B (286 E mg/Kg in MP-8D. The concentration of antimony below four feet in the middle of Parcel B decreased to 121 mg/Kg in SB-9. There were no samples collected from greater than four feet in the two areas on the lower portion of Parcel C due to the shallow water table.

Arsenic is another accessory metal commonly found in tungsten ore. The concentration of arsenic in the site-specific background samples averaged 6.3 mg/Kg; the TAGM guidance value is 7.5 mg/Kg. Overall, arsenic was detected in 85 soil samples. The concentration of arsenic exceeded the site-specific background concentration in 69 samples and exceeded the TAGM guidance value in 67 samples. The concentration of arsenic in the three ore residue samples ranged from 279 mg/Kg to 495 mg/Kg. The highest concentration of arsenic from 0-4 feet was found in four areas as shown on Figure 5-6. The four areas include: middle Parcel B (1,340 mg/Kg in SB-15); lower Parcel B (1,790 mg/Kg in SB-20); the northwest corner of Parcel C in the area of "scarred vegetation" (6,300, 6,210 and 1,620 mg/Kg in SB-27, SS-4 and SB-28, respectively); and lower Parcel C near Mud Pond and the fuel oil tank (2,950, 1,600, 503 and 442 mg/Kg in SB-40, SB-21, SB-25 and MP-18, respectively). The highest concentration of arsenic was found in SB-40, a storm sewer boring on Parcel C. In the deeper soils (greater than four feet), arsenic was detected in three of the same areas: middle of Parcel B (191 and 45.9 mg/Kg in SB-15 and SB-17, respectively); the area of "scarred vegetation" on Parcel C and C′ (2,230 and 1,290 mg/Kg in SB-28 and SB-26, respectively); and on the northern rim of Mud Pond (1,400 mg/Kg in SB-22). The distribution of arsenic at depths greater than 4 feet is presented in Figure 5-7.

Barium, another accessory metal in tungsten ore, was detected in all soil samples at concentrations ranging from 3.4 to 6,400 mg/Kg. The concentration of barium exceeded the

average site-specific background concentration of 49 mg/Kg in 54 samples, exceeded the USEPA SSL (82 mg/Kg) in 31 samples, and exceeded the TAGM guidance value (300 mg/Kg) in 14 samples. The concentration of barium in the three ore residue samples ranged from 506 - 994 mg/Kg. The highest concentration of barium occurred in a surface soil sample (6,400 mg/Kg in SS-3) near the former sodium hydroxide tank on Parcel A.

Beryllium is not an accessory metal in tungsten ore, however, its distribution is similar to the other accessory metals. Beryllium was detected in 60 samples at concentrations ranging from 0.22 to 11 mg/Kg. The concentration of beryllium exceeded the average site-specific background concentration of 0.5 mg/Kg in 25 samples and exceeded the TAGM guidance value (3 mg/Kg) in four samples. The concentration of beryllium in the three ore residue samples ranged from non-detect to 6.2 mg/Kg. The highest concentration of beryllium was found in three areas: middle Parcel B (6.8 and 3.3 mg/Kg in SB-15 and SB-17, respectively), Mud Pond (11 mg/Kg in SS-11), and in the vegetated area between the Dickson Warehouse and the Benbow Building (8.5 mg/Kg in SS-12).

Cadmium, which is also not an accessory metal in tungsten ore, was detected in 50 samples at concentrations ranging from 1.3 to 179 mg/Kg with an average concentration of 9.8 mg/Kg. Cadmium was not detected in any of the site-specific background samples. The TAGM guidance value (1 mg/Kg) was exceeded in 44 samples. The concentration of cadmium in the three ore residue samples ranged from 11.9 - 74.6 mg/Kg. In the near surface soils (0-4 feet), the highest concentration of cadmium was found in the middle portion of Parcel B (12.3, 11.7, 21.9 and 17.7 mg/Kg in SB-9, SB-11, TP-1 and TP-3, respectively); and in the area of "scarred vegetation" (6.3 and 6.6 mg/Kg in SB-27 and SB-28, respectively) and Mud Pond (23.9 and 18.8 mg/Kg in MP-18 and SB-21, respectively) on Parcel C. The highest concentration of cadmium below four feet, was detected in SB-28B (179 mg/Kg) near the area of "scarred vegetation" on Parcel C.

Calcium was detected in all soil samples and exceeded the site-specific background concentration of 796 mg/Kg in 78 samples (the TAGM guidance value for calcium is equivalent to the site background). The concentration of calcium in the three ore residue samples ranged from 12,500 - 24,600 E mg/Kg. The highest concentration of calcium was detected in SB-6 (145,000 mg/Kg) near the Carbide Building on Parcel A.

Chromium is a common accessory metal in tungsten ore and was detected in all samples. The concentration of chromium ranged from 2.6 J mg/Kg (MP-5B) to 1,620 E mg/Kg (SB-15). The concentration of chromium exceeded the average site-specific background concentration of 18.3 mg/Kg in 54 samples; the TAGM guidance value (10 mg/Kg) was exceeded in all but nine samples. The concentration of chromium in the three ore residue samples ranged from 328 - 414 mg/Kg. The distribution of chromium shows a similar pattern to other accessory metals. The highest concentration in the surface soils was found throughout Parcel B, in the area of "scarred vegetation" and in the vicinity of the fuel oil tank and Mud Pond on Parcel C. At sampling depths greater than four feet, chromium was found primarily in two areas on Parcel C: the "scarred vegetation" area and in the vicinity of Mud Pond.

Cobalt, another common accessory metal in tungsten ore, was detected in 102 samples at concentrations ranging from 1.7 (SB-26B) to 4,660 mg/Kg (SB-20). The measured concentration of cobalt exceeded the average site-specific background concentration of 7 mg/Kg in 70 samples and exceeded the TAGM value (30 mg/Kg) in 32 samples. The concentration of cobalt in the three ore residue samples ranged from 4,580 - 10,800 mg/Kg. The distribution of cobalt is somewhat different to other accessory metals. In the surface soils, cobalt was detected in some similar and some dissimilar areas to the other accessory metals as shown on Figure 5-8. The common areas include middle and lower Parcel B (554, 2,240 E, 4,620, 4,660 and 2,200 mg/Kg in SB-11, SB-14, SB-15, SB-20 and TP-1, respectively), and in the vicinity of the Mud Pond and fuel oil tank area on Parcel C (764 mg/Kg in SS-11). Cobalt was also detected in two areas on Parcel A (1,310, 1,210 and 1,560 mg/Kg in SB-6, SS-5 and SS-7, respectively). The concentration of cobalt at depths greater than four feet decreases to a maximum of 107 mg/Kg in SB-28B, as shown of Figure 5-9.

Copper, a common accessory metal in tungsten ore, was detected in 103 samples and ranged in concentration from 2 J mg/Kg (MP-4DB) to 6,740 mg/Kg (SB-21). The concentration of copper exceeded the average site-specific background concentration of 15.9 mg/Kg in 68 samples and exceeded the TAGM value (25 mg/Kg) in 58 samples. The concentration of copper in the three ore residue samples ranged from 12,600 - 64,400 mg/Kg.

Iron, which is not an accessory metal in tungsten ore, was detected in 104 samples. Iron concentration ranged from 4,190 mg/Kg (SB-41) to 313,000 mg/Kg (SB-27). The concentration of iron exceeded the average site-specific background concentration of 20,206 mg/Kg in 49

samples; all samples exceeded the TAGM value (2,000 mg/Kg). The concentration of iron in the three ore residue samples ranged from 90,700 - 98,700 mg/Kg.

Lead, another common accessory metal in tungsten ore, was detected in 89 samples at a concentration ranging from 2.7 mg/Kg (SB-9DB) to 6,100 mg/Kg (TP-3). The concentration of lead exceeded the site-specific background concentration of 23 mg/Kg in 63 samples. The TAGM guidance value for lead is equivalent to site background. Urban background levels for lead typically range from 200-500 mg/Kg. The concentration of lead in the three ore residue samples ranged from 1,300 E - 4,910 mg/Kg.

Magnesium was detected in all samples and exceeded the average site-specific background concentration of 2,172 mg/Kg in 49 samples. The highest magnesium concentration was detected in SB-6 (38,200 mg/Kg), located near the Carbide Building on Parcel A. The concentration of magnesium in the three ore residue samples ranged from 3,980 - 14,100 mg/Kg.

Manganese, another common accessory metal in tungsten ore, was detected in 99 samples at a concentration ranging from 59.4 E to 90,000 mg/Kg. The concentration of manganese exceeded the site-specific background concentration (664 mg/Kg) in 30 samples. The TAGM guidance value for manganese is equivalent to site background. The concentration of manganese in the three ore residue samples ranged from 9,320 - 21,000 mg/Kg. The areas of highest concentration occur in the middle of Parcel B (90,000 E, 20,800 E mg/Kg in SB 15 and SB-16, respectively), and two areas on Parcel C: between the Dickson Warehouse and the Benbow Building (61,700 E mg/Kg in SS-12) and in the "scarred vegetation" area (49,600 E and 3,650 E mg/Kg in SS-4 and SB-27, respectively). Another small area occurs on Parcel A, outside of the fence near the intersection of Herb Hill Road and Garvies Point Road (11,600 E mg/Kg in SS-1). The distribution of manganese in the near surface soils (0-4 feet) as shown on Figure 5-10

At sampling depths below four feet, manganese was detected in 22 samples at concentrations ranging from 46.9 mg/Kg (SB-4B) to 6,300 mg/Kg (SB-17B). A total of four of these samples exceeded site-specific background (676.6 mg/Kg). The sampling locations that exceeded site-specific background are all located in the middle of Parcel B and include SB-11B (1,880 mg/Kg), SB 13B (2,220 mg/Kg), SB-15B (1,040 mg/Kg) and SB-17B (6,300 mg/Kg). The distribution of manganese at depths greater than four feet is shown on Figure 5-11

Mercury was detected in 73 samples and ranged in concentration from non-detect (31 samples) to 29.5 mg/Kg (SB-21). Mercury exceeded the average site-specific background concentration of 0.03 mg/Kg in all 73 samples. In addition, mercury was above the TAGM value (0.1 mg/Kg) in 56 samples. The concentration of mercury in the three ore residue samples ranged from 1.1 E - 2.8 E mg/Kg. The highest mercury levels detected were in the area near Mud Pond and the fuel oil tank on Parcel C: SB-22 (16, 3 mg/Kg), SB-23B (3 E mg/Kg),SB-24 (1.7 E mg/Kg), SB-25 (1.3 E mg/Kg), MP-18 (2.3 E mg/Kg), SS-10 (1.7 mg/Kg) and SS-11 (1.5 mg/Kg); in the area of "scarred vegetation" on Parcel C: SB-28B (4.7 mg/Kg) and SS-4 (6.2 mg/Kg); near mounds of ore residue on Parcel B: TP-1 (8.4 E mg/Kg) and TP-5 (3 mg/Kg); and surface soil along the bulkhead on Parcel A: SS-7 (1.4 mg/Kg) and SS-5 (3.5 mg/Kg).

Nickel was detected in all samples and ranged in concentration from 3.4 J (SB-26B) to 22,000 mg/Kg (SB-15). Nickel exceeded the average site-specific background concentration of 12.7 mg/Kg in 69 samples. The TAGM value (13 mg/Kg) is virtually the same as the site-specific background level. The concentration of nickel in the three ore residue samples ranged from 13,100 - 24,600 mg/Kg.

Potassium was detected in all samples and exceeded the average site-specific background concentration of 1,414 mg/Kg in 17 samples. The concentration of potassium in the three ore residue samples ranged from 367 J - 1,140 mg/Kg. Selenium was detected in 61 samples and exceeded the average site-specific background concentration and the TAGM value (2 mg/Kg) in 49 samples. Selenium ranged in concentration from non-detect to 261 E mg/Kg (SS-10). The concentration of selenium in the three ore residue samples ranged from 55.9 - 107 mg/Kg. Silver was detected in 52 samples and exceeded the site-specific background concentration of 0.1 mg/Kg in all 52 samples. The concentration of silver ranged from non-detect to 114 mg/Kg (SB-9). The TAGM value is equivalent to site background. The concentration of silver in the three ore residue samples ranged from 106 - 122 mg/Kg.

Sodium, detected in 102 samples, exceeded the average site-specific background concentration of 51.6 mg/Kg in 82 samples. The highest detected sodium concentration was in SB-20 (36,500 mg/Kg). The concentration of sodium in the three ore residue samples ranged from 21,400 - 35,500 mg/Kg. Thallium was detected in only five samples and ranged in concentration from 1.1 J to 22.7 mg/Kg. Thallium exceeded or equaled the average site-specific background concentration of 0.2 mg/Kg in each sample. Thallium was only detected at

sampling locations on Parcel B (SB-10, SB-11B, SB-13B, SB-15 and SB-17). The analytical data for thallium in the three ore residue samples was rejected during data validation. Vanadium was detected in 98 samples at a concentration ranging from non-detect to a maximum of 165 mg/Kg in SS-12 (north of the Dickson Warehouse on Parcel C). Vanadium exceeded the average site-specific background concentration of 18.7 mg/Kg in 50 samples. The concentration of vanadium in the three ore residue samples ranged from 50.5 - 554 mg/Kg.

Zinc, detected in all soil samples, exceeded the average site-specific background concentration of 44 mg/Kg in 78 samples. The concentration of zinc in the three ore residue samples ranged from 5,040 - 5,980 mg/Kg. Cyanide was detected in 23 samples. Cyanide exceeded the average site-specific background concentration of 0.23 mg/Kg in 22 samples. Cyanide concentrations ranged from non-detect to 8 J mg/Kg in SB-22 (on the north rim of Mud Pond).

5.2.1.5 Radionuclides

Radionuclides (^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th, and ^{232}Th) were analyzed in soil samples collected from radiological borings, monitoring well borings, source area and storm sewer soil borings, and test pits. The results are compared to combined average of the site-specific background radionuclide concentrations. The average site-specific background concentrations that were calculated from on-site and off-site sampling locations are as follows: ^{238}U (0.7 pCi/g), ^{226}Ra (1.0 pCi/g), ^{228}Ra (1.1 pCi/g), ^{230}Th (0.7 pCi/g) and ^{232}Th (0.8 pCi/g). A summary of the determination of site-specific radionuclide background is presented in Table 5-3. In addition to the average site-specific background concentration, Table 5-3 also includes 1.5X the site-specific background.

<u>Uranium-238:</u>

The concentration of ^{238}U exceeded 1.5X the average background concentration (1.1 pCi/g) in 29 samples. Ten samples (SBB, SB-11B, SB-16, SB-29, SB-34, SB-35, SB-37, MP-4D, MP-9DB and MP-11D) had ^{238}U concentrations that were less than the minimum detectable concentration (MDC) of 0.3 pCi/g. The highest ^{238}U concentration (470 pCi/g) was detected in a surface soil sample (SS-4) in the area of "scarred vegetation" on Parcel C.

There are five main areas showing measurable concentrations of ^{238}U have been detected greater than 1.5X above site-specific background in the surface soils (0-4 feet). The distribution of ^{238}U in the surficial soils (0-4 feet) in the five areas is presented in Figure 5-12 and includes:

- outside the fence along Herb Hill Road in the northeast corner of Parcel A as defined by two surface soil samples: SS-1 (110 pCi/g) and SS-3 (33 pCi/g);
- the middle portion of Parcel B as defined by five radiological boring samples: RT-1B (25 pCi/g), RT-2 (140 pCi/g), RT-3 (230 pCi/g), RT-7 (260 pCi/g), RT-8 (86 pCi/g), three source area soil boring samples: SB-10 (29 pCi/g), SB-15 (180 pCi/g) and SB-17 (26 pCi/g), and one test pit sample: TP-5 (27 pCi/g);
- the upper portion of Parcel C as defined by one surface soil sample: SS-4 (470 pCi/g);
- the vegetated area north of the Dickson Warehouse on Parcel C as defined by one radiological boring: RT-12 (4 pCi/g) and one surface soil sample: SS-12 (37 pCi/g);
- the lower portion of Parcel C as defined by two radiological borings: RT-18 (3pCi/g) and RT-20 (4 pCi/g).

At depths greater than four feet, the concentration of ^{238}U in four of the five areas decreased (there were no samples collected at depth in the area along Herb Hill Road on Parcel A). A maximum value of 15 pCi/g was detected in a source area soil boring sample (SB-17B) in the middle of Parcel B. Other sampling points in the middle portion of Parcel B that reflected concentrations of ^{238}U greater than 1.5X above site-specific background included TP-4 (5.4 pCi/g), SB-15B (2.8 pCi/g) and RT-3B (1.5 pCi/g). The upper portion of Parcel C continued to show concentrations of ^{238}U greater than 1.5X the site-specific background in one source area soil boring sample (8.5 pCi/g in SB-28B). The vegetated area north of the Dickson Warehouse reflects levels of ^{238}U less than 1.5X site-specific background in three samples (0.5, 0.92, and 0.6 pCi/g in RT-12B, RT-14B and SB-42, respectively); the lower portion of Parcel C reflected ^{238}U concentrations greater than 1.5X above site-specific background in three samples (2.4, 2,.7 and 2.8 pCi/g in RT-18B, RT-19B and SB-22, respectively). The distribution of ^{238}U at sampling depths greater than four feet is presented in Figure 5-13.

Thorium-232

The concentration of ^{232}Th exceeded the average site-specific background concentration (0.8 pCi/g) in 81 samples and exceeded 1.5X background (1.2 pCi/g) in 50 samples. Overall the distribution of ^{232}Th closely matched ^{238}U in the five areas discussed above, but also included several other small areas on Parcels A and B. Two surface soil samples (SS-1 and SS-3) collected along Herb Hill Road in the northeast corner of Parcel A exceeded 1.5X background (48 and 93 pCi/g, respectively). Other areas on Parcel A where the concentration of ^{232}Th exceeded 1.5X site-specific background included three storm sewer soil boring samples in the eastern portion of Parcel A (1.7, 2.3 and 1.3 E pCi/g in SB-31, SB-32 and SB-34, respectively), and two surface soil samples (10 and 57 pCi/g in SS-5 and SS-7, respectively) along the bulkhead on Parcel A.

In the middle of Parcel B, the concentration of ^{232}Th exceeded 1.5X background (1.4 pCi/g) in six radiological soil boring samples: RT-1 (32 E pCi/g), RT-2 (17 E pCi/g), RT-4 (1.8 E pCi/g), RT-6 (6.1 pCi/g), RT-7 (30 pCi/g) and RT-8 (12 E pCi/g); four source area soil boring samples: SB-10 (2.2 pCi/g), SB-14 (16 pCi/g) and SB-15 (26 pCi/g); and four test pit samples: TP-1 (8.6 pCi/g), TP-3 (3.2 pCi/g), TP-5 (150 pCi/g) and TP-6 (1.5 pCi/g). Several samples collected in the lower portion of Parcel B also exceeded 1.5X background including one surface soil sample: SS-6 (16 pCi/g); two source area soil boring samples: SB-19 (3.8 pCi/g) and SB-20 (5.6 E (pCi/g); and one radiological soil boring sample: RT-9 (1.5 E pCi/g).

The highest concentration of ^{232}Th (220 pCi/g) was measured in a surface soil sample (SS-12) located north of the Dickson Warehouse on Parcel C. Other sample locations north of the Dickson Warehouse where the concentration of ^{232}Th exceeded 1.5X background included three radiological borings - RT-11 (62 pCi/g), RT-12 (190 E pCi/g) and RT-13 (16 E pCi/g). One sample collected from a source area soil boring (2 pCi/g in SB-8) in the upper potion of Parcel C exceeded 1.5X background. Four samples collected in the lower portion of Parcel C exceeded 1.5X background including two radiological soil boring samples: RT-19 (24 pCi/g) and RT-20 (1.7 pCi/g); one surface soil sample: SS-11 (2.4 pCi/g); and one source area soil boring sample: SB-25 (3.3 pCi/g). The distribution of ^{232}Th in the surficial soils (0-4 feet) is presented in Figure 5-14.

At depths greater than four feet, ^{232}Th was detected in 34 samples at concentrations that ranged from less than background to a maximum of 5.1 pCi/g (approximately 6X background). The distribution pattern again closely followed that of ^{238}U. None of the samples collected on Parcel A exceeded 1.5X site-specific background. A maximum value of 5.1 pCi/g was detected in a source area soil boring sample (SB-28B) in the upper portion of Parcel C. Sampling points in the middle portion of Parcel B that reflected concentrations of ^{232}Th greater than 1.5X above site-specific background included TP-4 (3 pCi/g), SB-14B (13 pCi/g), SB-17B (3.9 E pCi/g) and RT-4B (1.7 E pCi/g). One source area soil boring sample (8.5 pCi/g in SB-28B) in the upper portion of Parcel C showed a concentration of ^{238}U greater than 1.5X above site-specific background. Samples collected in the vegetated area north of the Dickson Warehouse reflect greater than 1.5X site-specific background in two radiological boring samples (15 and 2.8 E pCi/g in RT-12B and RT-14B, respectively). The lower portion of Parcel C reflected ^{232}Th concentrations above 1.5X site-specific background in one samples (1.5 pCi/g in RT-19B). The distribution of ^{232}Th at sampling depths greater than four feet is presented in Figure 5-15.

Radium-226:

The concentration of ^{226}Ra exceeded the site-specific background concentration (1.0 pCi/g) in 104 samples and exceeded 1.5X site-specific background (1.5 pCi/g) in 47 samples. Overall the distribution of ^{226}Ra closely matched ^{238}U and ^{232}Th in the areas discussed above. Two surface soil samples (SS-1 and SS-3) collected along Herb Hill Road in the northeast corner of Parcel A exceeded 1.5X site-specific background (41 and 38 pCi/g, respectively). Two storm sewer soil boring samples (3.7 and 2.2 pCi/g in SB-31 and SB-32, respectively) and one source area soil boring sample (3.3 pCi/g in SB-5) in the eastern portion of Parcel A, and two surface soil samples (9.0 and 2.0 pCi/g in SS-5 and SS-7, respectively) along the bulkhead on Parcel A also exceeded 1.5X site-specific background.

In the middle of Parcel B, the concentration of ^{226}Ra exceeded 1.5X site-specific background (1.5 pCi/g) in seven radiological soil boring samples: RT-1 (23 pCi/g), RT-2 (68 pCi/g), RT-3 (150 pCi/g), RT-5 (2.4 pCi/g), RT-6 (2.4 pCi/g), RT-7 (220 pCi/g) and RT-8 (59 pCi/g); eight source area soil boring samples: SB-9 (1.7 pCi/g), SB-10 (14 pCi/g), SB-11 (2.3 pCi/g), SB-12 (2.9 pCi/g), SB-14 (3.7 pCi/g), SB-15 (140 pCi/g), SB-16 (1.6 pCi/g) and SB-17 (14 pCi/g); and three test pit samples : TP-1 (2.0 pCi/g), TP-3 (2.6 pCi/g) and TP-5 (23 pCi/g).

Several samples collected in the lower portion of Parcel B also exceeded 1.5X site-specific background including one surface soil sample - SS-6 (5 pCi/g); two source area soil boring samples - SB-19 (2.3 pCi/g) and SB-20 (2.5 E (pCi/g); and one radiological soil boring sample - RT-9 (1.7 pCi/g).

The highest concentration of ^{226}Ra (250 pCi/g) was measured in a surface soil sample (SS-4) located in the upper portion of Parcel C. Other sample locations in the upper portion of Parcel C where the concentration of ^{226}Ra exceeded 1.5X site-specific background included two source area soil boring samples: SB-27 (1.8 pCi/g) and SB-28 (4.2 pCi/g). Other areas on Parcel C where the concentration of Ra exceeded 1.5X site-specific background included three radiological borings: RT-12 (5.6 pCi/g), RT-13 (2.0 pCi/g) and RT-15 (2.0 pCi/g) and one surface soil sample: SS-12 (86 pCi/g) north of the Dickson Warehouse. Four samples collected in the lower portion of Parcel C exceeded 1.5X site-specific background including two radiological soil boring samples: RT-18 (2.0 pCi/g) and RT-20 (2.0 pCi/g); two surface soil samples: SS-11 (6.3 pCi/g) and SS-12 (86 pCi/g); and three source area soil boring sample: SB-21 (1.8 pCi/g), SB-24 (1.9 pCi/g) and SB-25 (2.4 pCi/g). The distribution of ^{226}Ra in the surficial soils (0-4 feet) is presented in Figure 5-16.

5.2.2 Groundwater

Two rounds (December 1996 and January 1997) of groundwater samples were collected from each of the monitoring wells. The first round (December 3 - 18, 1996) and the resampling episode (January 6 - 8, 1997) were combined as the December 1996 sampling event). The second round of groundwater samples were collected from January 20 - 31, 1997. The results of the two sampling rounds are presented in Appendix N. On March 21, 1997, a groundwater sample was also collected from an upgradient monitoring well (Konica-1) located on The Place and adjacent to the Konica property. In the discussion below, the analytical results are compared to the USEPA Maximum Contaminant Levels (MCLs) and the NYSDEC groundwater standards (NYSDEC standard), whichever is the more stringent. In cases where there is no NYSDEC standard for a specific volatile organic compound, a Principal Organic Contaminant (POC) standard of 5 ug/L is applied (New York State Codes, Rules and Regulations Title 6, Chapter X Parts 700-705).

5.2.2.1 Volatile Organic Compounds

Round One

The first round of groundwater sampling reflects the presence of chlorinated hydrocarbon compounds such as trichloroethene (TCE), tetrachloroethene (PCE), trichloroethane (TCA) and their degradation products, along with the occasional presence of other VOCs such as benzene, toluene and other aromatic hydrocarbons. TCE, PCE and total benzene, toluene, ethylbenzene and xylene (BTEX) were selected as being most representative of all VOCs and are presented in Figures 5-18, 5-20 and 5-22, respectively.

In general, the highest concentration of VOCs were detected in the four wells on Parcel C′ (MW-8S, MW-8D, MW-10 and GM-10) adjacent to the Mattiace Petrochemical site. Other areas reflecting concentrations of VOCs include the cluster of wells in the middle portion of Parcel A/lower portion of Parcel B (MP-2D, MP-6, MP-20, MP-21, GM-2, GM-8, EMW-1) that are downgradient or cross-gradient to the Crown Dykman site; the middle portion of Parcel B (GM-13 and MP-19D); the area south of the Benbow Building on Parcel C (MP-16D); and to a lesser extent, the area around the aboveground fuel oil tank on Parcel C (MP-18/MP-18D).

Trichloroethene (TCE) was detected in 13 samples at concentrations ranging from 3 µg/L (MP-16D) to 31,000 µg/L (MW-10). The MCL (5 µg/L) was exceeded in eight samples The area north of the Mattiace Petrochemical site on Parcel C′ showed the highest concentrations (320-31,000 µg/L) and exceeded the MCL in all four wells - MW-8S (4,000 µg/L), MW-8D (15,000 µg/L), MW-10 (31,000 µg/L) and GM-10 (320 µg/L). The second highest concentrations exceeding the MCL were detected in middle portion of Parcel A/lower Parcel B in wells MP-2D (87 µg/L), MP-21D (140 µg/L) and EMW-1 (250 µg/L). TCE was also detected at concentrations below the MCL in three wells on Parcel A (4.4, 4.4 and 4.1 J µg/L in MP6, MP-20 and GM-1, respectively). The concentration of TCE detected in MW-18 (9 µg/L) adjacent to the aboveground fuel oil tank on Parcel C exceeded the MCL; the concentrations detected in middle portion of Parcel B (4 J µ/L in GM-13) and the area south of the Benbow Building (3 µg/L in MP-16D) were below the MCL. The distribution of trichloroethene concentration in the first round of groundwater sampling is presented in Figure 5-18.

Tetrachloroethene PCE) was also detected in 13 samples at concentrations ranging from 1 µg/L (GM-8) to 6,600 µg/L (MW-10). The MCL (5 ug/L) was exceeded in eleven samples.

The distribution of PCE in the groundwater is virtually identical to TCE. Again the area adjacent to the Mattiace Petrochemical site on Parcel C′ showed the highest concentrations (110-6,600 μg/L) and exceeded the MCL in each of the four wells - MW-8S (770 μg/L), MW-8D (3,100 μg/L), MW-10 (6,600 μg/L) and GM-10 (110 μg/L). The second highest concentrations exceeding the MCL were detected in the middle portion of Parcel A/lower Parcel B in wells MP-2D (61 μg/L), MP-6 (40 μg/L), MP-20 (38 μg/L), MP-21D (590 μg/L) and EMW-1 (1,300 μg/L). PCE was also detected in two wells (3.1 and 1 μg/L in GM-1 and GM-8, respectively) at concentrations below the MCL. PCE was not detected in GM-13 on Parcel B, but was detected in MP-19D (13 μg/L) at a concentration above the MCL. PCE was also detected in MW-18 adjacent to the aboveground fuel oil tank on Parcel C at 5 μg/L (equal to the MCL); but not detected in MP-16D south of the Benbow Building. The distribution of tetrachloroethene (PCE) concentration in the first round of groundwater sampling is presented in Figure 5-20.

The NYSDEC standard for benzene (0.7 μg/L) was exceeded in each of seven samples with detectable levels of benzene. Benzene concentrations ranged from 0.9 ug/L (MP-18) to 540 J μg/L (MW-8D and MW-10). Concentrations of toluene were detected in eight samples, ranging from 1 J μg/L (GM-14B, MP-11D and MP-18S) to 85,000 μg/L (MW-10). The MCL for toluene (1,000 μg/L) was exceeded in three samples; the NYSDEC POC (5 μg/L) was exceeded in four samples. Ethylbenzene was detected in five samples at concentrations ranging from 2 J μg/L (MP-18S) to 5,800 μg/L (MW-10). The MCL for ethylbenzene (700 μg/L) was exceeded in two samples; the NYSDEC POC of 5 μg/L was exceeded in four samples. Total xylenes were detected in six samples at concentrations ranging from 3 J μg/L (MP-17) to 32,000 μg/L (MW-10). The MCL for xylenes (10,000 μg/L) was exceeded in two samples; the DEC POC of 5 ug/L was exceeded in five samples.

Generally, benzene, toluene, ethylbenzene and total xylenes (BTEX) are constituents of petroleum products and, therefore, their concentrations are commonly added together for presentation purposes. Even though they represent different types of volatile organic compounds, the distribution of BTEX compounds is similar to both TCE and PCE discussed above. The highest concentrations were detected north of the Mattiace Petrochemical site on Parcel C′ in wells MW-10 (123,340 μg/L), MW-8D (77,640 μg/L) and MW-8S (1,842 μg/L). No BTEX compounds were detected in GM-10. A total concentration of 58 μg/L was detected in MP-16D south of the Benbow Building. Lesser concentrations were detected in the southern

portion of Parcel A near the bulkhead (10.7 μg/L in MP-17 and 3.3 μg/L in MP-2D) and adjacent to the aboveground fuel oil tank on Parcel C (12.9 μg/L in MP-18 and 2 μg/L in GM-14B). The distribution of total BTEX concentration for the first round of groundwater sampling is presented in Figure 5-22.

Other VOCs were detected in similar locations to TCE, PCE and total BTEX. Chloromethane was detected in one sample (MP-6) at a concentration of 2.2 J μg/L. There is no MCL or NYSDEC standard for chloromethane. Vinyl chloride was detected in four samples at concentrations ranging from 1 J μg/1 (MP-18S) to 72 μg/L (MP-2D). The MCL and NYSDEC standard for vinyl chloride of 2 μg/L was exceeded in three samples. Chloroethane was detected in only one sample (MP-2D) at a concentration of 28 μg/L, exceeding the NYSDEC POC standard of 5 μg/L. Methylene chloride was detected in six samples at concentrations ranging from 1 J μg/L (MP-5) to 120,000 μg/L (MW-8D). Although the concentrations detected in five of these samples exceeded the NYSDEC POC standard, methylene chloride is a common laboratory contaminant and may not represent a site-specific contaminant at the lower concentrations. Acetone was detected in 11 samples at concentrations ranging from 5 J μg/L (MP-4) to 17,000 μg/L (MW-8D). Acetone is also typically considered a laboratory contaminant and may not represent a site-specific contaminant at the lower concentrations. Carbon disulfide was detected at a concentration of 1 J μg/L in one sample (GM-14B). Concentrations of 1,1-DCE were detected in samples GM-10 (21 J μg/L), MW-8D (650 J μg/L), and MW-8S (160 J μg/L). The MCL for 1,1-DCE of 7 μg/L was exceeded in each of the three samples. The concentrations of 1,1-DCA ranged from 3 J μg/L (MP-18D) to 3,600 μg/L (MW-8D). The NYSDEC POC standard of 5 μg/L was exceeded in five samples. Total 1,2-DCE was detected in 14 samples at concentrations ranging from 4 J ug/L (MP-16D) to 150,000 μg/L (MW-8D). Separate MCLs are provided for the cis-isomer (70 μg/L) and the trans-isomer (100 μg/L). The MCL for the cis-isomer was exceeded in seven samples.

Chloroform was detected in two samples at concentrations of 230 J μg/L (MW-8D) and 2,200 J μg/L (MW-10), exceeding the NYSDEC standard of 7 μg/L. Concentrations of 1,2-DCA met or exceeded the MCL of 5 μg/L in two samples (5 J ug/L in GM-1 and 790 J μg/L in MW-8D). 2-Butanone was detected in eight samples, ranging in concentration from 72 J μg/L (GM-14B) to 15,000 μg/L (MW-8D), exceeding the NYSDEC POC in each sample. Concentrations of TCA ranged from 3 J μg/L (MP-18S) to 15,000 μg/L (MW-8D). The MCL

for TCA (200 µg/L) was exceeded in four samples. Carbon tetrachloride was detected in two samples, GM-10 (170 µg/L) and MP-18S (2 J µg/L). The MCL and NYSDEC standard for carbon tetrachloride is 5 µg/L. Concentrations of 1,1,2-TCA were detected in only two samples: GM-1 (26 µg/L) and MP-18S (1J µg/L). The MCL for 1,1,2-TCA is 5 µg/L. The NYSDEC POC for 4-methyl-2-pentanone (5.0 µg/L) was exceeded in the only sample (MW-8D) where concentrations were detected in thirteen samples, ranging from 1 J ug/L (GM-8) to 6,600 µg/L (MW-10). The concentration of both 1,1,2,2-PCA and chlorobenzene (1 J µg/L) was detected in MP-18S below the NYSDEC POC of 5 µg/L.

Round Two

The second round of groundwater sampling yielded results similar to the first round in terms of the specific compounds and concentration, but a few differences were noted. TCE was again detected in thirteen samples, ranging in concentration from 1 J µg/L (MP-17) to 28,000 µg/L (MW-10) and exceeded the MCL (5 µg/L) in ten samples. The distribution of TCE in the second round and the concentration at each well are virtually identical to the first round with two exceptions. At well GM-1 on the eastern end of Parcel A, the concentration of TCE increased to 2,200 µg/L from 4.1 J ug/L and was undetected at well M-16D after being detected at a concentration of 3 µg/L during the first round. The distribution of trichloroethene concentration in the second round of groundwater sampling is presented in Figure 5-19.

PCE was also detected in 13 samples during the second round, ranging in concentration from 4 J µg/L (GM-8) to 7,800 µg/L (MW-10). The MCL (5 µg/L) was exceeded in 12 samples. The differences in the measured concentration of PCE between the two rounds were minimal with one exception: the concentration of PCE at GM-1 increased to 6,900 µg/L from only 3.1 µg/L in the first round. The distribution of tetrachloroethene (PCE) concentration in the second round of groundwater sampling is presented in Figure 5-21.

Toluene was detected in five samples at concentrations ranging from 2 J µg/L (GM-11 and MP-16D) to 90,000 µg/L (MW-10). The MCL (1,000 ug/L) was exceeded in two samples and the NYSDEC POC standard (5 µg/L) was exceeded in three samples. Ethylbenzene was detected in three samples, MW-8D, MW-10 and MP-18 at concentrations of 2,100 J µg/L, 7,600 µg/L and 4 J µg/L, respectively. The MCL (700 µg/L) and the NYSDEC POC standard (5 µg/L) were exceeded in two samples. Total xylenes were detected in the same three wells, MW-

8D, MW-10, and MP-18 at concentrations of 12,000 µg/L, 36,000 µg/L and 17 µg/L, respectively. The MCL (10,000 µg/L) was exceeded in two samples and the NYSDEC POC standard (5 µg/L) was exceeded in all three samples. The distribution of total BTEX concentration for the second round of groundwater sampling virtually identical to the first rounds and is presented in Figure 5-23.

Other VOCs showed similar results to the first round. Vinyl chloride was detected in six samples at concentrations ranging from 1 J µg/L (MP-18) to 96 J µg/L (GM-1). The MCL (2 µg/L) was met or exceeded in five samples. Chloromethane was detected in only one sample (MP-2D) at a concentration (27 µg/L) that exceeded the NYSDEC POC standard (5 µg/L). Methylene chloride and acetone were detected in four samples and nine samples, respectively. Only one sample (MP-20) contained a detectable level of 1,1-DCE (3 J µg/L) at a concentration that was below the MCL (7 µg/L). Concentrations of 1,1-DCA ranging from 1 J µg/L (MP-5) to 3,400 J µg/L (MW-8D) were detected in ten samples. The NYSDEC POC standard (5 µg/L) was exceeded in five of those samples. Concentrations of 1,2-DCE (total) were detected in fourteen samples, ranging from 4 J (MP-22D) to 100,000 (MW-8D) µg/L. The MCL for the cis-isomer of 1,2-DCE (70 µg/L) was exceeded in seven of those samples. Chloroform was detected in only one sample (MW-10) at a concentration (4,000 J µg/L) that exceeded the NYSDEC standard (7 µg/L). Only one sample (MP-20) contained a detectable level of 1,2-DCA (8 J µg/L) above the MCL of 5 µg/L. 2-Butanone was detected in only one sample (MP-16) at a concentration of 170 µg/L), exceeding the NYSDEC POC standard (5 µg/L). TCA was detected in five samples at concentrations ranging from 4 J µg/L (MP-18) to 16,000 ug/L (MP-8D) exceeding the MCL of 200 µg/L in four of the samples. Only two samples (MP-18 and MP-20) contained detectable levels of 1,1,2-TCA at concentrations of 2 J µg/L and 65 µg/L, respectively. The MCL for 1,1,2-TCA is 5 µg/L. Benzene was detected in MP-2D and MP-5 at 2 J µg/L and 1 J ug/L, respectively. Both exceeded the NYSDEC standard for benzene of 0.7 ug/L. Only one sample, MW-8D, contained a detectable concentration of 4-methyl-2-pentanone at 7,900 µg/L. One sample (MP-18) detected 1,1,2,2-TCA, 2 J µg/L and was below the NYSDEC POC standard of 5 µg/L.

On March 21, 1997, one groundwater sample was collected from an off-site monitoring well (Konica-1), located on The Place approximately 400 feet from the northeast corner of

Parcel B. This location is hydraulically upgradient from each of the three parcels. Methylene chloride and acetone were detected at concentrations of 170 J µg/L and 16 µg/L, respectively.

5.2.2.2 Semi-volatile Organic Compounds

Several semi-volatile organic compounds (SVOCs) were detected in both rounds of groundwater sampling. There were no SVOCs detected in the sample collected from off-site background monitoring well (Konica-1). The primary SVOCs detected included phenols, polynuclear aromatic hydrocarbons (PAHs) and phthalates. Many of the SVOCs do not have MCLs or NYSDEC standards. Of the SVOCs detected only 1,4-dichlorobenzene (75 µg/L) and 1,2-dichlorobenzene (60 µg/L) have MCLs; phenol (1 µg/L), di-n-butylphthalate (50 µg/L) and bis (2-ethylhexylphthalate (50 µg/L) have NYSDEC standards. SVOCs were most frequently detected in the wells north of the Mattiace Petrochemical site on Parcel C′ (MW-8S, MW-8D and MW-10). Less frequent detections were found in the following locations: in the southwestern corner of Parcel A (MP-22 and MP-22D); in the vicinity of the aboveground fuel oil tank on Parcel C (MP-18, MP-18D and GM-14A); and in isolated wells on Parcel A (MP-2D and MP-17), Parcel B (GM-2 and GM-9) and Parcel C (GM-15).

In the first round of groundwater sampling results, phenol was detected in four samples at concentrations ranging from 9.5 µg/L (MP-22D) to 630 µg/L (MW-10). A measurable concentration of 1,3-dichlorobenzene was detected once in MW-8D (20 J ug/L). Two compounds, 1,4-dichlorobenzene and 1,2-dichlorobenzene were both detected in MW-8D (39 J and 440 µg/L) and MW-10 (100 and 1,300 µg/L). 2-Methylphenol was detected in wells north of Mattiace (MW-8, MW-8D and MW-10) at concentrations of 18 J µg/L, 140 µg/L and 410 J µg/L, respectively. Concentrations of 4-methylphenol were detected in six samples ranging from 2.1 µg/L (MP-22D) to 420 J µg/L (MW-10). Isophorone was detected in samples GM-9, MW-8D and MW-10 at concentrations of 6 J µg/L, 500 µg/L and 530 µg/L, respectively. Naphthalene was detected in six samples at concentrations that ranged from 0.54J µg/L (MP-2D) to 2,300 µg/L (MW-10). Concentrations of 2-methylnaphthalene were detected in six samples ranging from 0.5 J µg/L (MP-18) to 120 µg/L (MW-10 and MW-18D). Dimethylphthalate was detected in only one sample (MP-17) at a concentration of 1.3 J µg/L. Acenaphthene, dibenzofuran, fluorene and phenanthrene were detected in only two samples, MP-18D and MP-22D. Individual concentrations for each of these compounds did not exceed

5 ug/L in MP-18D or 1 ug/L in MP-22D. Di-n-butylphthalate was detected in nine samples at concentrations ranging from 0.72 J µg/L (MP-22) to 790 µg/L (MW-10) and exceeded the NYSDEC standard (50 µg/L) in two samples. Bis(2-ethylhexyl)phthalate was detected in nine samples at concentrations that ranged from 0.51 J µg/L (GM-2) to 2,400 µg/L (MW-10) exceeding the NYSDEC standard (50 µg/L) in one sample.

The second round of groundwater sampling results indicate that phenol was detected in five samples at concentrations ranging from 3 J µg/L (MW-8 and MP-17) to 470 µg/L (MW-10) exceeding the NYSDEC standard (1 µg/L) in each sample. Concentrations of 1,4-dichlorobenzene were detected in samples MW-8D (20 J µg/L) and MW-10 (54 J µg/L), below the MCL (75 µg/L). Concentrations of 1,2-dichlorobenzene were also detected in samples MW-8D (240 µg/L) and MW-10 (630 µg/L), but at concentrations below the MCL (600 µg/L). 2-Methylphenol was detected in samples (MW-8, MW-8D and MW-10 at concentrations of 2 J µg/L, 98 µg/L and 410 µg/L, respectively; 4-methylphenol was detected in five samples ranging from 3 J (µg/L) MW-8) to 380 µg/L (MW-10). Isophrone and 2,4-dimethylphenor were detected in MW-8D and MW-10 at concentrations of 210 µg/L and 220 µg/L (isophrone) and 26 J µg/L and 110 J µg/L (2,4-dimethylphenol), respectively. Naphthalene was detected in five samples ranging from 1 J µg/L (MW-8) to 850 µg/L (MW-10). 2-Methylnaphthalene was detected in four samples at concentrations that ranged from 10 µg/L (MP-22D) to 100 µg/L (MP-18). Acenaphthene and dibenzofuran were detected in only one sample (MP-18) at a concentration of 3 J µg/L and 4 J µg/L, respectively. Diethylphthalate was detected in samples MW-8D, MW-10 and GM-15 at concentrations of 75 µg/L, 62J µg/L and 75 µg/L, respectively. Fluorene was detected in two samples (GM-14A and MP-18) at concentrations of 3 J µg/L and 4 J µg/L, respectively. Phenanthrene was detected in GM-14A, MP-18 and MP-22D at concentrations of 3 J µg/L, 2 J µg/L and 0.8 J µg/L, respectively. Di-n-butylphthalate was detected in four samples ranging in concentration from 0.5 J µg/L (MP-18D) to 170 µg/L (MW-8D), exceeding the NYSDEC standard (50 µg/L) in two samples. Concentrations of bis(2-ethylhexyl)phthalate were detected in thirteen samples ranging from 1 J µg/L (MP-2D and MP-17) to 180 J µg/L (MW-10), exceeding the NYSDEC standard (5 µg/L) in three samples. Di-n-octylphthate was detected in only one sample, MP-18D, at a concentration of 1 J µg/L.

5.2.2.3 Pesticides/PCBs

Several pesticides were detected in both rounds groundwater sampling. The pesticides that were detected were limited to wells MW-8D, MW-10, GM-14A and MP-18. Polychlorinated biphenyls (PCBs) were not detected in any of the samples during either round.

Alpha-BHC was detected at a concentration of 0.05 J µg/L and 0.032 J µg/L in MW-8D and MP-18, respectively. There is no available MCL or NYSDEC standard for alpha-BHC. Gamma-BHC (lindane) was detected in sample GM-14A and MP-18 at a concentration of 0.04 J and 0.031 J µg/L, respectively. The MCL for lindane is 0.2 µg/L. Heptachlor was detected in GM-14A and MP-18 at a concentration of 0.029 J µg/L and 0.046 J µg/L, respectively. The MCL for heptachlor is 0.04 µg/L, however, the NYSDEC standard is zero or non-detect. Aldrin was detected at a concentration of 0.066 J µg/L and 0.05 µg/L in MW-8D and MP-18, respectively. The NYSDEC standard for aldrin is non-detect. Endosulfan I was detected in samples GM-14A, MW-8D and MW-10 at a concentration of 0.03 J µg/L, 0.053 µg/L and 0.68 µg/L, respectively. There is no available MCL or NYSDEC standard for Endosulfan I. The groundwater sample from GM-14A contained 0.045 µg/L of 4,4'-DDE and exceeded the NYSDEC standard of non-detect. Endrin was detected in MW-8D at a concentration of 1.3 J µg/L. The MCL for Endrin is 2 µg/L, however the NYSDEC standard is non-detect. Endosulfan II was detected in samples GM-14A, MW-8D and MP-18 at a concentration of 0.08 J µg/L, 0.19 J µg/L and 0.094 J µg/L, respectively. There is no available MCL or NYSDEC standard for Endosulfan II. MW-8D contained 0.23 J µg/L of 4,4'-DDD, exceeding the NYSDEC standard of non-detect. Concentrations of 4,4'-DDT (0.93 J µg/L and 0.054 J µg/L) were detected in MW-8D and MP-18, respectively. The NYSDEC standard for 4,4'-DDT is non-detect. Sample MW-8D contained 0.16 J µg/L of endrin aldehyde. There is no MCL or NYSDEC standard for endrin aldehyde. Alpha-chlordane (0.038 J µg/L) and gamma-chlordane (0.038 J µg/L) were detected in sample GM-14A, below the NYSDEC standard of 0.1 µg/L.

The second round sampling results indicate similar specific compounds at comparable concentrations. The sample collected from MW-8D contained .048 J µg/L beta-BHC which does not have a MCL or NYSDEC standard. Lindane was detected at a concentration of 0.033 J µg/L in sample GM-14A, but below the MCL of 0.2 µg/L. Heptachlor was detected in sample MW-8D at a concentration of 0.03 J µg/L, exceeding the NYSDEC standard of non-detect. Aldrin was detected in GM-14A, MW-8D and MW-10 at a concentration of 0.042 J, 0.042 J,

and 0.059 µg/L respectively above the NYSDEC standard of non-detect. Dieldrin as detected in samples GM-14A and MW-10 at a concentration of 0.058 J µg/L and 0.32 µg/L, respectively. Endrin was detected in one sample (MW-8D) at a concentration of 0.44 µg/L which exceeded the NYSDEC standard of non-detect. Endosulfan sulfate was also detected in one sample (GM-14A) at a concentration of 0.081 J µg/L. There is no available MCL or NYSDEC standard for endosulfan sulfate.

5.2.2.4 Inorganics

All groundwater samples were filtered in the field. Both the filtered and unfiltered samples were analyzed for inorganics, however, despite extended development efforts, many of the samples retained a high turbidity level. For this reason, the unfiltered sample results are not considered to represent the true aquifer conditions and the following discussion pertains to the filtered sample results only. Both the filtered and unfiltered results are presented in the summary tables in Appendix N.

Overall, many of the inorganics were frequently detected. Results were reviewed and the distribution pattern repeated itself for the majority of inorganics. The highest concentrations of any individual metal were generally detected in wells near the aboveground fuel oil tank, Mud Pond and the two Mud Holes on Parcel C (MP-18, MP-18D, GM-14A and GM-14B). The distribution of arsenic, antimony and manganese were chosen as being representative of all other inorganics. In addition, both arsenic and manganese was chosen because of their wide distribution in the soils (refer to Section 5.2.1.4). The concentration of these three constituents for the first and second groundwater sampling rounds are presented in Figures 5-24 through 5-29.

In the first sampling round, arsenic was detected in 10 samples at concentrations ranging from 4.2 J (GM-1) to 14,500 µg/L (GM-14B). The NYSDEC standard of 25 µg/L was exceeded in six of those samples; the MCL of 50 µg/L was exceeded in three samples. Arsenic was not detected in either the on-site background well (MP-11D) or the off-site background well (Konica-1). The highest concentration of arsenic occurs in the southern portion of Parcel C (14,500 µg/L in GM-14B) and rapidly decreases in a cross-gradient direction extending to the western Site boundary (40 µg/L in MP-18) and in a downgradient direction to the southern portion of Parcel A (403, 84.7, 35.3 and 27.2 µg/L in MP-22, EMW-4, MP-22D and GM-2,

respectively). Arsenic was not detected in any other wells at a concentration that exceeded the NYSDEC standard. The concentration of arsenic in groundwater during the first sampling round is presented in Figure 5-24.

Antimony was detected in seven wells at concentrations ranging from 5.8 J µg/L (MP-22D) to 4,300 µg/L (GM-14B). The NYSDEC standard (3 µg/L) was exceeded all seven samples. Antimony was not detected in the on-site background well (MP-11D) or the off-site background well (Konica-1). Similar to arsenic, the highest concentration of antimony appears in the southern portion of Parcel C (4,300 µg/L in GM-14B) and gradually decreases in a cross-gradient direction extending to the western Site boundary (48.1 J and 16.6 µg/L in MP-18 and MP-18D, respectively) and in a downgradient direction to the southern portion of Parcel A (52.8 J and 6.1 µg/L in MP-22 and GM-2, respectively). Antimony was not detected in any other wells across the Site. The concentration of antimony in groundwater during the first sampling round is presented in Figure 5-26.

Manganese was among the most frequently detected metal and was detected at all wells locations except one (MP-21D on Parcel A) at concentrations ranging from 2 J µg/L (MP-2D) to 64,700 E µg/L (MP-18D). The NYSDEC standard for manganese is 300 µg/L and was exceeded at 24 well locations. The concentration of manganese in the site-specific background well (MP-11D) was 0.42 J µg/L; the concentration in the off-site background well (Konica-1) was 0.73 µg/L.

The highest concentration of manganese was detected in MP-18D (64,700 µg/L). Other wells in the lower portion of Parcel C (MP-18, EMW-4, GM-14A and GM-14B) reflected concentrations of 5,500, 4,000, 1,720 and 246 µg/L, respectively. The second highest concentration of manganese was detected in the south-central portion of Parcel A (MP-2D and GM-2) at a concentration of 34,200 and 5,020 µg/L, respectively. The wells north of the Mattiace Petrochemical site also reflected high concentrations of manganese: 18,000 µg/L in MW-10; 8,320 µg/L in MW-8D; 6,790 µg/ lin MW-8S and 163 µg/L in GM-10. Other areas of high manganese concentration were centered on wells GM-1 (6,940 µg/L) and MP-6 (6,880 µg/L) on Parcel A, GM-13 (10,000 µg/L) on Parcel B and MP-4 (6,880 µg/L) on Parcel C. The concentration of manganese in groundwater during the first sampling round is presented in Figure 5-28.

During the first groundwater sampling round, the concentration of other inorganics were detected above the MCLs or NYSDEC standards. Sodium (63,200 µg/L) was detected above the standards of 20,000 µg/L in sample GM-1. Sample GM-2 contained concentrations of iron (19,700 µg/L) and nickel (1,150 µg/L) above the MCLs or NYSDEC standards of 300 µg/L and 1000 µg/L, respectively. Sample GM-2 also contained elevated levels of sodium (157,000 µg/L). Concentrations of sodium (51,400 E µg/L) were detected above NYSDEC standards in sample GM-7. Sample GM-9 contained levels of iron (1,780 µg/L) and sodium (34,800 E µg/L) that exceeded NYSDEC standards. No metals were detected above appropriate MCLs or NYSDEC standards in sample GM-10. Samples GM-12 and GM-13 contained concentrations of iron and sodium that exceeded NYSDEC standards. Sample GM-13 also contained thallium (9.6 J µg/L) at a concentration that exceeded the MCL (2 µg/L). Sample GM-14A contained elevated levels of cadmium, copper, iron, sodium, thallium and zinc.

The MCLs or NYSDEC standards for cadmium, copper, zinc are 5,200 and 300 µg/L, respectively. The MCLs or NYSDEC standards for chromium, iron, selenium and sodium were exceeded in sample GM-14B. The NYSDEC standards for chromium and selenium are 50 and 10 µg/L, respectively. Concentrations of iron and sodium were detected in samples GM-15 and EMW-1 that exceeded their respective NYSDEC standards. Sample EMW-1 also contained 5.1 J µg/L of thallium. Sample EMW-4 contained concentrations of cadmium, copper, iron, sodium, thallium and zinc that exceeded the appropriate MCL or NYSDEC standard. Sample MW-8 contained levels of iron (51,300 µg/L) and thallium (7.7 J µg/L) that exceeded their respective MCL or NYSDEC standard. Samples MW-8D and MW-10 contained concentrations of iron, sodium and thallium that exceeded the appropriate MCLs or NYSDEC standards. Sample MW-10 also contained cadmium (144 µg/L) at a level that exceeded the MCL.

Concentrations of iron, lead, nickel, selenium, sodium and zinc were detected above their respective MCLs or NYSDEC standards in sample MP-2D. Samples MP-4 contained levels of thallium (7.1 J µg/L) that exceeded the appropriate MCL or NYSDEC standard. Concentrations of iron (4,800 µg/L) and sodium (21,800 E µg/L) were detected in sample MP-5 that exceeded the NYSDEC standards. Sample MP-6 contained elevated levels of cadmium, iron, sodium, thallium and zinc. Only sodium (65,000 E µg/L) was detected in sample MP-11D above the NYSDEC standards. Selenium was detected above the NYSDEC standards in sample MP-16 and MP-16D at concentrations of 11.7 E µg/L and 23.4 E µg/L, respectively. Sample

MP-16D also contained 87,900 E µg/L sodium, above the NYSDEC standard. Sample MP-17 contained concentrations of iron (19,800 µg/L), selenium (28.6 µg/L) and sodium (113,000 E µg/L) that exceeded their respective MCL or NYSDEC standard.

Sample MP-18 contained elevated levels of beryllium, cadmium, copper, iron, nickel, sodium, thallium and zinc. The MCLs or NYSDEC standards for cadmium, iron, nickel, sodium, thallium and zinc were exceeded in sample MP-18D. Elevated levels of manganese and sodium were detected in both samples MP-19D and MP-20. Sample MP-19D also contained 3.9J µg/L thallium, above the MCL. Only sodium (67,600 µg/L) was detected above the MCL or NYSDEC standard in sample MP-21D. Sample MP-22 contained concentrations of nickel (383 µg/L), sodium (44,000 µg/L) that exceeded the appropriate MCL or NYSDEC standard. Sample MP-22D contained concentrations of barium (277 E µg/L), selenium (22.6 µg/L) and sodium (642,000 µg/L) that exceeded the appropriate MCL or NYSDEC standard.

During the second round of groundwater sampling, arsenic was again detected in 10 samples, but not in all the same wells. The NYSDEC standard (25 µg/L) was exceeded in only four wells. The highest concentration again occurred in GM-14B (9,440 E µg/L) and concentrations decrease in a cross-gradient direction extending to the western Site boundary on Parcel C (36.4 µg/L in MP-18) and in a downgradient direction to the southern portion of Parcel A (160, 25.8, 16.2 and 13.5 µg/L in MP-22, MP-22D EMW-4 and GM-2, respectively). Arsenic was not detected in any other wells at a concentration that exceeded the NYSDEC standard or MCL. The concentration of arsenic in groundwater during the first sampling round is presented in Figure 5-25.

Antimony was detected in only five wells at lower concentrations that those measured during the first round. Overall, the concentrations ranged from 7.5 J µg/L (MP-18D) to 824 E µg/L (GM-14B). The MCL (3 µg/L) was exceeded in all five samples. Similar to the first round, the highest concentration of antimony appears in the southern portion of Parcel C (824 E and 66 ug/L in GM-14B and GM-14A, respectively). The concentration of antimony decreases in a cross-gradient direction extending to the western Site boundary (10 J and 7.5 µg/L in MP-18 and MP-18D, respectively) and in a downgradient direction to the southern portion of Parcel A (18.5 J µg/L in MP-22). Antimony was not detected in GM-2 in the south central portion of Parcel A or in any other wells across the Site. The concentration of antimony in groundwater during the second sampling round is presented in Figure 5-27.

Manganese was detected at all wells locations except the site-specific background well MP-11D on Parcel B (data from well MP-20 was rejected). Concentrations ranged from 0.42 µg/L (MP-22D) to 69,800 µg/L (MP-18D). The highest concentration of manganese was again detected in MP-18D, but slightly higher than in the first round (69,800 µg/L compared to 64,700 µg/L). Other wells in the lower portion of Parcel C (MP-18, EMW-4, GM-14A and GM-14B) reflected comparable concentrations to the first round of 4,950, 3,410, 1,720 and 375 E µg/L, respectively. The second highest concentration of manganese was again detected in the south-central portion of Parcel A (MP-2D and GM-2) at a concentration of 24,900 and 7,600 µg/L, respectively. The wells north of the Mattiace Petrochemical site again reflected high concentrations of manganese at comparable levels: 14,000 µg/L in MW-10; 6,020 µg/L in MW-8D; 5,790 µg/L in MW-8S and 325 µg/L in GM-10. Other areas of high manganese concentration were centered on wells GM-1 (1,820 µg/L) and MP-6 (6,070 µg/L) on Parcel A, GM-13 (8,170 µg/L) on Parcel B and MP-4 (4,650 µg/L) on Parcel C. The concentration of manganese in groundwater during the second sampling round is presented in Figure 5-29.

GM-1 contained concentrations of sodium (46,300 µg/L) that exceeded the NYSDEC standard. Concentrations of iron (48,700 µg/L), nickel (921 µg/L) and sodium (159,000 µg/L) were detected above their respective MCLs or NYSDEC standards in sample GM-2. Sample GM-7 contained sodium (58,700 µg/L) at a concentration above the NYSDEC standard. Sample GM-8 contained concentrations of cadmium (5.6 µg/L), copper (326 E µg/L) and sodium (21,600 E µg/L) that exceeded their respective MCLs or NYSDEC standards. Concentrations of iron (1,590 µg/L), and sodium (27,500 µg/L) were detected above their respective NYSDEC standards. Sample GM-12 contained concentrations of iron (2,080 µg/L), and sodium (22,000 µg/L) that exceeded the NYSDEC standards. Sample GM-13 contained concentrations of cadmium (8.5 µg/L), iron (433 µg/L), sodium (80,000 µg/L), and thallium (5.9J µg/L) that exceeded their respective MCLs or NYSDEC standards. Sample GM-14A contained cadmium (26.4 µg/L), copper (478 µg/L), iron (4,730 µg/L), sodium (93,500 µg/L), and zinc (1,450 µg/L) that exceeded their respective MCL or NYSDEC standard. Concentrations of beryllium (9.1 E µg/L), chromium (255 E µg/L) and iron (6,560 E µg/L) were detected in sample GM-14B that exceeded their respective MCLs or NYSDEC standards. Sample GM-15 contained a concentration of iron (6,250 µg/L), sodium (59,200 µg/L) and thallium (4.5 J µg/L).

Sample EMW-1 contained concentrations of iron (8,000 µg/L) and sodium (32,400 µg/L) that exceeded their respective NYSDEC standards. Concentrations that exceeded the MCLs or NYSDEC standards of cadmium (23.8 µg/L), copper (441 E µg/L), iron (5,110 µg/L), nickel (214 µg/L), sodium (71,300 µg/L), thallium (6.7 J µg/L) and zinc (3,440 E µg/L) were detected in sample EMW-4. Sample MW-8 contained levels of iron (65,800 µg/L) and thallium (7.1 J µg/L) that exceeded the appropriate MCL or NYSDEC standard. Sample MW-8D contained levels of iron (114,000 µg/L), sodium (21,500 µg/L) and thallium (4.4 J µg/L). Sample MW-10 contained concentrations of barium (202 µg/L), cadmium (104 µg/L), iron (93,400 µg/L), sodium (82,900 E µg/L) and thallium (13.2 µg/L) that exceeded their respective MCLs or NYSDEC standards. Concentrations of iron (198,000 µg/L), sodium (337,000 µg/L) and zinc (1,390 µg/L) were detected above the MCL or NYSDEC standard in sample MP-2D. Sample MP-4 contained thallium (707J µg/L) at concentrations that exceeded the appropriate MCL or NYSDEC standard.

Sample MP-5 contained concentrations of iron (3,420 µg/L) and sodium (21,700 µg/L) that exceeded the NYSDEC standard. Concentrations of cadmium (22.3 µg/L), iron (751 µg/L), sodium (45,000 µg/L), thallium (7.5 J µg/L) and zinc (1,290 E µg/L) were detected above their respective MCLs and NYSDEC standards in sample MP-6. Only sodium (46,600 µg/L) was detected above the NYSDEC standard in sample MP-11D). Sample MP-16 contained only iron (1,160 µg/L) at concentrations above the NYSDEC standard. No metals were detected at concentrations above the appropriate MCL or NYSDEC standard in sample MP-16D. Sample MP-17 contained iron (62,700 µg/L), selenium (78.5 µg/L) and sodium (92,400 µg/L) at concentrations that exceeded their respective NYSDEC standards.

Samples MP-18 and MP-18D concentrations exceeding the appropriate MCLs or NYSDEC standards of cadmium, iron nickel, sodium and zinc. Sample MP-19D contained levels of nickel (169 µg/L) and sodium (70,100 µg/L) that exceeded their respective MCLs or NYSDEC standards. Only sodium (48,600 µg/L) and thallium (7J µg/L) were detected in sample MP-20 at concentrations that exceeded the NYSDEC standards. Sample MP-21D contained concentrations of iron (3,510 µg/L) and sodium (46,300 µg/L) that exceeded their respective NYSDEC standards. Sample MP-22 contained cadmium (5.2 µg/L), copper (509 µg/L) nickel (880 µg/L) selenium (14.3 µg/L), silver (68.2 E µg/L) and sodium (74,600 µg/L) at concentrations that exceeded their respective MCL or NYSDEC standard. Sample MP-22D

contained elevated levels of barium (872 µg/L), selenium (22.5 µg/L) and sodium (607,000 µg/L).

5.2.2.5 Radionuclides

Two rounds of groundwater samples were collected for radionuclide analyses (^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th and ^{232}Th). There are no standards, either MCLs or NYSDEC water quality standards, for uranium or thorium, although the drinking water concentration of thorium is limited by the 15 pCi/L gross alpha MCL. The USEPA and NYSDEC have established a 5 pCi/L MCL for the sum of ^{226}Ra and ^{228}Ra. In addition, NYSDEC limits the concentration of ^{226}Ra to 3 pCi/L. Revisions to the National Drinking Water Regulations for radionuclides (40 CFR Parts 141 and 142) were proposed but never enacted. The revisions included 20 pCi/L for ^{226}Ra and ^{228}Ra; 300 pCi/L for ^{222}Ra (radon); 20 µg/L (approx. 30 pCi/L) for uranium; 4 millirem effective dose equivalent/year for beta and photon emitters (excluding ^{228}Ra); and 15 pCi/L for adjusted gross alpha emitters (excluding ^{228}Ra, U and ^{222}Ra). In the absence of element-specific MCLs, the uranium and thorium concentration measured during the two rounds of groundwater sampling are compared to the site-specific background concentration determined from three hydraulically upgradient monitoring wells (MP-5, MP-11D and Konica-1). In addition to a comparison to background, radium concentrations are compared to the NYSDEC standard of 3 pCi/L.

During the first sampling round, ^{238}U concentrations exceeded the <2.2 pCi/L average site-specific background concentration in 13 groundwater samples. The concentration of ^{238}U that exceeded the site-specific background value ranged from 2.4 E pCi/L (GM-12) to a maximum of 67 pCi/L (GM-14B). The location of the wells where the concentration of ^{238}U exceeded the site-specific background (<2.2 pCi/L) included three wells along the northern and southern boundaries of Parcel A (GM-1, MP-17D and MP-22D), one well in the southern portion of Parcel B (GM-8) and nine wells throughout Parcel C (GM-11, GM-12, GM-14B, GM-15, MW-8S, MW-10, MP-11D, MP-16D and MP-18D). The concentration of ^{238}U during the first round of groundwater sampling is presented on Figure 5-30.

The site-specific background concentration for ^{232}Th (<0.8 pCi/L) was exceeded in eight samples ranging from 1 pCi/L (GM-10 and MW-10) to 7 pCi/L (MP-18D). The location of the wells where the concentration of ^{232}Th exceeded the site-specific background (<0.8 pCi/L)

included one well in the south-central portion of Parcel A (MP-2D), one well in the middle of Parcel B (GM-13) and six wells throughout Parcel C (GM-11, GM-12, GM-14B, GM-15, MW-8S, MW-10, MP-11D, MP-16D and MP-18D). The concentration of ^{232}Th during the first round of groundwater sampling is presented on Figure 5-31.

The concentration of ^{226}Ra exceeded the NYSDEC standard (3 pCi/L) in eight samples and the site-specific background concentration of <1.9 pCi/L in 13 samples. The concentrations exceeding the site-specific background ranged from 2.3 pCi/L (GM-7) to 11 pCi/L (MP-16D). The location of the wells where the concentration of ^{226}Ra exceeded the site-specific background (<1.9 pCi/L) included three wells along the northern and southern boundaries of Parcel A (GM-1, MP-2D and MP-22D), three wells in the southern portion of Parcel B (GM-7, GM-8 and GM-9) and seven wells throughout Parcel C (GM-10, GM-11, GM-12, MW-10, MP-11D, MP-16D and MP-18D). The concentration of ^{226}Ra during the first round of groundwater sampling is presented on Figure 5-32.

The 5 pCi/L NYSDEC and USEPA standard for the sum of ^{226}Ra and ^{228}Ra was exceeded in ten samples. Total radium concentration in these samples ranged from 5.4 pCi/L (MW-10) to 21 pCi/L (MP-16D). During one sample round, the concentration of ^{226}Ra and ^{228}Ra in the site-specific background well MP-5 and MP-11D were 6.4 pCi/L and 5.2 pCi/L respectively, which exceed the NYSDEC and USEPA standards.

During the second sampling round, the concentration of ^{238}U exceeded the site-specific background concentration (2.2 pCi/L) in nine samples and ranged from 2.5 pCi/L (GM-14A) to 80 pCi/L (GM-14B). Other wells where the concentration of ^{238}U exceeded the site-specific background concentration included GM-1 (4.1 E pCi/L) and MP-22 (4.1 pCi/L) on Parcel A; GM-8 (2.8 pCi/L) and GM-9 (5.6 pCi/L) on the lower portion of Parcel B; and MW-10 (31 pCi/L), GM-15 ((7.5 pCi/L) and MP-18 (3.9 pCI/L) on Parcel C. The concentration of ^{238}U during the second round of groundwater sampling is presented on Figure 5-33.

The site-specific background concentration of ^{232}Th (0.8 pCi/L) was exceeded in eight samples and ranged from 0.98 pCi/L (MP-16D) to 6.8 E pCi/L (GM-14B). Other wells where the concentration of ^{232}Th exceeded the site-specific background concentration included GM-1 (3.6 pCi/L), MP-2D (3.8 pCi/L) and MP-17D (<1.2 pCi/L) on Parcel A; GM-13 (1.3 pCi/L) on Parcel B; and GM-14A (1.2 pCi/L), MP-18 (1.6 pCi/L) and MP-18D (2.2 pCI/L) on Parcel C.

The concentration of ^{232}Th during the second round of groundwater sampling is presented on Figure 5-34.

Fifteen samples contained concentrations of ^{226}Ra that exceeded the site-specific background (1.9 pCi/L) and 11 samples exceeded the NYSDEC standard (3 pCi/L). The total radium standard (5 pCi/L) was exceeded in ten samples. Overall the measured concentrations above the site-specific background ranged from 2 pCi/L (GM-13) to 11 pCi/L (MP-16D). Other wells where the concentration of ^{226}Ra exceeded the site-specific background concentration included GM-1 (3.6 pCi/L), MP-2D (4.3 pCi/L) and MP-22 (4 pCi/L) on Parcel A; GM-7 (6.3 pCi/L), GM-8 (6 pCi/L) and GM-9 (9 pCi/L) on Parcel B; and GM-11 (7 pCi/L), GM-12 (2.8 pCi/L), GM-10 (3.3 pCi/L), MW-10 (3.3 pCi/L), GM-14B (2.7 pCi/L), GM-15 (3.7 pCi/L) and MP-18D (3.3 pCI/L) on Parcel C. The concentration of ^{226}Ra during the second round of groundwater sampling is presented on Figure 5-35.

5.2.3 Surface Water

The nomenclature presented in the Work Plan for the surface water sampling stations was adopted from previous investigations (NUS, 1990). The sampling station number designation for those original locations that were to be resampled (SW-1 through SW-9) were maintained. A new sample designation (SW-10 and SW-11) was developed at locations that were not previously sampled. At the time of sampling, however, both Mud Holes (SW-2 and SW-3) no longer contained surface water and could not be sampled. Previous sampling locations in Glen Cove Creek (SW-6 and SW-7) were not part of the scope of this RI. The sample station number designation was maintained, which explains why although the numbering sequence extends to 11, only seven samples were actually collected.

The seven surface water samples were collected from the ponds and wetland areas on Parcel B (SW-8 and SW-9) and Parcel C (SW-4, SW-10 and SW-11), and two concrete surface impoundments on Parcel A (SW-1 and SW-5). The discussion in this Report does not address the two surface water impoundments on Parcel A, because the impoundments have recently been emptied by the Removal Branch and the water has been shipped off-site for disposal. Site-specific background samples for surface water were not collected because no area could be found that potentially was not affected by operations at the Site. The analytical results for the five samples are compared to NYSDEC standards for Class D Fresh Water, where listed. If a

Class D standard is not provided, an alternative standard (Class C, Class B or Class A) is used. While the Class D standard represents the lowest quality fresh water, this classification includes surface water suitable for fish survival, and primary and secondary contact recreations.

5.2.3.1 Volatile Organic Compounds

VOCs were not detected in any of the three surface water samples on Parcel C (SW-4, SW-10 and SW-11). The pond on Parcel B (SW-8) contained acetone (13 E µg/L), total 1,2-DCE (15 µg/L) and PCE (6 J µg/L). The wetland associated with the pond on Parcel B (SW-9) only contained trace levels of 1,1-DCA (2 J µg/L). There are no NYSDEC surface water standards for acetone or the two chlorinated hydrocarbons, however, the concentration of the three constituents are near the drinking water MCLs, which represents a more stringent standard.

5.2.3.2 Semi-Volatile Organic Compounds

SVOCs were not detected in two samples on Parcel C (SW-4 and SW-10) or the pond on Parcel B (SW-8). Bis(2-ethylhexyl)phthalate was detected in samples SW-9 (1 J µg/L) and SW-11 (4 J µg/L), exceeding the Class C Surface Water Standard of 0.6 µg/L. Di-n-butylphthalate was detected in sample SW-11 (1 J µg/L). Sample SW-5 contained 1 J µg/L of diethylphthalate.

5.2.3.3 Pesticides/Polychlorinated Biphenyls

PCBs were detected in two of the seven surface water samples. Two PCB congeners (aroclor 1254 and aroclor 1260) were detected in SW-1 at concentrations of 3.8 E µg/L and 2.3 E µg/L, respectively; one PCB congener (aroclor-1254) was detected in SW-4 (1 E µg/L). The Class D Surface Water Standard for total PCBs is 0.01 µg/L. Pesticides were detected in only one of seven surface water samples. Three pesticide compounds, 4,4'-DDE, 4,4'-DDD and 4,4'-DDT were detected in SW-8 at concentrations of 1.6 JN µg/L, 9.1 JN µg/L and 4.6 JN µg/L, respectively. The Class D Surface Water Standard for DDE, DDD and DDT is 0.001 µg/L.

5.2.3.4 Inorganics

All of the surface water samples exceeded surface water standards for some inorganics. The sample from Mud Pond on Parcel C (SW-4) contained aluminum (1,220 µg/L), cobalt (905

µg/L), copper (222 µg/L), iron (7,090 µg/L), magnesium (58,200 µg/L), manganese (1,460 µg/L) and selenium (24.3 µg/L) at concentrations that exceeded the surface water standards. The pond on Parcel B (SW-8) showed aluminum (77,000 µg/L), arsenic(8,090 µg/L), cadmium (846 µg/L), chromium (215 µg/L), cobalt (42,300 µg/L), copper (17,100 µg/L), iron (722,000 µg/L), lead (1,180 µg/L), manganese (5,390 µg/L), mercury (3.6 µg/L), selenium (200 µg/L), silver (256 µg/), thallium (47,800 µg/L), vanadium (210 µg/L) and zinc (91,200 µg/L) at concentrations that exceeded the appropriate surface water standards. Surface water adjacent to the pond on Parcel B (SW-9) contained aluminum (127 J µg/L), cobalt (55.7 E µg/L), iron (13,000 E µg/L) and manganese (4,970 µg/L) at concentrations exceeding surface water standards. The pond and wetland area on Parcel C (SW-10 and SW-11) contained aluminum, cadmium, copper, iron, manganese and zinc at concentrations that exceeded surface water standards. Sample SW-10 also contained chromium (12 µg/L) at a concentration that exceeded surface water standards.

5.2.3.5 Radionuclides

As stated in Section 5.2.2.5, USEPA MCLs and NYSDEC standards have been promulgated for radium; radionuclide-specific standards for uranium and thorium do not exist. The Class A Surface Water Standard for ^{226}Ra is 3 pCi/L; the Class A Surface Water Standard for the sum of the ^{226}Ra and ^{228}Ra is 5 pCi/L. Uranium-238 was detected in each of the five surface water samples at a concentration ranging from less than 0.23 pCi/L (SW-9) to 4.8 pCi/L (SW-4). Radium-226 was detected in five samples at concentrations that ranged from less than 0.45 pCi/L (SW-10) to 4.5 pCi/L (SW-8). Radium-228 was detected in samples SW-4 and SW-8 at concentrations of less than 1.0 pCi/L and 2.4 pCi/L, respectively. SW-8 exceeded both the regulatory standard for ^{226}Ra and the combined standard for ^{226}Ra and ^{228}Ra. Concentrations of ^{232}Th were detected in four of the five samples ranging in concentration from less than 0.23 pCi/L (SW-11) to less than 0.41 pCi/L (SW-4). Thorium-230 was detected in samples SW-4 and SW-8 at concentrations of 0.64 pCi/L and less than 0.46 pCi/L, respectively.

5.2.4 Sediment

Sediment samples were collected from locations where surface water samples were collected. Sediment results for VOC, SVOC, inorganics, pesticides and PCBs are compared to

the NYSDEC TAGM values. Sediment results for radiological parameters are compared to background concentrations because TAGM guidance do not exist. Sediment sample results are presented in Appendix N.

5.2.4.1 Volatile Organic Compounds

Trace levels (below NYSDEC standards) of several VOCs were detected in five sediment samples. Principal organic contaminants included 2-butanone, carbon disulfide and chlorinated and aromatic hydrocarbons. Acetone was detected at a concentration (240 E µg/Kg and 160 E µg/Kg) in samples SED-9 and SED-8, respectively that exceeded the appropriate TAGM value (15 µg/Kg).

5.2.4.2 Semi-Volatile Organic Compounds

SVOCs were detected in each sediment sample except SED-10. The principal semi-volatile organic contaminants included PAHs and phthalates, but at concentrations that were below TAGM guidance values. Sample SED-5 contained concentrations of benzo(a)anthracene (290 µg/Kg), chrysene (580 µg/Kg), benzo(b)fluoranthene (600 µg/Kg) and benzo(k)fluoranthene (260 µg/Kg) at concentrations that exceeded the respective TAGM guidance values.

5.2.4.3 Pesticides/Polychlorinated Biphenyls

Analytical results indicate that PCBs were detected in three sediment samples (SED-2, SED-3 and SED-9. The PCBs detected were primarily aroclor-1254, aroclor-1260, and to a lesser frequency aroclor-1248. Total PCB concentrations of 2,891 µg/Kg, 1,806 µg/Kg and 873 µg/Kg were detected in samples SED-2, SED-9 and SED-3, respectively. The TAGM value for total PCBs in sediment is 328 µg/Kg. The only pesticides (4,4'-DDD and 4,4'-DDE) detected in one sediment sample (SED-8) was above the TAGM guidance values.

5.2.4.4 Inorganics

Inorganic analytical results were compared to available TAGM guidance values for sediment (e.g., arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc). Concentrations of arsenic, cadmium, copper and iron in all eight sediment samples

exceeded the TAGM guidance values for that individual constituent. The concentration of chromium exceeded the TAGM guidance value (26 mg/Kg) in three samples (SED-4, SED-5 and SED-11). The concentration of lead exceeded the TAGM guidance value (31 mg/Kg) in all but one sample (SED-8). The concentration of manganese exceeded the TAGM guidance value (460 mg/Kg) in four samples (SED-2, SED-4, SED-5 and SED-9). Mercury exceeded the TAGM guidance value (0.2 mg/Kg) in five samples (SED-2, SED-3, SED-4, SED-5 and SED-11). The TAGM guidance value for nickel (16 mg/Kg) was exceeded in all samples except SED-10 and SED-11. The concentration of zinc exceeded the TAGM guidance value (120 mg/Kg) in all samples except SED-3, SED-8 and SED-9.

5.2.4.5 Radionuclides

The sediment samples were analyzed for the same radiological parameters (e.g., ^{238}U, ^{226}Ra, ^{228}Ra, ^{220}Th and ^{232}Th) as the surface and subsurface soils. Since there are no available Federal or State guidance values for these parameters in sediment, the analytical results are compared to site-specific background that was calculated for the soils.

The three sediment samples collected from the two Mud Holes (SED-2 and SED-3) and Mud Pond (SED-4) exceeded the site-specific background for each radionuclide except ^{228}Ra in SED-2. The concentration of ^{238}U in the three samples ranged from 4.5 (SED-2) to 46 pCi/g (SED-4); the concentration of ^{232}Th ranged from 2.1 pCi/g (SED-2) to 5.7 pCi/g (SED-4); and the concentration of ^{226}Ra ranged from 2.2 pCi/g (SED-2) to 5.7 pCi/g (SED-4). The concentration of each radionuclide in the two samples collected on Parcel B (SED-8 and SED-9) and one sample on the upper portion of Parcel C (SED-10) were all less than the site-specific background level. The concentration of ^{226}Ra (2.2 pCi/g), ^{230}Th (1.3 pCi/g) and ^{232}Th (1.5 pCi/g) in SED-11 exceeded site-specific background.

5.2.5 Storm Sewer Sediment

Sediment samples were collected from locations on Parcels A and C. Storm sewer sediment results for VOC, SVOC, inorganics, pesticides and PCBs are compared to the NYSDEC TAGM values. Storm sewer sediment results for radiological parameters are compared to background concentrations because TAGM guidance do not exist. Storm sewer sediment sample results are presented in Appendix N.

5.2.5.1 Volatile Organic Compounds

Trace levels (below NYSDEC standards) of several VOCs were detected in four storm sewer sediment samples. Principal organic contaminants included 2-butanone, carbon disulfide and chlorinated and aromatic hydrocarbons. Acetone was detected at a concentration (22 E µg/Kg and 16 µg/Kg) in samples SED-DP-2 and SED-DP-29, respectively that slightly exceeded the appropriate TAGM value (15 µg/Kg).

5.2.5.2 Semi-Volatile Organic Compounds

SVOCs were detected in each of the four storm sewer sediment samples. The principal semi-volatile organic contaminants included PAHs and phthalates. Concentrations of pyrene (3,100 E µg/Kg), chrysene (3,000 E µg/Kg), benzo(b)fluoranthene (3,700 E µg/Kg), benzo(a)pyrene (4,800 E µg/Kg), indeno(1,2,3-cd)pyrene (1,100 E µg/Kg) and benzo(g,h,i) perylene (1,100 E µg/Kg) were detected in sample SED-DP3 at concentrations that exceeded the TAGM guidance values. Sample SED-DP5 contained 13,000 E µg/Kg of pyrene and benzo(b)fluoranthene, 7,400 E µg/Kg benzo(a)pyrene, and 560 E µg/Kg of indeno(1,2,3-cd)pyrene and 3,600 E µg/Kg of benzo(g,h,i)perylene, thereby exceeding their respective TAGM guidance values. Concentrations of pyrene (1,600 µg/Kg), benzo(a)anthracene (1,200 µg/Kg), chrysene (1,100 µg/Kg), benzo(b)fluoranthene (1,600 E µg/Kg), benzo(k)fluoanthene (500 E µg/Kg), benzo(a)pyrene (570 E µg/Kg), indeno(1,2,3-cd)pyrene (330 J µg/Kg) and benzo(g,h,i)perylene (260 J µg/Kg) were detected above the TAGM guidance values in sample SED-DP29.

5.2.5.3 Pesticides/Polychlorinated Biphenyls

Analytical results indicate that PCBs were detected in two storm sewer sediment samples (SED-DP-3, SED-DP-5) at concentrations that exceeded the TAGM guidance values. The PCBs detected were primarily aroclor-1254, aroclor-1260, and to a lesser frequency aroclor-1248. Total PCB concentrations of 853 µg/Kg, and 614 µg/Kg were detected in samples SED-DP-3 and SED-DP-5, respectively. The TAGM value for total PCBs in sediment is 328 µg/Kg. No pesticides were detected in any storm sewer sediment sample.

5.2.5.4 Inorganics

Inorganic analytical results were compared to available TAGM guidance values for sediment. The concentrations of all inorganic constituents, for which there are TAGM guidance values (e.g., arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc), were exceeded in every storm sewer sediment sample.

5.2.5.5 Radionuclides

The storm sewer sediment samples were analyzed for the same radiological parameters (e.g., ^{238}U, ^{226}Ra, ^{228}Ra, ^{220}Th and ^{232}Th) as the sediment, surface and subsurface soils. Since there are no available Federal or State guidance values for these parameters in sediment, the analytical results are compared to site-specific background that was calculated for the soils.

The majority of all storm sewer sediment samples exceeded 1.5X the site-specific background concentration of the five radionuclides. The exception occurred in sample SED-DP-29 where the concentration of of ^{232}Th and ^{226}Ra were below the site-specific background concentration. The maximum and minimum concentrations of ^{238}U, ^{232}Th and ^{226}Ra each occurred in samples SED-DP-3The concentration of ^{238}U in the four samples ranged from 1.7 (SED-DP-29) to 29 pCi/g (SED-DP-3); the concentration of ^{232}Th ranged from 1.1 pCi/g (SED-DP-29) to 15 pCi/g (SED-DP-3); and the concentration of ^{226}Ra ranged from 1.9 pCi/g (SED-DP-29) to 6.6 pCi/g (SED-DP-3).

5.3 TOXICITY CHARACTERISTIC LEACHING PROCEDURE SAMPLES

Toxicity characteristic leaching procedure (TCLP) analyses were performed on seven soil samples (SB-3B, SB-17, SB-27, SB-40, SB-41, TP-5, and TP-7). Three of these samples were collected from source area borings (SB-3, SB-17, and SB-27), two from storm sewer borings (SB-40 and SB-41), and two from test pits (TP-5 and TP-7). Results indicate that no organic compounds were detected in any of the seven soil samples. Trace levels (well below RCRA regulatory standards) of arsenic, barium, cadmium, lead, selenium, and silver were detected in the samples. Analytical results of the TCLP analyses are presented in Appendix N. Based upon the TCLP results, none of the seven soil samples would be characterized as a RCRA hazardous waste.

The purpose of the TCLP testing was to tentatively classify various areas that may be considered during the feasibility study for off-site analysis. Even though the TCLP sample results did not indicate that any of the soil samples tested can be classified as a RCRA hazardous waste, additional sampling will be necessary prior to shipping any material off-site for disposal. Additional TCLP testing of the ore residues stored in Dickson Warehouse is proposed during the Captain's Cove FFS to determine if the ore residues may also be RCRA hazardous.

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6.0 FATE AND TRANSPORT

6.1 INTRODUCTION

This section describes the processes by which contaminants are transported or transformed in the environment at the Site. The discussion is predominantly qualitative with regards to the specific compounds at the Site. No quantitative modeling effort was undertaken as a part of this analysis.

Fate and transport of the different types of contaminants at the Site will be addressed for the various types of contaminated media, though the primary focus is activity occurring in the saturated and unsaturated soils. The types of contaminants detected at the site include: volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, PCBs, metals and radiological elements. The transport processes discussed include advection, dispersion, facilitated transport, volatilization and attenuation on soils. The transformation processes discussed include biodegradation, biotransformation, bioactivation, oxidation-reduction reactions, precipitation and complexation.

6.2 TRANSPORT PROCESSES

6.2.1 Advection

Advection is the process of conveying a contaminant by virtue of the motion of the fluid in which it is contained, whether dissolved or suspended. Advection is the primary means by which soluble compounds are transported in the subsurface. Non-aqueous phase liquids (NAPLs) may also be transported by advection. Light non-aqueous phase liquids (LNAPLs) tend to float on the top of a groundwater table, and when they are floating on the water table they tend to move in the direction of groundwater flow. Dense non-aqueous phase liquids (DNAPLs) tend to travel vertically towards the bottom of the saturated zone. This gravity driven transport may result in movement of a DNAPL plume that is not in the direction of groundwater flow. This anisotropic migration is not uncommon.

6.2.2 Dispersion

Dispersion is the process of transport of a dissolved solute from a region of higher concentration to a region of lower concentration. Dissolved contaminants tend to move in the direction of lower concentration, which typically results in radial dispersion from the source of a groundwater contamination. The rate of diffusion will be a function of the difference in concentration between the source area and the uncontaminated area.

6.2.3 Facilitated Transport

Facilitated transport is the increase in the rate of mobility of a contaminant beyond that expected based solely on considerations of idealized Darcian flow and equilibrium sorptive interactions. Facilitated transport is most commonly associated with hydrophobic organic compounds (HOCs) such as PCBs, pesticides and PAHs, and heavy metal species which have a high affinity for surfaces. The rate of mobility of strongly sorbed compounds may be increased above the predicted level when a compound such as a cosolvent or surfactant is present which reduces the sorption coefficient of a compound. Another common mechanism for facilitated transport is sorption of HOCs and metals to colloidal particles which are then readily transported through advection.

The cosolvent effect occurs when a miscible organic compound such as acetone or methyl ethyl ketone is present in sufficient concentration to reduce the sorption coefficient of an HOC such that it is more soluble in solution. Since many contaminated sites often have multiple contaminant sources it is not uncommon to find strongly sorbing organic compounds and metals as contaminants along with miscible organic compounds.

Surfactants are another class of compounds that act to alter the sorption coefficient of a surface, and may lead to increased concentration of a contaminant in solution that is typically found sorbed. Surfactants are found naturally occurring in the environment, or they may be introduced and coincident with the source of contamination at a site.

Facilitated transport occurs in large part due to colloids and other particulate matter to which organic and inorganic contaminants sorb. Colloids are defined as particles of less than 10μm in diameter, but they may be several orders of magnitude smaller than this. There is an ill-defined area between the existence of the smallest colloids and dissolved species.

Colloids may be organic or inorganic in their composition. Organic colloids are further characterized as biocolloids such as bacteria or spores, macromolecules such as humic substances and organic fibers, and non-aqueous phase liquids such as oil droplets and surfactant micelles. Inorganic colloids include clays, metal oxides, and inorganic precipitates which may be naturally occurring or from anthropogenic sources.

Organic compounds, metals and radionuclides which have strong sorption properties may become associated with colloids. Colloids often have a low affinity for the greater porous media or other nearby surfaces, and they will be transported by advection along with the fluid in which they are suspended. The velocity of colloids may actually be faster than the velocity of the bulk fluid medium because colloids will travel a less tortuous path than the bulk fluid. Colloids will not have access to many of the pore spaces through which the bulk fluid passes, but colloids will travel through the larger pores where local flow velocities are faster than the bulk velocity.

6.2.4 Volatilization

The volatility of a compound is a measure of the transfer of the compound from the aqueous phase to the gaseous phase. The aqueous phase may include a pure liquid compound or a compound dissolved in solution. Among the factors which affect a compound's volatilization are solubility, molecular weight, vapor pressure and the physical properties of its environment such as velocity and turbulence. The Henry's Law constant is defined as the vapor pressure divided by the aqueous solubility. The Henry's Law constant is useful in characterizing a compound for its propensity to volatilize. Compounds with a high Henry's Law constant are more volatile. Therefore, compounds with a high vapor pressure and low solubility are most volatile.

Volatilization is generally observed among a group of organic compounds which display characteristics of volatility and are referred to as volatile organic compounds. In addition, there are some metals which exhibit volatility. Elemental metals such as mercury and lead are volatile under ambient conditions. There are also a number of metals which have greatly increased volatility when they are in organic forms. This is most drastically observed with methylated metal species. Among metals which have volatile methylated species are arsenic, mercury, lead and tin. Methylation of metals is known to be a microbiological process. The methylation,

volatilization and loss of mercury and arsenic from anaerobic environments is a well documented process.

6.2.5 Attenuation on Soils

There are a number of mechanisms that result in the attenuation of organic and inorganic compounds onto soils, including sorption, ionic exchange and isomorphic substitution.

Sorption refers generally to the removal of a solute from the aqueous phase of an environmental system by the solid phase at its surface. Sorption of contaminants to the material comprising a porous medium can greatly reduce the mobility of a compound. Often this is accompanied by a reduction in biodegradation because of reduced bioavailability. Sorption will not affect the mass or toxicity of a contaminant, but the reduction in mobility may result in a substantial reduction in public health and ecological risk.

Anion exchange and cation exchange are specific sorption phenomena referring to specific ionic species usually inorganic in nature.

Isomorphic substitution occurs during the formation of clays when inorganic ions are substituted for Mg^{2+} and Al^{3+}. This is not expected to be a significant source of removal of cationic metal contaminants at a polluted site.

6.3 TRANSFORMATION PROCESSES

6.3.1 Biodegradation and Biotransformation

Biodegradation is the biologically mediated chemical breakdown of compounds to smaller products. Generally, in reference to environmental issues, the term biodegradation is used to describe the breakdown of organic contaminants to less toxic forms. Virtually all organic compounds are subject to biodegradation especially under idealized laboratory conditions, however, the occurrence and rate of biodegradation at a given site are subject to a number of microscale physio-chemical phenomena, mesoscale transport phenomena and macroscale environmental phenomena. These phenomena affect the bioavailability, kinetics of biodegradation and toxicity of a compound.

Biotransformation refers to biologically mediated chemical changes in metal species. These processes may include oxidation, reduction, and methylation or incorporation of other

chemical species that do not result in a change in oxidation state of the metal of interest. Biotransformations of metals may result in extreme changes in toxicity and/or mobility.

6.3.2 Bioactivation

Bioactivation is the biologically mediated chemical breakdown of compounds to smaller products which are carcinogenic, mutagenic or toxic, or more toxic than the original contaminants. There are many known examples of bioactivation but one of the greatest problems seen at typical sites of soil and groundwater contamination is the anaerobic dechlorination of chlorinated compounds such as perchloroethylene, trichloroethylene and dichloroethylene to vinyl chloride. While all of the chlorinated compounds listed above have some measure of toxicity, vinyl chloride is the most toxic of the group. Vinyl chloride is the least oxidized of the chlorinated alkenes, therefore its dechlorination to ethylene has the slowest kinetic rate. This often results in an increase in the concentration of vinyl chloride as the more oxidized chlorinated alkenes are dechlorinated.

6.3.3 Oxidation-Reduction Reactions

Oxidation-Reduction (Redox) reactions greatly affect the mobility and toxicity of metals. Redox reactions may be chemically mediated or biologically mediated as discussed in Section 6.3.1. Among commonly observed chemical redox processes are the oxidation of reduced metal species in anoxic sediments when exposed to air, or, conversely, the reduction of oxidized metal species as redox potential decreases in a given environment. Ferrous iron is a common reducing agent in anoxic environments. Ferrous iron is often important in the reduction of hexavalent chromium to trivalent chromium. Also, under certain conditions, managanese can oxidize trivalent chromium to hexavalent chromium.

6.3.4 Precipitation

Precipitation is an equilibrium phenomenon. Precipitation will occur when the water chemistry equilibrium is disturbed by a change in pH, temperature, concentration of a complexing ion, or other variable. Typically compounds precipitate much more easily than they solubilize so precipitation can represent a significant mechanism for decreased mobility of an inorganic species.

6.3.5 Complexation

Complexation is the formation of an ion pair, typically between a metal ion and a ligand. The ligand may be organic or inorganic, and the resulting complex may result in increased or decreased mobility of the metal. The toxicity of the complex may be greater or lesser than the metal ion species alone, primarily due to the potential change in solubility of the metal.

6.4 SITE SPECIFIC PROCESSES

6.4.1 Site Conditions Affecting Transport and Transformation

The nature and extent of contamination at the Site is summarized in Section 5.0. The media evaluated include surface and subsurface soil, groundwater and surface water. While there has been frequent identification of the contaminants of concern (VOCs, SVOCs, pesticides/PCBs, metals and radionuclides) and frequent exceedences of the various guidance values, the gross exceedences appear to be isolated and associated with areas of previous disposal.

Several characteristics of the surface and subsurface soil favor advection, dispersion and volatilization of contaminants. The soil is primarily sand and gravel which would allow transport of groundwater and associated contamination. The hydraulic conductivity ranges from about 10^{-2} cm/s to 10^{-7} cm/s. The coarse particle distribution may also allow volatilization of contaminants in the surface soils. Low organic matter content (0.55%) and low clay content would result in low attenuation of contaminants, as clay particles and organic matter are soil components with high sorptive capacities.

Little data was collected regarding soil and groundwater chemistry or microbiology so conclusive statements regarding Site characterization that might influence biodegradation, biotransformation, bioactivation, oxidation-reduction reactions, precipitation or complexation can not be made. Patterns of contamination can be used to conjecture about some of those processes.

Groundwater flow at the Site is generally in the southeast direction perpendicular to Glen Cove Creek. The hydraulic gradient is gentle, in the range 0.031 to 0.039. The hydraulic gradient in the vicinity of the Mattiace Petrochemical site is steeper (0.075) and in the northeast direction. Groundwater flow is likely to follow preferential pathways that occur in the porous

medium. Areas of high hydraulic conductivity are likely to carry the bulk of the flow. The hydraulic conductivity is known to vary widely with the average being about 3×10^{-3} cm/s. Another path of preferential flow known to exist at the Site is the areas adjacent to the sewer lines which run perpendicular to Glen Cove Creek, and into it. A number of borings in the vicinity of the storm sewers confirm the preferential transport of contaminants along the sewer lines.

6.4.2 Fate of Organic Compounds

6.4.2.1 Fate of Volatile Organic Compounds (VOCs)

VOCs were detected widely in soils throughout the Site and often exceeded the USEPA SSL or the NYSDEC TAGM guidance values, but generally the exceedences were not excessive. This would indicate that VOCs in soils are subject to several processes which result in their reduction in concentration in soil. VOCs in soil may be volatilized, transported by advection, dispersion, facilitated transport, or biodegraded. Given that there were high concentrations of VOCs in groundwater in the vicinity of the Mattiace Petrochemical site (MW-10, MW-8D, MW-8S) but not in the soils, it is likely that the compounds are being transported from the Mattiace Petrochemical site by advection.

In another instance where high levels of PCE were detected (EMW-1) there were also coincident detections of TCE and DCE at lesser concentrations. Given the proximity of EMW-1 to the Crown Dykman site and the use of PCE at that site, this may suggest that natural dechlorination of the chlorinated compounds is occurring. While anaerobic conditions seem unlikely in a water table aquifer, further evidence of natural dechlorination is found in samples from Round 2 at GM-1, MP-2D and MP-21D.

VOCs in soils at the Site were not detected often or at high concentrations except for a few specific cases. As was shown from other evidence, it is likely that VOCs in soil are subject to transport and biodegradation. There may also be some sorption of VOCs to soil, especially non-polar organic compounds.

6.4.2.2 Fate of Semi-Volatile Organic Compounds (SVOCs)

The data regarding the nature and extent of contamination of soil and groundwater by SVOCs suggests transport and/or biodegradation of the lower molecular weight, lower ring

compounds, and attenuation of the higher molecular weight, higher ring compounds on soil constituents.

Analysis of soil samples resulted in the detection of higher ring PAHs (3-ring: phenanthrene; 4-ring: pyrene, fluoranthene, benzo[a]anthracene, chrysene; 5-ring: benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene). These compounds have high sorption coefficients, low solubility and are more likely to be found sorbed to soil. Among these compounds, only phenanthrene, which is slightly soluble, was detected in groundwater. Other SVOCs detected in groundwater included naphthalene, and phenols. Naphthalene has a relatively high solubility in water as do the phenols. Naphthalene and phenols also have sorption coefficients that are much lower than the high ring PAHs, and they are subject to higher rates of biodegradation due primarily to their higher solubility. Naphthalene and phenols were not detected in soils.

The observations regarding SVOCs leads to several conclusions about their likely fate and transport. It appears that naphthalene and the phenols were transported from the soils to the groundwater by advection. In addition it is likely that they were subject to biodegradation in soils but not in groundwater to the same degree. It is possible that biodegradation occurs at a faster rate in unsaturated soils than groundwater because oxygen does not become limited as quickly in soil as in the groundwater. Therefore, it is likely that biodegradation and advection of naphthalene and phenols in soil resulted in low concentrations being detected.

High ring PAHs are likely to become sorbed to the soil constituents to the extent that they will no longer be leached from the soil to the groundwater. The higher sorption coefficient of the PAHs and the low water solubility makes the high ring PAHs resistant to biodegradation. The higher ring PAHs are likely to remain at close to their current concentration in soil with a slow decline due to biodegradation, and without measureable impact to the groundwater.

6.4.2.3 Fate of Pesticides/PCBs

Endrin was detected in three samples and 4,4'-DDT was detected in one sample of the surface and subsurface soils at the Site. Pesticides generally have low water solubility, high sorption coefficients and low biodegradability, therefore, it is unlikely that the pesticides will be directly transported to the groundwater or be subject to biodegradation. There may be mobility of the pesticides through facilitated transport. Pesticides such as DDT and Endrin are known for

their persistence in the environment, and the source of those pesticides detected may be applications decades ago. The concentrations found were at the part-per-billion level.

Detection of pesticides in groundwater were limited to samples from wells in the vicinity of the Mattiace Petrochemical site. These pesticides were detected at the part-per-trillion concentration level in the groundwater. Given the generally low water solubility and high sorption coefficient of pesticides, and the high concentration of organic contaminants in this area, it is likely that the pesticides are coincident with the organic contaminants. Though the exact source of the contaminants in unknown, they may be trace contaminants associated with the organic contaminant plume suspected to be from the Mattiace Petrochemcial site. It is also possible that there is a cosolvency effect from the organic compounds in the highly contaminated groundwater where low levels of pesticides in the saturated or unsaturated soil are extracted from a state of otherwise long term sorption. Again, the source may be applications decades ago.

PCBs were detected as total PCBs at concentrations above the NYSDEC TAGM guidance values in four samples. PCBs were not detected in any groundwater samples. PCBs have low water solubility and are generally subject to slow rates of biodegradation. PCBs are not likely to leach to groundwater in significant quantity. The PCBs in soil are likely to remain at present concentration with only a slow biodegradation reducing the concentration.

6.4.3 Fate of Inorganic Compounds

6.4.3.1 Inorganics

A wide array of inorganics were detected in numerous soil samples at concentrations above their background concentration. This may be the result of widespread placement and storage of raw and partially processed ore throughout the Site. Inorganics in soil are subject to a variety of transport and transformation processes. Inorganics in soil will be subject to complexation reactions, redox reactions, precipitation, attenuation on soils, advection and dispersion when dissolved in the soil solution or groundwater, and facilitated transport. In general, inorganics introduced into soil will be affected by these processes until an equilibrium condition is achieved. However, as soil conditions change the equilibrium may change with a resultant change in the concentration of inorganics in the soil solution.

Inorganics were also found widely detected in groundwater samples from the Site. Metal concentrations were very high in many unfiltered groundwater samples but often the filtered

counterpart sample had a very low concentration of the metal or no detection. This indicates that many of the inorganics and much of the mass of the inorganics in groundwater is in the form of colloids or sorbed to particulate matter. This reinforces commonly found evidence that facilitated transport is an important mechanism for transport of inorganics and demonstrates that this is the case at the Site.

The highest concentration of inorganics in groundwater were found to be clustered together and near areas of known high inorganics contamination. High concentrations of inorganics were found in wells in the vicinity of the bermed aboveground fuel oil tank on Parcel C and Mud Pond (GM-14A, GM-14B, MP-18, MP-18D, EMW-4). The berm is at least partially constructed of ore residue and the pond is known to have been used for disposal of process water. Inorganics of concern commonly found in the groundwater at levels exceeding a environmental criterion include antimony, arsenic, cobalt and nickel. Cadmium, chromium and selenium were also detected periodically. Cobalt and nickel was detected regularly in groundwater samples. The aquatic chemistry of cobalt and nickel indicates that they might be more likely to occur as dissolved species in groundwater.

Cobalt and nickel were also detected at relatively high concentrations in groundwater samples from wells between the warehouse where ore was off loaded from barges and the Glen Cove Creek. It is possible that contamination occurred as a result of the material handling of the raw ore in and around the area.

Nickel is considered to be one of the more mobile heavy metals. Under aerobic conditions and at near neutral pH precipitation reactions are discouraged. Complexation reactions occur with carbonate, sulfate and hydroxide. Carbonate and hydroxide compounds are generally insoluble, but the region in the vicinity of the saline Glen Cove Creek would have a high concentration of sulfate that would dominate complexation. Sulfate complexation reduces the sorption of nickel thus leading to greater mobility. Continued solubilization and transport of nickel is likely to occur in these areas at the Site.

Cobalt is also considered a relatively mobile metal under acid conditions in soil. This may be the reason for the high concentrations of cobalt detected in these groundwater monitoring wells. Cobalt is likely to remain mobile until it encounters regions of higher pH or sorbing material.

6.4.3.2 Radionuclides

Radionuclides of uranium, thorium and radium were widely detected in the surface soils at the Site. Partially processed tungsten ore containing naturally occurring radiological materials was stockpiled throughout the Site. There is also some evidence that ore residue material was used to construct the berm around the aboveground fuel oil tank on Parcel C.

Radionuclides were detected in sediments and surface water samples at the Site indicating that surface runoff was a major transport mechanism, and may continue to be a significant transport mechanism of radionuclides at the Site.

Radionuclides were detected in only a few groundwater samples and many of the locations where they were detected were the same monitoring wells where significant inorganics contamination was found. These locations were in the vicinity of the bermed above ground storage tank and Mud Pond on Parcel C. Thorium and radium are virtually insoluble, so it is likely that they are transported to groundwater as colloids or as sorbed constituents on fine particles in a facilitated transport scenario. Uranium does have soluble species though the forms of uranium likely to be found in the original ore material would be insoluble. Chemical or biochemical oxidation of uranium species to a soluble U(VI) form is possible and may serve as an additional mechanism for which promotes the transport of uranium.

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7.0 BASELINE RISK ASSESSMENT

7.1 INTRODUCTION

This section presents evaluations of baseline human health and ecological risks associated with radiological and chemical contamination detected at the Site.

The objectives of the baseline risk assessment are:

- to provide an analysis of potential health risks, currently and in the future, in the absence of any major action to control or mitigate radiological and chemical contamination, and
- to assist in determining the need for and extent of remediation.

It provides a basis for comparing a variety of remedial alternatives and determining which will be most protective of human health and the environment.

The baseline risk assessment follows guidance outlined in the U.S. Environmental Protection Agency's (USEPA) Risk Assessment Guidance for Superfund (RAGS) Volume I Human Health Evaluation Manual (Part A) and Volume II Environmental Evaluation Manual and other USEPA guidance cited in the human health evaluation and ecological risk assessment. In addition, methodology described in the USEPA RAGS Volume I Human Health Evaluation Manual (Part B) and the RESRAD computer model (Yu et al., 1993) are utilized in the evaluation of radiological contamination. For the readers of this section who are unfamiliar with risk assessment terminology, a glossary of risk assessment terms is provided in the front of this Report. A separate section describing radiological terms is provided in Section 4.

7.1.1 Overview of the Human Health Evaluation Process

There are four components to the human health evaluation process: 1) data evaluation, 2) exposure assessment, 3) toxicity assessment, and 4) risk characterization. In the data evaluation, relevant site data are compiled and analyzed, to select contaminants of

potential concern, termed radionuclides of potential concern (ROPC) in the radiological risk assessment and chemicals of potential concern (COPC) in the chemical risk assessment that are representative of those detected at the Site. In the exposure assessment, actual or potential contaminant release pathways are analyzed, potentially exposed human populations and exposure pathways are identified, contaminant concentrations at potential points of human exposure are determined, and contaminant intakes are estimated. In the toxicity assessment, qualitative and quantitative toxicity data for each COPC are summarized and appropriate guidance levels with which to characterize risks are identified. The likelihood and magnitude of adverse health risks are estimated in the risk characterization, in the form of non-cancer hazard quotients and excess lifetime cancer risks. Sources of uncertainty in the evaluation are then noted and discussed. This stepwise process is used in the following sections to evaluate potential health risks that may be associated with exposure to radiological and chemical contaminants detected at the Site.

7.1.2 Overview of the Ecological Evaluation Process

The ecological risk assessment process involves a preliminary step called problem formulation, that includes identification of:

- ecosystems potentially at risk,
- potential stressors, pathways, and effects,
- ecological endpoints, and
- a conceptual model.

Problem formulation is followed by the analysis phase, which includes:

- exposure assessment, and
- ecological effects assessment.

Risk characterization, the third and final phase, includes:

- risk estimation,
- risk description, and
- risk reporting (including assessment of uncertainty and identification of data gaps).

The Ecological Evaluation includes separate risk characterizations for radiological and chemical contaminants in surface water, sediment and surface soil for aquatic, semi-aquatic and terrestrial receptors.

7.2 HUMAN HEALTH EVALUATION: RADIOLOGICAL RISK

In its series of risk assessment guidance (RAGS) documents, the USEPA has published a methodology for calculating the carcinogenic risk due to exposure to radioactive materials[1]. The methodology is similar to that developed for chemical carcinogenic risk assessment, in that exposure pathway-specific radionuclide intakes are determined and multiplied by cancer slope factors, which result in pathway-specific risks. The risks from each pathway are summed, yielding the total excess lifetime cancer risk.

Over the past several years, researchers at Argonne National Laboratory have developed the RESRAD computer model, which can be used to calculate pathway-specific radiation dose levels and carcinogenic risk resulting from exposure to radioactive materials in soil. A related computer model, RESRAD-Baseline, that uses radionuclide concentrations measured in environmental media (other than soil) at the Site and, following RAGS methodology, calculates carcinogenic risk, has also been developed. In assessing the risks to current and future populations occupying the Site posed by radioactive materials, cancer risks were calculated by both the RESRAD and RAGS methodologies. Whenever possible, parameter values used by RESRAD were set equal to the default values incorporated in the

[1]There are no non-carcinogenic hazards posed by exposure to the radioactive contaminants present at the Site.

RAGS methodology. The differences between the two sets of results are discussed in Section 7.2.5.

7.2.1 Data Evaluation

This section of the human health evaluation focuses on radiological contamination in surface and subsurface soils throughout the Site, groundwater underlying the Site, and sediment from the on-site ponds and drainages. While the entire environmental data set has been presented earlier, data summary tables, organized to facilitate the data evaluation, are presented and discussed in the following sections. The intent is to identify those environmental media and ROPC that pose potential risks to human health. Where they exist, federal or state criteria are presented in the data summary tables as a frame of reference in evaluating the levels of radiological contamination.

Regarding environmental media, the soils, groundwater, and sediment are of concern because they are or may become readily available for human contact. Air is also of concern due to the potential for airborne radiologically-contaminated respirable particulate matter.

For the purposes of this human health evaluation, there is a potential concern if a radionuclide is detected at concentrations above those typically found due to natural background. All of the radionuclides that were quantified in the environmental samples (^{232}Th, ^{230}Th, ^{228}Ra, ^{226}Ra, and ^{238}U) are naturally occurring and therefore exist in environmental media at some background concentration. Site-specific background concentrations have been established so that the risks attributed to Site contaminants do not include the unavoidable risk due to exposure to natural background radiation.

All of the radionuclides that were quantified in the environmental samples are members of the thorium and uranium series and are selected as ROPC. Since all of these radionuclides produce additional radionuclides upon decay, the radioactive decay products are also considered ROPC. ROPC for soil, groundwater, and sediment are presented in Table 7-1. Both of the methodologies used to estimate risk (i.e., RESRAD and RAGS) quantify the additional risk from these other series radionuclides present in soil (^{234}U and ^{210}Pb of the

uranium series and ^{228}Th of the thorium series and their respective radioactive decay products). When uranium series members ^{238}U, ^{230}Th, and ^{226}Ra are in secular equilibrium (i.e., they appear in approximately equal concentrations), the concentrations of ^{234}U and ^{210}Pb, which were not determined analytically, are assumed equal to the average concentration of ^{238}U, ^{230}Th, and ^{226}Ra, which were determined analytically. When the three are in disequilibrium (i.e., in unequal concentrations), the concentration of ^{234}U is assumed to equal the concentration of ^{238}U and the concentration of ^{210}Pb is assumed to equal the concentration of ^{226}Ra. Similarly, if thorium series members ^{232}Th and ^{228}Ra are in secular equilibrium, then the ^{228}Th concentration (which was not determined analytically) is assumed equal to the average of the other two thorium series members. When disequilibrium exists between ^{228}Th and ^{228}Ra, the ^{228}Th concentration is assumed to equal the concentration of its ^{228}Ra parent.

The radiological analytical data for soil, groundwater, and sediment from the RI field investigation are summarized in Tables 7-2 to 7-4, respectively. Sediment samples collected from the mud ponds on lower Parcel C have been added to the soil data base. Background concentrations of ROPC are included in these tables. Figures depicting sample locations can be referenced in previous sections of the report. Data for soil (Table 7-2) are grouped into surface soil (only) and surface and subsurface soils combined (termed "all soils") for the following areas: Parcel A (Area A); lower Parcel B (Area B); middle Parcel B combined with middle and upper Parcel C (Area B & C); and lower Parcel C (Area C). These areas are depicted on Figure 7-1. Soil data from middle Parcel B and middle and upper Parcel C are combined to form Area B & C because they represent areas of the Site that were used historically to dispose radioactive process materials. This observation is supported by surface exposure rate readings as well as by the gross radiological screening that was conducted during borehole and test pit installations. Surface exposure rate readings and radiological screening results are discussed in Section 2.5.

Site-specific background radionuclide concentrations in soil are derived based on data from selected samples collected on upper Parcel B and upper parcel C, because it does not appear that these areas have been impacted by site-related activities, and from surface soil

sample data from background samples collected at locations within a few miles of the Site. Data from the following thirteen soil samples at three boring locations, one test pit location, and six off-site surface soil locations are used to characterize site-specific background:

MP-5	SS-13
MP-5B	SS-14
SB-13	SS-15
SB-13B	SS-16
TP-06	SS-17
MP-11D	SS-18
MP-11DB	

Groundwater data for both sampling rounds of all on-site monitoring wells (except those used to represent background) are combined because while they are screened at different depths, all are screened above the Port Washington Clay which acts as a confining unit. The range of radionuclide groundwater concentrations are provided (Table 7-3) along with USEPA MCLs promulgated under the Federal Safe Drinking Water Act and New York State maximum contaminant levels (NYS MCLs). An MCL is the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

Sediment data from the pond on Parcel B and from the drainage and pond on Parcel C are summarized separately (Table 7-4).

7.2.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of human exposure to the ROPC that are present in or migrating from the environmental media being evaluated.

7.2.2.1 Potentially Exposed Populations

As no use is currently being made of the Site, only trespassers are regarded as a potentially exposed on-site population in the current scenario. Trespassers are assumed to be 12-18 year-old adolescent males. Casual exposure to ROPC in surface soil on Areas B,

B&C, and C and in sediment on Parcels B and C may be possible for trespassers making unauthorized entry. Since Parcel A is covered by pavement or buildings, and most of the soil samples from Parcel A were taken from beneath pavement, the majority of soil on Parcel A is currently inaccessible. An exception is the soil located between the fence and Herb Hill Road along the northern ridge of Parcel A. While accessible, it is a small grass-covered area that presents no particular attraction to members of the public.

Potable water in Glen Cove is provided by the City of Glen Cove; the water is obtained from groundwater aquifers and treated by the City of Glen Cove. Thus, exposure via potable use of the groundwater in the current scenario is unlikely. As the residents near the Site have expressed concerns regarding the possible release of contaminated dust from the Site, current off-site residential exposure to wind-blown respirable particulates is evaluated in the current scenario.

The potential for exposure of trespassers to ROPC in surface soil and sediment is assumed to continue in the future, with the further assumption that shallow soil on Parcel A currently covered by pavement and buildings would be accessible. Tentative redevelopment plans for the Site include commercial, retail and light industrial uses. Thus, site worker exposure to ROPC in surface soil at Areas A, B, B&C, and C is evaluated.

Residential exposure to ROPC in all soils at Areas A, B, B&C, and C is also evaluated since the redevelopment plans have not been finalized. In addition, construction worker exposure to ROPC in all soils at Areas A, B, B&C, and C is evaluated. While the City of Glen Cove should continue to provide potable water, potable use of the groundwater underlying the Site by workers and residents is considered in the future scenario.

Sensitive receptors are typically any subpopulation that may be at increased risk from exposure due to increased sensitivity, behavior patterns, and/or current or past exposures from other sources. Since children represent a sensitive subpopulation that could be at increased risk of exposure, they are evaluated in the residential scenarios.

7.2.2.2 Exposure Pathways

Soil at Areas B, B&C, and C and sediment on Parcels B and C represent the exposure pathways of concern for the current scenario, while soil at Areas A, B, B&C and C, sediment on Parcels B and C, and groundwater underlying the Site represent the exposure pathways of concern for the future scenario. The exposure pathways selected for evaluation and the basis for inclusion or exclusion of certain exposure scenarios are provided in Table 7-5. A matrix of potential exposure routes is provided in Table 7-6.

It is not possible to quantify inhalation exposure to radon and radon decay products for the future residential adult and child for use in the USEPA risk assessment guidance (RAGS) baseline risk assessment because no site-specific radon/radon decay product data were collected during the RI[2]. However, RESRAD does calculate the dose and risk from inhalation of radon/radon decay products based on ^{226}Ra and ^{228}Th soil concentrations. Therefore, the risks due to this pathway is quantified only with RESRAD. However the radon risks quantified with RESRAD have been added to the risks quantified using the RAGS methodology so that the total risks calculated for the future resident adult and child using the RAGS methodology include all appropriate pathways.

7.2.2.3 Data Utilization

In utilizing the analytical data to derive representative exposure point concentrations, samples and their duplicates are not considered as separate sampling values. Rather, a radionuclide-specific value representing the average value of the sample and its duplicate is used. If a ROPC is not found present in a sample at a concentration exceeding the analytical minimum detectable concentration (MDC), it is assumed to be present at its MDC, as a conservative "proxy" concentration. Adjusting "less than MDC" data by assigning values equal to the MDC assumes that a radionuclide may be present at a concentration just below the reported MDC, which, for the ROPC at the Site, is often within the range of natural background. Radiological data that was noted (i.e., qualified) by the laboratory or the data

[2]Initial plans to collect radon/radon decay product data were canceled due to the dilapidated condition of Site buildings.

validator with an indicator that the concentration is estimated, or that the identity of the radionuclide and the concentration are based on presumptive evidence, are treated the same way as data without such qualifiers.

7.2.2.4 Estimates of Radionuclide Intake

Estimates of radionuclide intake are developed to portray reasonable maximum exposures (RME) that might be expected to occur under current and future exposure scenarios. That is to say, the highest exposure at the Site that is considered, is one that is above the average exposure but still within the range of possibility.

To develop exposure point concentrations that reflect RME, it is necessary to evaluate the entire analytical data set. The USEPA recommends that the arithmetic average concentration of the data be used for evaluating long-term exposure and that, because of the uncertainty associated with estimating the true average concentration at a site, the 95% upper confidence limit (UCL) on the arithmetic average be used as the exposure point concentration (USEPA, 1992b, 1989b). The 95% UCL provides reasonable confidence that the true average will not be underestimated. Since data sets with fewer than 10 samples per exposure area provide poor estimates of the average concentration (USEPA, 1992b), 95% UCL concentrations are only calculated for data sets with 10 or more samples. The maximum detected concentration is used for data sets with fewer than 10 samples.

In most cases, it is reasonable to assume that Superfund soil sampling data are lognormally distributed. However, in cases where there is a question about the distribution of the data set, a statistical test is used to identify the best distributional assumption (USEPA, 1992b). Therefore, before calculating the 95% UCL concentrations, either the Shapiro and Wilk W statistical test (for sample sizes ≥ 10 and ≤ 50) or the D'Agostino's D statistical test (for sample sizes >50) is run on the data for each ROPC to determine if the data represent a normal distribution (Gilbert, 1987). If the results of the W or D tests indicate that the data are not normally distributed, a lognormal distribution is assumed. The appropriate equation (USEPA, 1992b) is then used to calculate the 95% UCL concentrations. If there is great

variability in measured concentrations, the 95% UCL concentration may be high and occasionally exceed the maximum detected value. In such cases, the maximum detected concentration is used.

The derivation of the exposure point concentrations for the ROPC is presented in Appendix O. Exposure point concentrations of ROPC on respirable particles released from soil into the air and in home-grown produce are calculated as described in Appendix O. Two respirable particulate models are developed. For current off-site residents, the potential for release of ROPC on respirable particulates to ambient air by wind action over surface soil at Areas B, B&C, and C is evaluated and annual average ROPC concentrations in the ambient air at five locations (termed receptors) representing the nearby residential community are estimated. The exposed areas (termed area sources) and the receptor locations are shown in Figure 7-2. For future construction workers, the potential for release of ROPC on respirable particulates to ambient air during the excavation of a trench at Areas A, B, B&C, and C is evaluated and 1-hour average ROPC concentrations in the ambient air over the trench are estimated.

The radionuclide in soil concentrations used in the RESRAD calculation for the particulate inhalation route for the current off-site residential scenario are equal to the exposure point concentrations calculated from surface soil data from Areas B, B&C, and C. Area A data are omitted because the majority of Area A is covered with cement and asphalt. Several assumptions built into the RESRAD model result in extremely conservative risk estimates for this pathway (i.e., they clearly overestimate the radiation dose and carcinogenic risk to current off-site residents). Short periods of high dust suspension and sustained periods of normal activity on a farm, activities which produce significant quantities of dust, are assumed in the RESRAD model. However, air samples collected during intrusive field activities at the Site showed that there were no measurable concentrations of gross alpha particle activity being released to off-site air. Currently, Areas B and C are highly vegetated and subject to no human activity, with the exception of the hypothetical trespasser. These current conditions are not likely to result in significant quantities of resuspended dust.

The RESRAD calculations for the particulate inhalation route for the future construction worker are based on the exposure point concentrations calculated from Area-specific data for soils over all depths ("all soils").

Exposure point concentrations in each environmental medium (shown in Table 7-7 for the ROPC) include the contribution from natural background. Therefore, the risk assessment calculations are also conducted on the average background concentrations for each scenario. Subtracting the risk due to exposure to natural background concentrations results in "above background" risk estimates.

In addition to the derivation of representative exposure point concentrations, evaluation of potential human exposure involves the estimation of several parameters such as ingestion and inhalation rates, and exposure time, frequency, and duration. Table 7-8 presents a generic equation for estimating intakes and defines the intake variables and their default values. Application of this type of equation is consistent with RAGS. The radiological risks estimated with this methodology are compared to the risks generated with the RESRAD computer code as part of the radiological risk assessment uncertainty analysis (Section 7.2.5).

The RESRAD Version 5.70 and RESRAD-Baseline Version 2.2 computer models were developed at Argonne National Laboratory as tools to implement the U.S. Department of Energy (DOE) requirements for evaluating residual radioactive material. Originally released in 1989, RESRAD has been modified several times and has been included in Title 10, Part 834 of the *Code of Federal Regulations* (March 1993). In addition to its use at DOE facilities, RESRAD is currently being used to show compliance with U.S. Nuclear Regulatory Commission (NRC) decommissioning criteria and has been used at CERCLA federal facilities and by USEPA headquarters personnel to draft proposed residual radioactivity standards.

RESRAD calculates the radiation dose equivalent and subsequent carcinogenic risk for several environmental pathways based on radionuclide concentrations in soil. The RESRAD-Baseline code calculates the dose equivalent and risk from radionuclide

concentrations in environmental media other than soil[3]. RESRAD provides a more detailed risk analysis than does the RAGS methodology; it models the environmental fate of the ROPC through several environmental media and calculates the risk at user-selected future times. It accounts for the decay of radionuclides and the buildup and decay of radionuclide decay products in addition to the original ROPC. RESRAD-Baseline closely replicates the RAGS methodology. Intake quantities are calculated based on the environmental media concentrations and the exposure parameters chosen. Radiogenic cancer risks are determined by two means: (1) dose conversion factors published by USEPA in Federal Guidance Reports No. 11 and 12 (USEPA, 1988; 1993) are used to calculate the total committed effective dose equivalent, which is then multiplied by the default value of 7.6×10^{-7} risk/mrem (USEPA, 1988; 1993), and (2) carcinogenic slope factors published in the USEPA Health Effects Assessment Summary Tables (HEAST) (USEPA, 1995) are multiplied by the intake quantities and summed to derive the total risk.

Table 7-9 lists the parameters selected for the various exposure scenarios. RESRAD includes default values for many parameters related to the contaminated and uncontaminated zones, saturated and unsaturated zones, and ingestion of produce which is potentially contaminated with radionuclides. The RAGS methodology contains values for some, but not all, of the RESRAD parameters; the parameters used in both methodologies are shown in Table 7-9. Where RESRAD default values differ from values cited in the literature as being appropriate for use in the RAGS methodology, the RESRAD values were changed to conform to those shown in 7-9.

RESRAD also requires values for some parameters which do not appear in the RAGS methodology calculations. The RESRAD default values for the geological and hydrological parameters (such as effective porosity, hydraulic conductivity, evapotranspiration coefficient, runoff coefficient, erosion rate, etc.) were reviewed and where appropriate, replaced with site-specific values. These RESRAD parameter values utilized are shown in Table 7-10.

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[3]RESRAD-Baseline has not yet officially been released by the DOE, but is has been distributed to interested persons within various Federal and State agencies and to other interested professionals.

The parameters necessary to estimate radionuclide intakes and/or radiation doses are described below.

Soil - For trespassers, an average ingestion rate (IR) of 100 mg of soil/day is used to evaluate inadvertent ingestion of soil (as might result from hand-to-mouth behavior) (U-SEPA, 1991). The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this evaluation, it is assumed that 100% of the soil ingested is contaminated with concentrations equivalent to the estimated exposure point concentrations. The exposure frequency (EF) is assumed to be 120 days/year (equivalent to about three times a week during two-thirds of a 350-day year, with one-third of the year representing poor weather days) and the exposure duration (ED) is assumed to be 6 years. RESRAD distinguishes between indoor and outdoor time fractions[4] because while indoors, there is a reduction in the external gamma radiation exposure because gamma rays emitted from the soil are absorbed within the floor and walls of the structure. On-site for 2 hours per day, assuming that 25% and 75% of the trespasser's time is spent indoors and outdoors, respectively for Areas B & C and C, the indoor and outdoor time fractions are equal to 0.006 and 0.018, respectively. For Areas A (future) and C (current), where there are no buildings, the entire fraction of the year spent on the Site by the trespasser is outdoors, resulting in an outdoor time fraction of 0.024.

An inhalation rate (IR_i) of 0.83 m^3/hour, which represents the average adult inhalation rate (USEPA, 1989b), is used to assess inhalation of respirable particulates by off-site resident adults and children (USEPA, 1997). For consistency with the estimated annual average concentrations of ROPC in air, the exposure time (ET) and (EF) represent continuous, full-time exposure (i.e., 24 hours per day, 365 days per year). The ED for resident adults is 30 years, the national 90th percentile upper-bound time at one residence (USEPA, 1991). The ED for resident children is 6 years (USEPA, 1991). Adults are

[4]The total time fraction is the fraction of a year which a person spends being exposed to the RPOC. It is equal to: (# hours on-site/24 hours) x (# days on-site/365 days). RESRAD allows the user to apportion the total time fraction between indoor and outdoor occupancy.

assumed to spend 75% of their residential time indoors, while children are assumed to spend 87.5% of their residential time indoors. These values result in indoor and outdoor time fractions of 0.509 and 0.170, respectively, for adults and 0.594 and 0.085, respectively, for children.

For site workers, an average IR of 50 mg of soil/day is used to evaluate inadvertent ingestion of soil. The EF is assumed to be 250 days/year (USEPA, 1991) and the ED is assumed to be 25 years. Equal amounts of time are assumed for indoor and outdoor occupancy; the total time fraction is 0.23, with indoor and indoor and outdoor time fractions equal to 0.114. All other parameters are as described previously.

For construction workers, an IR of 480 mg of soil/day is used to evaluate inadvertent ingestion of soil (USEPA, 1991). An IR_i of 2.3 m^3/hr is used to evaluate inhalation exposure to ROPC adsorbed to respirable particulates potentially released to the ambient air during the digging of an excavation (USEPA, 1991). The ET for is assumed to be 8 hours. The EF is assumed to be 60 days/year because construction work is limited in duration and the ED is assumed to be 1 year. Assuming that the worker spends 75% of his time outdoors and 25% of his time indoors results in RESRAD indoor and outdoor time fractions of 0.014 and 0.041, respectively. All other parameters are as described previously.

IRs of 100 mg/day and 200 mg/day are used to evaluate inadvertent ingestion of soil for on-site resident adults and children, respectively. As part of the residential scenario, locally grown produce could result in ingestion of radionuclides incorporated into plants. The "typical" adult consumes approximately 200 g/day of vegetables and 140 g/day of fruit (USEPA, 1991). Research suggests that the "reasonable worst-case" proportion of vegetables and fruits that are home-grown are 40 and 30 percent, respectively. This corresponds to 80 g/day of vegetables and 42 g/day of fruit (USEPA, 1991). To incorporate estimated radionuclide concentrations in the edible portions of above-ground and root produce, the ingestion rates are further categorized into vegetable and fruit types.

Three garden crops (carrots, lettuce, and tomatoes) are selected as representative of all homegrown produce, including root vegetables, leafy vegetables, and garden fruit and

legumes, respectively. Ingestion rates for the individual crops are based on U.S. Department of Agriculture data presented by the USEPA (1986). The carrot ingestion rate is based on the consumption of all root vegetables including potatoes; the lettuce ingestion rate is based on the consumption of all leafy vegetables; and the tomato ingestion rate is based on the consumption of garden fruits and legumes. Legumes are included with garden fruit because of their similar chemical transfer coefficients (Baes et al., 1984). These groupings simplify the exposure methodology while giving consideration to all potential garden crops. Based on the data, the following ingestion rates are derived for the three selected crops. Resident adults are assumed to ingest 17 g/day of lettuce, 48 g/day of carrots, and 57 g/day of tomatoes (42 g/day of garden fruit or tomatoes plus 15 g/day of legumes). These values proportionally correspond to the 122 g/day of vegetables and fruit suggested by USEPA for use in risk assessments. Ingestion rates of garden produce by resident children could be determined only for a 2-year-old (USEPA, 1986). Resident children are assumed to ingest 4 g/day of lettuce, 27 g/day of carrots, and 24 g/day of tomatoes. The EF for the residents is 350 days per year, assuming only a 2-week vacation away from the area over the course of a year USEPA, 1991). All other parameters are as described previously.

Exposure to penetrating gamma radiation emitted by the decay of radionuclides in soil is evaluated for all current and future on-site receptors. The USEPA gamma shielding factor default value of 0.8 is used to evaluate the risk from exposure to external gamma radiation (USEPA, 1989a). The ETs, EFs, EDs, and time fractions for each potentially exposed population are as described previously.

Groundwater - The groundwater pathway is included for the future scenario Site worker and the future residential scenario (adult and child). As discussed earlier, all groundwater data are grouped together to determine site-wide exposure point concentrations for each ROPC. The risks from this pathway would apply to all future Site workers and residents, regardless of Site area. An IR of 1 liter/day (about four 8-ounce glasses per day) is used for Site workers (USEPA, 1991). All other parameters used in the Site worker ingestion of groundwater calculation are as described previously for Site worker exposure

to soil.

An IR of 2 liters/day (about eight 8-ounce glasses per day) is assumed for resident adults; this represents the 90th percentile value for adult daily water consumption (USEPA, 1989a). An IR of 1 liter/day (about eight 4-ounce glasses per day), which represents the 90th percentile of daily water consumption for infants (USEPA, 1989a), is used for resident children. All other parameters are as described previously for residential exposure to soil.

Sediment - The values for IR, FI, EF, and ED are the same as those for trespasser exposure to soil. However, the entire exposure time is assumed to occur outdoors.

7.2.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, characterizes the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves determining whether exposure to a radionuclide can cause an increase in the incidence of a particular adverse health effect, and characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The carcinogenic potential of radiation exposure is the only health effect of concern due to chronic exposure to the radionuclides present at the Site. Long-term radiation exposure has been found to increase the risk of developing cancer in humans. By applying carcinogenic slope factors to any dose, no matter how small, the risk assessment methodology is consistent with the "no-threshold" hypothesis, i.e., any radiation dose conveys some measurable carcinogenic risk. Due to the magnitude of the exposures which can occur at the Site, acute effects from high level, short-term radiation exposures are not possible and are therefore not evaluated as part of this radiological risk assessment.

The USEPA and other regulatory agencies have performed cancer potency assessments for numerous radionuclides and the guidance they provide is used in this human health evaluation. Carcinogenic slope factors for the evaluation of cancer risk from lifetime

exposure to radionuclides are obtained from the USEPA HEAST, which are tabular presentations of provisional toxicity data (USEPA, 1995).

As mentioned above, RESRAD and RESRAD-Baseline also incorporate the HEAST carcinogenic slope factors to calculate radiogenic risk from radionuclide intake/exposure data[5]. These are included in the RESRAD and RESRAD-Baseline reports provided in Appendix O. In addition, the codes calculate the total committed dose equivalent by multiplying the radionuclide intakes by dose conversion factors published by the USEPA in Federal Guidance Reports No. 11 and 12 (USEPA, 1988; 1993).

7.2.4 Risk Characterization

Typically, remediation of carcinogenic hazardous materials at CERCLA sites are designed to reduce lifetime risks to the 10^{-4} (i.e., 1 in 10,000) to 10^{-6} (i.e., 1 in 1,000,000) range[6]. However, when assessing radiological risk from radionuclides which occur naturally in the environment, the risks associated with the populations and pathways selected for evaluation must be compared to the unavoidable risk from natural background radiation. For most long-term scenarios, this background risk approaches or even exceeds the typical upper bound acceptable risk of 10^{-4}. Therefore, remedial actions implemented at a site contaminated with radioactive materials are often not capable of reducing the overall risk to less than 10^{-4}.

There currently are no USEPA standards which define an acceptable dose equivalent rate to a member of the general public following remediation of a CERCLA site. However, recent attempts to promulgate a residual radioactivity standard by USEPA (which have yet

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[5]During an evaluation of the RESRAD and RESRAD-Baseline results, it was discovered that the ingestion carcinogenic slope factors for ^{210}Pb differed. RESRAD-Baseline was using the carcinogenic slope factor from the HEAST, 1994 table while RESRAD had been updated to include the carcinogenic slope factors published in the 1995 version of HEAST. RESRAD-Baseline does not allow the user to change the carcinogenic slope factors used in the calculations; therefore the risk for groundwater ingestion was recalculated by hand using the updated ^{210}Pb carcinogenic slope factor.

[6]The upper boundary of the risk range should not be considered to be a discrete value, but rather an approximation, taking into consideration appropriate site conditions, occupancy patterns, etc.

to result in the publication of a proposed standard or guidance directive) indicate that there is some consensus within the agency on limiting the annual dose equivalent to 15 mrem at a remediated site. This would be similar, although somewhat more restrictive than the U.S. Nuclear Regulatory Commission's (NRC) 25 mrem per year standard for decommissioned sites which was approved by the commissioners in May 1997, and published in the Federal Register on July 21, 1997 (62 FR 39058).

RESRAD calculations performed as part of this risk assessment equate a 15 mrem dose equivalent with a risk of approximately 9 E-06, (i.e., 9×10^{-6} or 9 in 1,000,000) which is in close agreement with the 1.1 E-05 risk derived by multiplying 15 mrem and the 7.6 E-07 per mrem dose conversion factor currently cited by USEPA and other agencies. Averaging the two results in a 1 E-05 annual risk, or a 3 E-04 lifetime risk following an exposure duration of 30 years. It would therefore be prudent to consider annual and lifetime radiological above background risks that exceed 1 E-05 and 3 E-04, respectively, as being potentially limiting. Similarly, the 6-year exposure duration of a trespasser or residential child receiving 15 mrem per year equates to a 6 E-05 total risk, and the 25 year exposure duration to a Site worker equates to a 2.5 E-04 total risk.

In the sections that follow, the RESRAD and RAGS methodology total risks are provided and discussed for each population evaluated. The RESRAD results are used to describe the risk to each population. A comparison of the RESRAD and RAGS results is presented in Section 7.2.5. The pathway-specific, radionuclide-specific risk tables for both methodologies are provided in Appendix O. Emphasis is not placed herein on the specific radionuclide(s) responsible for the majority of the risk to each population. The various radionuclides present in Li Tungsten waste will be considered as a single waste source in the subsequent evaluation of remedial alternatives.

7.2.4.1 Current Off-Site Residents

Inhalation of radionuclides associated with respirable particulates is the only pathway evaluated for exposure to the current off-site resident adult and child. As noted in Section

7.2.2.4, the assumptions built into the RESRAD air dispersion model are extremely conservative. The code generates dust concentrations based on activities representative of those at a typical farm. The contaminated soils at Li Tungsten are primarily in highly vegetated, undisturbed areas which result in little, if any, resuspended material. This was confirmed by collecting particulate air samples during the Li Tungsten interim remedial actions. Despite sample collection during intrusive activities (such as digging into and moving large piles of soil/ore and debris), no airborne alpha particle activity was detected at the Site boundaries. Additional conservatism in the risks generated is a result of modifying the exposure frequency values to represent 24 hour per day occupancy for 365 days per year. This is done for consistency with the estimated maximum annual average radionuclide concentrations used in the RAGS methodology evaluation.

The risk to the off-site resident adult and child are shown in Tables 7-11 and 7-12, respectively. The risk to both populations are less than the potential limiting risks identified previously for 30-year and 6-year exposures.

7.2.4.2 Current and Future Adolescent Trespassers

Tables 7-13 and 7-14 show the risk to the adolescent trespasser from radionuclides in soil and sediment, respectively. At Area A, the trespasser is assumed to occupy the Site at some future time; trespasser occupancy at the other areas occurs under the current and future scenarios.

The trespasser at Areas A and B&C receives greater than 15 mrem per year from radionuclides in soil (Table 7-13) during the 6-year exposure duration and therefore assume total risks of 2.3 E-04 and 4.3 E-04, respectively, which are greater than the 6 E-05 potential risk limit. The major exposure pathway is external gamma irradiation, which accounts for greater than 99 percent of the total risk.

Exposure to radionculides in sediment was only evaluated for Parcel B and Parcel C. As seen in Table 7-14 the risk from Parcel B sediment is less than the risk from exposure to background concentrations of the radionuclides of concern. This is not the case at Parcel C,

although the risk did not exceed the 6 E-05 potential risk limit.

7.2.4.3 Future Site Workers

The risks to the future Site worker are shown in Table 7-15. The annual dose to workers at all areas exceed 15 mrem, ranging from 64.9 mrem at Area B (equivalent to a lifetime 8.6 E-04 risk) to 979 mrem at Area B&C (equivalent to a lifetime 1.4 E-02 risk). The risks for all areas exceed the potential risk limit for a 25 year exposure of 2.5 E-04. The major contribution to the total risk is via the external gamma pathway. However, it should be noted that the Site worker is assumed to ingest groundwater with 4.0 and 2.4 pCi/L of ^{226}Ra and ^{228}Ra, respectively. Summing the two yields a radium concentration of 6.4 pCi/L, which exceeds the current 5 pCi/L MCL for the sum of the concentrations of these two radionuclides.

7.2.4.4 Future Construction Workers

Since an exposure duration of one year is assumed for the construction worker, the radiogenic risk attributable to Li Tungsten Site radionuclides is evaluated relative to a risk of 1 E-05. As shown in Table 7-16, the 1.3 E-05 risk to the worker at Area A and the 2.7 E-05 risk to the worker at Area B&C slightly exceeds the 1 E-05 potential risk limit. While external gamma exposure remains the predominant contributor to the total risk, approximately 30 percent of the risk to this population is due to particulate inhalation.

7.2.4.5 Future Residents

The risks to the future residential adult (30-year exposure) and future residential child (6-year exposure) are shown in Tables 7-17 and 7-18, respectively. The potential limiting risk levels corresponding to these two populations are 3 E-04 for the adult and 6 E-05 for the child.

The data show that the appropriate potential limiting risks to both the adult and child are exceeded by exposure via the external gamma pathway alone. A maximum 1.1 E-02 total

risk to the adult occurs on Area B&C. Similarly, a maximum of 2.2 E-03 total risk to the child occurs on Area B&C. Approximately 70 percent of the total risk is delivered via the external gamma pathway. Inhalation of radon and radon decay products is the next highest contributor to the total dose, accounting for an average of 16 percent for the four areas. Groundwater ingestion delivers 28.7 mrem per year. As noted in Section 7.2.4.3, the groundwater is not in compliance with the 5 pCi/L drinking water MCL for radium. In descending order of magnitude, less than 10 percent of the total risk is contributed by groundwater ingestion, produce ingestion, and inadvertent soil ingestion.

7.2.5 Uncertainty Analysis

Tables 7-11 through 7-18 show the pathway-specific and total above background lifetime risk estimates using both the RESRAD model and the RAGS methodology. With the exception of the air pathways, the risks are calculated from the same data set of radionuclide concentrations in each environmental medium. Both methodologies utilize carcinogenic slope factors published in HEAST (USEPA, 1995). The RAGS methodology incorporates a straightforward calculation of intake over the exposure period, which is multiplied by the pathway-specific carcinogenic slope factor for each radionuclide. The total intake quantities computed by RESRAD is influenced by its ability to 1) model the movement of radionuclides through environmental media over time; and 2) account for the ingrowth and mobility of radioactive decay products. Differences in the calculated risks may result from RESRAD's ability to perform environmental modeling of radionuclides. As mentioned earlier, the RESRAD-Baseline code is used to generate the risk from groundwater ingestion. It takes medium-specific data, in this case radionuclide concentration in groundwater, and directly applies the RAGS methodology. Therefore, the groundwater ingestion risk calculations from the two methods are identical.

A comparison of the results generated with the two methods show extremely consistent risk calculations. For the future residential adult and child (which represent the two population scenarios with the largest number of exposure pathways), the risks computed

by RESRAD and the RAGS methodology are nearly identical; there is less than 10 percent difference for each area, with the RAGS result usually slightly greater than the RESRAD result. The largest pathway discrepancy between the two methodologies is usually determined for the risk from produce ingestion, with the RESRAD risk up to one order of magnitude higher than the RAGS risk in some cases. The major contributor to total risk for both methodologies is the external gamma pathway. The percent differences in the lifetime risk from this pathway calculated by RESRAD and RAGS are within 10 percent in all areas for both the residential adult and child. The second leading contributor to the total risk is the inhalation of radon and radon decay products. A comparison of the two methodologies is not possible since the pathway risk for radon was only calculated with RESRAD.

Exposure of the trespasser to contaminated soil also results in RESRAD and RAGS risks that are within approximately 10 percent of each other. Results did differ significantly for the trespasser exposed to sediment in Parcel C, with total above background risks of 4.0 E-07 and 2.1 E-06 from RESRAD and RAGS, respectively. However, the magnitude of each of these risks is less than the background risk. At such low levels, there is a much higher amount of uncertainty associated with the risk calculations.

The risks calculated for the future Site worker and future construction worker are comparable; in general, the risks calculated with the RAGS methodology are 30-70 percent higher than those calculated with RESRAD. For both types of worker, the external gamma and soil ingestion pathways contribute to the risk estimates.

Exposure to the current off-site adult and child are computed based on site-wide surface soil data (excluding Area A soil). The RAGS methodology calculations are based on the results from an air dispersion model used to predict off-site dust concentrations from which airborne radionuclide concentrations were calculated. These concentrations are the basis for the RAGS intake and risk calculations. The risks to the current residents are approximately 60 and 90 percent lower for the RAGS methodology compared to RESRAD for the adult and child, respectively.

Reducing the radionuclide in soil concentration data to values such as the average

concentration, rather than the 95% UCL concentration, would result in lower risk values that reflect more realistic exposures to the populations studied in this risk assessment. However, the risks calculated for several populations in several areas on the Site (especially Area B&C) are much greater than the potential risk limits identified in Section 7.2.4. As a result, the risks to some populations under some scenarios would still fall in the unacceptable range, even if more likely soil concentration values were used for the risk calculations.

7.2.6 Summary

Radionuclide analyses of Site soil samples indicate that thorium and uranium series radionuclides are present on all parcels at concentrations which exceed the range of natural background. For several populations evaluated, the lifetime cancer risk due to exposure to these radioactive contaminants exceed both the post-remediation risk range generally deemed acceptable at CERCLA sites as well as the dose-based risk levels currently used to evaluate the impact of residual radioactivity at facilities formerly licensed to possess radioactive materials. As reflected in the risk calculations, the most highly contaminated soils were found in Area B&C; however, samples containing elevated radionuclide concentrations were collected from all areas (and all parcels) of the Site. Concentrations of ROPC in Site sediments were within the background range. Exposure to sediments, therefore, do not pose any above background risk to current or future populations.

It is unclear if ROPC have migrated into groundwater. The sum of the ^{226}Ra and ^{228}Ra concentrations in several wells ranged from 5-20 pCi/L, which exceed the 5 pCi/L MCL set by the USEPA. However, these include the background Konica well and background well GW-MP-11D (January 330, 1997 sampling event). Uranium-238 concentrations were, for the most part, less than 5 pCi/L, although three deep monitoring wells had approximately 30-80 pCi/L which caused the exposure point concentrations used in the risk assessment to rise considerably. Similarly, while most groundwater data for thorium were less than 1 pCi/L, two Malcolm Pirnie wells and one Geraghy and Miller well had ^{232}Th and ^{230}Th concentrations ranging from 3-9 pCi/L. These fluctuations in concentrations of naturally

occurring radionuclides may reflect regional variability.

7.3 HUMAN HEALTH EVALUATION: CHEMICAL RISK

7.3.1 Data Evaluation

This section of the human health evaluation focuses on chemical contamination in surface and subsurface soils throughout the Site, groundwater underlying the Site, and surface water and sediment from the on-site ponds and drainages. While the entire environmental data set has been presented earlier, data summary tables, organized to facilitate the data evaluation, are presented and discussed in the following sections. The intent is to identify those environmental media and chemicals of potential concern (COPC) that, if contacted, pose potential risks to human health. Where available, federal or state criteria are presented in the data summary tables as a frame of reference in evaluating the levels of chemical contamination.

Laboratory analytical methodologies and data validation procedures were selected to meet the data quality objectives identified in the Work Plan. All samples were analyzed by non-RAS laboratories; CLP laboratories could not accept any samples from the Site due to the potential for radioactive contamination. The laboratory statement of work and analytical methodologies were developed to be consistent with the latest CLP methodology (ILM0.40 and OLM03.2 for TAL/TCL analyses) or USEPA-approved analytical methods for other parameters. Analytical data were validated following USEPA guidelines by USEPA Region II certified data validators. Validation protocols for the radiological data were developed specifically for this work assignment, reviewed by the USEPA, and were included in the FSP. Tentatively identified compounds (TICs) were found most commonly in the BNA analysis for soils; very few occurred in the VOA or pesticide/PCB analysis. Those compounds that could be presumptively identified, were flagged with a "N" qualifier and an "E" as estimated. Most of these data, however, were ultimately rejected because the TICs also showed up in some of the blanks. All other TICs were identified as "unknown

hydrocarbons". For these reasons, TICs have not been included in the summary tables and have been omitted from this evaluation. A more detailed discussion of the laboratory analytical methods and data validation procedures are presented in Section 5.1.1.

Regarding environmental media, the soils, groundwater, surface water and sediment are of concern because they are or may become readily available for human contact. Air is also of concern due to the potential for airborne chemically-contaminated respirable particulate matter.

Regarding chemical contamination, the following process was used to select COPC. A concentration-toxicity screen was conducted first, to identify those chemicals in a particular medium most likely to contribute significantly to the risk estimates. For the inorganic chemicals, since they naturally occur in soil, if the average detected concentration in soil or sediment is less than twice the site-specific average background concentration the chemical is eliminated as a COPC. For the essential nutrients (i.e., calcium, iron, magnesium, potassium and sodium), if the concentrations are less than **nutrient screening** concentrations calculated using recommended Daily Allowances (RDA) the chemical is eliminated as a COPC. Further, pending the toxicity of the chemical and the impacted medium, if a chemical is detected infrequently (i.e., in less than 5% of all samples collected from a medium for sample sizes greater than 20), the chemical is eliminated as a COPC.

A number of detected chemicals are without USEPA toxicity criteria and could not be included in the concentration-toxicity screen. With few exceptions, chemicals without toxicity criteria are selected as COPC and evaluated qualitatively. Only where they were detected at low frequencies or at a concentration less than twice the site-specific average background concentration are such chemicals eliminated as COPC. The concentration-toxicity screen methodology and results, as well as the reason for selection or elimination of COPC where not based solely on the screen, are presented in Appendix O. The derivation of the nutrient screening concentrations is also presented in Appendix O.

Chemical analytical data for soil, groundwater, surface water, and sediment from the RI field investigation are summarized in Tables 7-19 to 7-24 and discussed below. The

PCBs, a class of chlorinated hydrocarbons with a biphenyl nucleus, were manufactured commercially in the U.S. as chemical mixtures under the trade name Aroclor. They are routinely analyzed, quantified, and reported in environmental samples as individual Aroclor mixtures (e.g., Aroclor 1254). Aroclors 1242, 1248, 1254, and 1260 were detected in one or more samples. Concentrations of the Aroclor mixtures, where detected in a sample, are summed and reported throughout this evaluation as simply "PCBs". Figures depicting sample locations can be referenced in previous sections of the report. COPC for surface soil and all soils by area, for groundwater underlying the Site, and surface water and sediment by parcel are summarized below and presented on the following page (and repeated as Table 7-25). With the exception of six COPC without USEPA toxicological criteria, all of the COPC are evaluated quantitatively. The six COPC without USEPA toxicological criteria, which include two organic chemicals classified as polycyclic aromatic hydrocarbons (PAHs) (benzo[g,h,i]perylene and phenanthrene) and four inorganic chemicals (calcium, lead, magnesium and sodium), are evaluated qualitatively.

7.3.1.1 Soil

Soil quality data are summarized in Tables 7-19 and 7-20; the frequency of detection and the range of detected concentrations are provided. Data for soil are grouped as previously discussed in Section 7.2.1 Data Evaluation for the human health evaluation, radiological risk.

Site-specific background inorganic chemical concentrations in soil are derived based on data from selected samples from upper Parcel B and upper Parcel C; it does not appear that these areas have been impacted by site-related activities. Data from the following seven soil samples at three boring locations and one test pit location are used to characterize site-specific background:

MP-5	TP-06
MP-5B	MP-11D
SB-13	MP-11DB
SB-13B	

Site-specific background data are presented in Table 7-21; the frequency of detection and range of detected concentrations are provided. The elemental composition of soils, including New York State soils data where available, are also presented in Table 7-21 for comparison. With the exception of lead and selenium concentrations, the background soil data compares favorably with the published data.

Area A:

Sixteen volatile organic chemicals (VOCs), 23 semi-volatile organic chemicals (SVOCs), PCBs, 22 inorganic chemicals, and cyanide were detected in surface soil. Of these, one VOC, four SVOCs, PCBs, and ten inorganic chemicals were selected as COPC in surface soil. Sixteen VOCs, 27 SVOCs, PCBs, 22 inorganic chemicals, and cyanide were detected in all soils. Of these one VOC, seven SVOCs, PCBs, and ten inorganic chemicals were selected as COPC in all soils.

Area B:

Five VOCs, 13 SVOCs, two pesticides, PCBs, 22 inorganic chemicals, and cyanide were detected in surface soil. Of these, one VOC, two SVOCs, and ten inorganic chemicals were selected as COPC in surface soil. Five VOCs, 13 SVOCs, two pesticides, PCBs, 22 inorganic chemicals, and cyanide were detected in all soil. Of these, one VOC, two SVOCs, and ten inorganic chemicals were selected as COPC in all soil.

Area B&C:

Four VOCs, 17 SVOCs, one pesticide, PCBs, 23 inorganic chemicals, and cyanide were detected in surface soil. Of these, two SVOCs, PCBs, and 11 inorganic chemicals were selected as COPC. Five VOCs, 17 SVOCs, one pesticide, PCBs, 23 inorganic chemicals, and cyanide were detected in all soil. Of these, two SVOCs, PCBs, and ten inorganic chemicals were selected as COPC.

Area C:

Eight VOCs, 13 SVOCs, PCBs, 22 inorganic chemicals, and cyanide were detected in surface soil. Of these, one VOC, two SVOCs, PCBs, and ten inorganic chemicals were selected as COPC. Sixteen VOCs, 15 SVOCs, PCBs, 22 inorganic chemicals, and cyanide were detected in all soil. Of these, one VOC, two SVOCs, PCBs, and eleven inorganic chemicals were selected as COPC.

7.3.1.2 Groundwater

Groundwater quality data from monitoring well samples are summarized in Table 7-22; the frequency of detection and the range of detected concentrations are provided. The data are assembled as described in Section 7.2.1 Data Evaluation for the human health evaluation, radiological risk. USEPA MCLs promulgated under the Federal Safe Drinking Water Act, NYS MCLs, and New York State water quality standards and guidance values (NYS WQS) for Class GA groundwater are also provided for comparison. An MCL is the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. Class GA groundwaters are intended for household uses (e.g., drinking, cooking).

Site-specific background chemical concentrations in groundwater are derived based on two rounds of data from monitoring wells MP-5 and MP-11D, as well as one sample collected from the well (GW-Konica-01) installed for an investigation of the neighboring Konica Imaging property that has been identified as representing background conditions. Site-specific background data are presented in Table 7-22; the frequency of detection and range of detected concentrations are provided.

Twenty-four VOCs, 19 SVOCs, 16 pesticides, 23 inorganic chemicals, and cyanide were detected in groundwater. Of these, eight VOCs, one SVOC, and ten inorganic chemicals were selected as COPC.

7.3.1.3 Surface Water and Sediment

Surface water and sediment quality data are summarized by parcel in Tables 7-23 and 7-24, respectively; the frequency of detection and the range of detected concentrations are provided. The data are assembled as described in Section 7.2.1 Data Evaluation for the human health evaluation, radiological risk. Data from two sampling locations on Parcel B (SW/SED-08 and SW/SED-09) and two sampling locations on Parcel C (SW/SED-10 and SW/SED-11) are presented. Surface water and sediment samples from the impoundments on Parcel A are not evaluated due to the removal of the impoundments.

Four VOCs, one SVOC, three pesticides, 21 inorganic chemicals, and cyanide were detected in surface water from Parcel B. Of these, 11 inorganic chemicals are selected as COPC. Two SVOCs and 19 inorganic chemicals were detected in surface water and Parcel C. Of these, ten inorganic chemicals were selected as COPC.

Five VOCs, four SVOCs, two pesticides, PCBs, and 20 inorganic chemicals were detected in sediment from Parcel B. Of these, benzene, PCBs, and five inorganic chemicals are selected as COPC. One VOC, ten SVOCs, 21 inorganic chemicals, and cyanide were detected in sediment from Parcel C. Of these, five inorganic chemicals are selected as COPC.

7.3.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of human exposure to the COPC that are present at or migrating from the media being evaluated.

7.3.2.1 Potentially Exposed Populations

Potentially exposed populations are as discussed previously in Section 7.2.2.1 Potentially Exposed Populations for the human health evaluation, radiological risk with the following exceptions: the trespasser scenario will also include exposure to surface water on Parcel B and Parcel C.

7.3.2.2 Exposure Pathways

Exposure pathways are generally as discussed in Section 7.2.2.2 Exposure Pathways for the human health evaluation, radiological risk with the following exceptions: surface water on Parcel B and Parcel C also represent exposure pathways of concern in the current and future scenarios. The exposure pathways selected for evaluation and the basis for inclusion or exclusion of certain exposure scenarios are provided in Table 7-26. A matrix of potential exposure routes is provided in Table 7-27.

7.3.2.3 Data Utilization

Data utilization is as discussed previously in Section 7.2.2.3 Data Utilization for the human health evaluation, radiological risk with one exception. If a COPC was not detected in a sample, a value of ½ its limit of detection is used as a "proxy" concentration. Adjusting non-detects by assigning values of ½ the limit of detection assumes that a chemical may be present at a concentration just below the reported limit of detection.

7.3.2.4 Estimates of Chemical Intake

Estimates of chemical intake are as discussed previously in Section 7.2.2.4. Estimates of Contaminant Intake for the human health evaluation, radiological risk with the following exceptions. Exposure point concentrations of volatile COPC in air from release from groundwater during showering were calculated as described in Appendix O following guidance in Schaum et al., (1992). A value of 0.6 times the exposure point concentration was used to evaluate exposure of the skin (termed dermal exposure) to the volatile COPC in groundwater during showering (Schaum et al., 1992). The exposure point concentrations are presented in Table 7-28.

Estimation of skin surface areas available for contact and skin permeability factors are necessary for evaluation of the dermal contact exposure route.

Presented in Table 7-29 is a generic equation for estimating chemical intakes which defines the intake variables in terms of chemical-related, population-related and evaluation-

determined parameters. The averaging time (AT) referenced in Table 7-29 depends on the type of toxic effect being assessed. When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This is equal to the exposure duration (ED) multiplied by 365 days/year. When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative intake over a lifetime (i.e., lifetime average daily intake). For calculation purposes, this is equal to 70 years multiplied by 365 days/year. This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Other variables used in estimating chemical intakes are as discussed previously in Section 7.2.2.4 Estimates of Contaminant Intake for the human health evaluation, radiological risk and are presented in Table 7-30 for soil, groundwater, surface water, and sediment. The variables for estimating absorbed dose from dermal exposure are also presented in Tables 7-30 and are described below. Application of the exposure equations results in estimates of chemical intake or absorbed dose expressed in mg of chemical per Kg body weight per day (mg/Kg-day).

Soil - Table 7-30 presents the parameters and assumptions used in assessing potential dermal exposure to COPC in soil. Dermal contact with soil is evaluated for arsenic and PCBs only; this is due to the general lack of chemical-specific data on dermal absorption from the soil matrix (USEPA, 1992a). For dermal contact with soil, the surface area available for contact (SA), the soil-to-skin adherence factor (AF), and the rate of absorption (ABS) are considered.

A SA of 1970 cm^2 is used to evaluate dermal contact with soil by trespassers; this value represents 12.5% of the total body surface area. The 50th percentile total body surface area of 12-18 years is 15,757 cm^2 (USEPA, 1989a). An AF of 1.00 mg/cm^2 is used (USEPA, 1992a). The average body weight (BW) of 12-18 year olds is 57.7 kg (USEPA, 1989a). An ABS of 3% is used for arsenic; this is the value recommended by Cal EPA (USEPA, 1993a). An

ABS of 14% is used for the PCBs as recommended by the USEPA (1996a).

For Site workers and construction workers, a SA of 2570 cm^2 corresponding to the surface area of the hands, forearms, and face (calculated as half the surface area of the head) is used (USEPA, 1989a). An adult BW of 70 Kg is used (USEPA, 1991). All other dermal exposure parameters and assumptions are as discussed previously for trespassers.

SAs of 2425 cm^2 and 872.5 cm^2 are assumed in assessing dermal exposure of resident adults and resident children, respectively. The SAs for resident adults and resident children were also derived using 12.5% of the total body surface area. The 50th percentile total body surface area for an adult (USEPA, 1989a) is 19,400 cm^2. The 50th percentile total body surface area (SA) for 2-6 year old children is 6980 cm^2 (USEPA, 1992a). BWs of 70 and 15 Kg are used for resident adults and children, respectively (USEPA, 1991). All other dermal contact parameters and assumptions are as discussed previously for trespassers.

Groundwater - Table 7-30 presents the parameters and assumptions used in assessing potential exposure to COPC in groundwater. As dermal exposure of Site workers may be possible during washing, a SA of 2570 cm^2, representing the skin surface of the hands, forearms, and face (calculated as half the surface area of the head) is used (USEPA, 1989a). The permeability coefficients (PCs) used to estimate dermal exposure are provided in Table 7-31.

In the home, the greatest opportunity for dermal exposure to the COPC in groundwater is during showering or bathing. Thus, the entire surface areas of the body, presented above, are used to evaluate exposure via dermal contact. An exposure time (ET)of 12 minutes/day (or 0.2 hours/day) is used to evaluate dermal exposure to the COPC in groundwater; this value represents the 90th percentile value for showering for all age groups (USEPA, 1989a). An inhalation rate of 0.83 m^3/hr is used to evaluate inhalation of volatile COPC released from groundwater during showering (USEPA, 1989a) by both resident adults and children.

Surface Water: Table 7-30 presents the parameters and assumptions used in assessing potential dermal exposure to COPC in surface water by trespassers. The PCs used

to estimate dermal exposure are provided in Table 7-31. An ET of 2 hours is assumed. All of the other parameters and assumptions were discussed previously for trespasser exposure to soil.

Sediment: Table 7-30 presents the parameters and assumptions used in assessing potential dermal exposure to COPC in sediment by trespassers. All of the dermal exposure parameters and assumptions were discussed previously for trespasser exposure to soil.

7.3.3 Toxicity Assessment

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect, and characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the contaminant received and the incidence of adverse effects in the exposed population is evaluated.

The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used in this human health evaluation. These include verified reference doses, or RfDs, for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slope factors for the evaluation of cancer risk from lifetime exposure. Each of these is discussed below. Sources of toxicological information and criteria, in order of preference, include IRIS (Integrated Risk Information System), which is a USEPA database containing current health risk and regulatory information for many chemicals (USEPA, 1997a), the USEPA Health Effects Assessment Summary Tables (HEAST) which are tabular presentations of provisional toxicity data (USEPA, 1995), and the USEPA National Center for Environmental Assessment's (NCEA) Superfund Technical Support Center (formerly the Environmental Criteria and Assessment Office, ECAO) (USEPA, 1997b).

7.3.3.1 Noncarcinogenic Effects

The potential for noncancer health effects associated with chemical exposure is evaluated by comparing an estimated intake [such as a chronic daily intake (CDI)] over a specified time period with a reference dose (RfD) derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. According to the USEPA, RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical. For the construction/utility maintenance worker assumed to have exposure over a 1-year period, subchronic RfDs are the more appropriate criteria. However, as subchronic RfDs are often lacking or in some cases set equal to chronic RfDs, chronic RfDs are used as conservative approximations.

The RfDs for the characterization of chronic noncancer risk via both oral and inhalation exposure routes are presented in Table 7-32, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD, and any uncertainty or modifying factors used in the derivation of the RfD. Generally order of magnitude (i.e., in increments of 10) uncertainty factors reflect the various types of data (e.g., a no observable adverse affect level from a valid chronic study in humans) used to estimate the RfDs. Modifying factors, that can range from greater than zero to 10, reflect qualitative professional judgement regarding scientific uncertainties (e.g., the completeness of the overall database) not covered under the uncertainty factor. All of the reference doses and concentrations have been developed by the USEPA.

RfDs for oral exposure are available for most of the chemicals of concern. RfDs are not available, however, for dermal exposure. In their absence, oral RfDs are used and adjusted as per USEPA guidance (USEPA, 1989b) to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. In the absence of chemical-specific information on oral absorption, a default efficiency was assumed. Oral absorption factors are presented in Table 7-33.

A limited number of reference concentrations (RfCs) for inhalation exposure are available. Following consultation with the USEPA NCEA, the available RfCs were converted into RfDs based on a standard inhalation rate of 20 m^3/day , a standard body weight of 70 kg, and appropriate chemical-specific information.

The RfD for Aroclor 1254, the lower of the two available Aroclor-specific RfDs (the RfD for Aroclor 1016 is the other), is used as representative of all PCB mixtures. As presented earlier, Aroclors 1242, 1248, 1254, and 1260 were detected in one or more samples. Use of the RfD for Aroclor 1254 may overestimate the hazard for the other Aroclor mixtures.

The ratio of the estimate of chronic daily intake to the health-protective criterion (CDI/RfD) is called a hazard quotient (USEPA, 1989b). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, the greater the level of concern.

7.3.3.2 Carcinogenic Effects

Regardless of the mechanism of effect, risk evaluation methods employed by the USEPA generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk evaluation methods often require extrapolation from high dose exposures to laboratory animals, workers, or other highly exposed individuals to evaluate low doses more typical of environmental exposures. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low-dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis.

Through application of this approach, the USEPA has derived estimates of

incremental excess cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical substance through critical evaluation of the various test data and fitting dose-response data to a low-dose extrapolation model. The slope factor (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per $(mg/Kg\text{-}day)^{-1}$]. The slope factors for the carcinogenic chemicals of concern presented in Table 7-34 are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. For children, the estimated cancer risk reflects the potential risk over a lifetime due to childhood exposure. The weight-of-evidence classification for carcinogenicity and the basis and source of the slope factor are also presented in Table 7-34.

The USEPA recommends a tiered approach for selecting the appropriate slope factor for evaluating exposure to PCBs (USEPA 1996 and USEPA, 1997a). Based on this approach, since exposure via soil ingestion, dermal contact (with application of an absorption factor), and inhalation of respirable particulates are evaluated, the "high risk and persistence" upper-bound slope factor is used as representative of all PCB mixtures.

A relative potency approach recommended by the USEPA (1993b) is used to estimate cancer risks from exposure to the carcinogenic PAHs. The relative potency approach, which takes into account the differing potencies of the carcinogenic PAHs, is used rather than the former practice of assuming that all carcinogenic PAHs are equivalent in potency to benzo[a]pyrene. Estimates of cancer risks under the equivalent potency assumption overestimates the carcinogenic potency of most PAH mixtures since benzo[a]pyrene has been demonstrated to be one of the most potent carcinogenic PAHs. The slope factor for benzo[a]pyrene is adjusted based on the following potencies of the other carcinogenic PAHs relative to benzo[a]pyrene:

benzo[a]pyrene	1.0	
benzo[a]anthracene	0.1	
benzo[b]fluoranthene	0.1	
dibenz[a,h]anthracene		1.0
ideno[1,2,3-c,d]pyrene	0.1	

The following equation is used to arrive at an estimate of incremental cancer risk (USEPA, 1989b):

$$\text{Risk} = \text{CDI} \times \text{SF}$$

where:

Risk = a unitless probability (e.g., 2×10^{-5} or 2 in 100 thousand) of an individual developing cancer;

CDI = chronic daily intake averaged over 70 years (mg/Kg-day); and

SF = slope factor, expressed in $(\text{mg/Kg-day})^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). According to the USEPA, this approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, the USEPA has not derived slope factors for dermal exposure. In their absence, slope factors for oral exposure are used and adjusted to reflect absorbed dose. This allows for risk estimation based on exposures estimated as absorbed doses and slope factors expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting slope factors.

7.3.3.3 Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and cancer effects posed by multiple chemicals. For the evaluation of noncarcinogenic health effects, this approach assumes that exposures to several chemicals at the same time could result in an adverse health effect. The sum of the hazard quotients (for individual chemicals, exposure routes, exposure pathways, or potentially exposed populations) is the hazard index. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect (termed toxic endpoint) by the same mechanism of action. COPC that can affect the same target organ or system (i.e., have the same toxic endpoint), based on

the toxicological basis used to derive the RfD (as presented in Table 7-32), are as follows:

Toxicological Basis	Chemical
Central Nervous System	1,1,1-Trichlorethane Aluminum Lead Manganese Mercury Selenium
Circulatory System	Benzene Antimony Barium Lead Zinc
Development	Barium Lead Nickel
Immune System	PCBs
Kidney	Trichloroethene Cadmium Lead
Liver	1,1-Dichloroethene 1,2-Dichloroethene (total) Methylene chloride Tetrachloroethene Trichloroethene
Skin	Arsenic Silver

In this evaluation, the hazard quotients of a mixture of chemicals that can have different effects are first summed into a hazard index as a screening-level analysis, as recommended by the USEPA (1989b). This approach may overestimate the likelihood of adverse, noncarcinogenic health effects. Then, for hazard indices that are greater than the USEPA acceptable level, toxic endpoint-specific hazard indices are calculated.

For the evaluation of carcinogenic risks, the individual risks associated with exposure to each chemical are summed. This additive approach, which assumes that the chemicals act independently of each other (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect) is used to approximate the probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens.

7.3.3.4 COPC without Toxicological Criteria

USEPA-derived toxicological criteria (i.e., RfDs, RfCs, and cancer slope factors for oral and inhalation exposure) are not available to quantitatively assess the potential for human health risks for six COPC including two PAHs (benzo[g,h,i]perylene and phenanthrene) and four inorganic chemicals (calcium, lead, magnesium, and sodium). Concentrations of the three essential nutrients (calcium, magnesium and sodium) were elevated in a number of groundwater samples relative to background concentrations and the nutrient screening concentrations used to select COPC. These COPC are evaluated qualitatively in the Risk Characterization section.

7.3.3.5 Toxicity Profiles

Toxicological summaries (termed ToxFAQs) prepared by the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Public Health Service are provided in Appendix O for those COPC found to be the predominant contributors to risk estimates greater than the USEPA acceptable levels.

7.3.4 Risk Characterization

The human health risks associated with potential exposure to the individual COPC for each potentially exposed population, currently and in the future in the absence of remedial action, are presented in Appendix O. The potential for noncarcinogenic and carcinogenic health effects associated with possible exposure to COPC in the media of concern are

summarized in Table 7-35 in the form of total hazard indices and total estimated cancer risks and discussed below. Where the total hazard index or total estimated cancer risk is greater than the USEPA acceptable levels, the COPC that are the predominant contributors to the risk estimates are also presented in Table 7-35; the risks for those COPC identified as predominant contributor are either greater than the USEPA acceptable levels or contribute significantly to total risks greater than the USEPA acceptable levels. Total pathway hazard indices and total estimated pathway cancer risks are also presented. Where a total hazard is greater than the USEPA acceptable level, toxic endpoint-specific hazard indices are calculated and presented in Table 7-36. As described earlier, potential carcinogenic health risks are assessed through the computation of a probability estimate, the likelihood of developing a cancer following exposure to the chemicals of concern under the set of exposure conditions evaluated.

The estimated risks are compared to the USEPA acceptable levels specified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (USEPA, 1990). For noncarcinogenic health effects, the NCP states that acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety. In practice, the USEPA defines this as both hazard quotients and hazard indices less than or equal to 1.0. For known or suspected carcinogens, the NCP states that acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} (1 in 10,000) and 10^{-6} (1 in 1,000,000).

7.3.4.1 Current Off-Site Residents

The total hazard index (Table 7-35) for adult off-site resident exposure to the COPC on respirable particulate from inhalation is 2E+01 (i.e., $2x10^1$ or 20); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Inhalation of manganese (at an annual average concentration

in air based on the maximum detected manganese concentrations in surface soil at Areas B, B&C, and C) is the predominant contributor to the risk estimate. The toxic endpoint-specific hazard index for central nervous system effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-04 (i.e., $1x10^{-4}$ or 1 in 10,000), within the upper bounds of the USEPA acceptable risk range. Inhalation of arsenic (at an annual average concentration in air based on the maximum detected arsenic concentrations in surface soil at Areas B, B&C, and C) is the predominant contributor to the risk estimate.

The total hazard index (Table 7-35) for child off-site resident exposure to the COPC on respirable particulate from inhalation is 9E+01 (i.e., 90); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Inhalation of manganese and cobalt (at annual average concentrations in air based on the maximum detected manganese and cobalt concentrations in surface soil at Areas B, B&C, and C) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for central nervous system effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-04 (i.e., 1 in 10,000), within the upper bounds of the USEPA acceptable risk range. Inhalation of arsenic (at an annual average concentration in air based on the maximum detected arsenic concentrations in surface soil at Areas B, B&C, and C) is the predominant contributor to the risk estimate.

The maximum detected arsenic, manganese, and cobalt concentrations in surface soil were used due to either too few samples to calculate 95% UCL concentrations (Areas B and C) or 95% UCL concentrations that exceed the maximum detected concentrations (Area B&C). This scenario is reevaluated in the Central Tendency Analysis based on arithmetic average arsenic, manganese, and cobalt concentrations is surface soil.

7.3.4.2 Current and Future Adolescent Trespassers

Future Scenario: Area A

The total hazard index (Table 7-35) for adolescent trespasser exposure to the COPC in surface soil from ingestion and dermal contact is 1E+00 (i.e., 1); this hazard index is

equal to the USEPA acceptable level of 1.0. The total estimated cancer risk (Table 7-35) is about 5E-05 (i.e., 5 in 100,000), within the USEPA acceptable risk range.

Current and Future Scenarios: Area B

The total hazard index (Table 7-35) for adolescent trespasser exposure to the COPC in surface soil from ingestion and dermal contact is 8E+00 (i.e., 8); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for skin effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 2E-04 (i.e., 2 in 10,000), within the upper bounds of the USEPA acceptable risk range.

Current and Future Scenarios: Area B&C

The total hazard index (Table 7-35) for trespasser exposure to the COPC in surface soil from ingestion and dermal contact is 3E+01 (i.e., 30); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration), and ingestion of antimony and manganese (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, developmental, immunological and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 8E-04 (i.e., 8 in 10,000), greater than the USEPA acceptable risk range. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

Current and Future Scenarios: Area C

The total hazard index (Table 7-35) for trespasser exposure to the COPC in surface

soil from ingestion and dermal contact is 9E+00 (i.e., 9); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of antimony (at the maximum detected concentration) and arsenic (at the maximum detected concentration) and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 2E-04 (i.e., 2 in 10,000), within the upper bounds of the USEPA acceptable risk range.

Current and Future Scenarios: Parcel B

The total hazard index (Table 7-35) for trespasser exposure to the COPC in surface water from dermal contact and in sediment from ingestion and dermal contact is 4E+00 (i.e., 4); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Dermal contact with antimony, arsenic, cadmium, aluminum, and nickel in surface (all at the maximum detected concentration) water are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for circulatory system effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 3E-05 (i.e., 3 in 100,000), within the USEPA acceptable risk range.

Current and Future Scenarios: Parcel C

The total hazard index (Table 7-35) for trespasser exposure to the COPC in surface water from dermal contact is 7E+00 (i.e., 7); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) in sediment are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for skin effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 3E-04 (i.e., 3 in 10,000), within the upper bounds of the

USEPA acceptable risk range.

7.3.4.3 Future Site Workers

Area A

The total hazard index (Table 7-35) for Site worker exposure to the COPC in surface soil from ingestion and dermal contact is 2E+00 (i.e., 2); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for skin effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 3E-04 (i.e., 3 in 10,000), within the upper bounds of the USEPA acceptable risk range.

Area B

The total hazard index (Table 7-35) for Site worker exposure to the COPC in surface soil from ingestion and dermal contact is 1E+01 (i.e., 10); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for skin is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-03 (i.e., 1 in 1,000), greater than the USEPA acceptable risk range. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

Area B&C

The total hazard index (Table 7-35) for Site worker exposure to the COPC in surface soil from ingestion and dermal contact is 4E+01 (i.e., 40); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected

concentration) and ingestion of antimony and manganese (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, developmental, immunological, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 5E-03 (i.e., 5 in 10,000), greater than the USEPA acceptable risk range. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

Area C

The total hazard index (Table 7-35) for site worker exposure to the COPC in surface soil from ingestion and dermal contact is 1E+01 (i.e., 10); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Dermal contact with arsenic (at the maximum detected concentration) and ingestion of antimony and arsenic (both at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-03 (i.e., 1 in 1,000), greater than the USEPA acceptable risk range. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

Groundwater

The total hazard index (Table 7-35) for Site worker exposure to the COPC in groundwater from ingestion and dermal contact is 6E+01 (i.e., 60); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of arsenic, 1,2-dichloroethene, antimony, trichloroethene, tetrachloroethene, and cadmium are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, liver, kidney, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk

(Table 7-35) is about 4E-03 (i.e., 4 in 1,000), greater than the USEPA acceptable risk range. Ingestion of arsenic and vinyl chloride are the predominant contributors to the risk estimate.

7.3.4.4 Future Construction Workers

Area A

The total hazard index (Table 7-35) for construction worker exposure to the COPC in all soils from ingestion, dermal contact and inhalation is 3E+00 (i.e., 3); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Inhalation of cobalt is the predominant contributor to the risk estimate. The toxic endpoint-specific hazard index for skin effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 7E-06 (i.e., 7 in 1,000,000), within the USEPA acceptable risk range.

Area B

The total hazard index (Table 7-35) for construction worker exposure to the COPC in all soils from ingestion, dermal contact and inhalation is 7E+01 (i.e., 70); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Inhalation of cobalt (at the maximum detected concentration in all soils) and manganese and ingestion of arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, developmental, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 7E-05 (i.e., 7 in 100,000), within the USEPA acceptable risk range.

Area B&C

The total hazard index (Table 7-35) for construction worker exposure to the COPC in all soils from ingestion, dermal contact and inhalation is 1E+02 (i.e., 100); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Inhalation of manganese and cobalt and ingestion of arsenic

(at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 3E-04 (i.e., 3 in 10,000), within the upper bounds of the USEPA acceptable risk range. Inhalation and ingestion of arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

Area C

The total hazard index (Table 7-35) for construction worker exposure to the COPC in all soils from ingestion, dermal contact and inhalation is 5E+01 (i.e., 50); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of antimony and arsenic (both at the maximum detected concentration) and inhalation of manganese and cobalt (at the maximum detected concentration in all soils) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-04 (i.e., 1 in 10,000), within the upper bounds of the USEPA acceptable risk range.

7.3.4.5 Future On-Site Residents

Area A:

The total hazard index (Table 7-35) for adult resident exposure to the COPC in all soils from ingestion and dermal contact is 2E+00 (i.e., 2); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for skin effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 6E-04 (i.e., 6 in 10,000), greater than the USEPA acceptable risk range. Ingestion of and dermal contact

with arsenic are the predominant contributors to the risk estimate.

The total hazard index (Table 7-35) for child resident exposure to the COPC in all soils from ingestion and dermal contact is 9E+00 (i.e., 9); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion and dermal contact of arsenic are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard index for skin effects is greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 3E-04 (i.e., 3 in 10,000), within the upper bounds of the USEPA acceptable risk range.

Area B:

The total hazard index (Table 7-35) for adult resident exposure to the COPC in all soils from ingestion and dermal contact is 2E+01 (i.e., 200); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) and ingestion of nickel (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, developmental, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 6E-03 (i.e., 6 in 1,000), greater than the USEPA acceptable risk range. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

The total hazard index (Table 7-35) for child resident exposure to the COPC in all soils from ingestion and dermal contact is 1E+02 (i.e., 100); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of arsenic, nickel, and antimony (all at the maximum detected concentration) and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, developmental, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 3E-03

(i.e., 3 in 1,000), greater than the USEPA acceptable risk range. Ingestion of arsenic (at the maximum detected concentration) is the predominant contributor to the risk estimate.

Area B&C:

The total hazard index (Table 7-35) for adult resident exposure to the COPC in all soils from ingestion and dermal contact is 6E+01 (i.e., 60); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 2E-02 (i.e., 2 in 100), greater than the USEPA acceptable risk range. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

The total hazard index (Table 7-35) for child resident exposure to the COPC in all soils from ingestion and dermal contact is 4E+02 (i.e., 400); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) and ingestion of antimony are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, developmental, immunological, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-02 (i.e., 1 in 100), greater than the USEPA acceptable risk range. Ingestion of arsenic (at the maximum detected concentration) is the predominant contributor to the risk estimate.

Area C:

The total hazard index (Table 7-35) for adult resident exposure to the COPC in all soils from ingestion and dermal contact is 4E+01 (i.e., 40); this hazard index is greater than

the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) and ingestion of antimony are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-02 (i.e., 1 in 100), greater than the USEPA acceptable risk range. Ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate.

The total hazard index (Table 7-35) for child resident exposure to the COPC in all soils from ingestion and dermal contact is 3E+02 (i.e., 300); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of antimony and ingestion of and dermal contact with arsenic (at the maximum detected concentration) are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, central nervous system, developmental, immunological, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 6E-03 (i.e., 6 in 1,000), greater than the USEPA acceptable risk range. Ingestion of arsenic (at the maximum detected concentration) is the predominant contributor to the risk estimate.

Groundwater

The total hazard index (Table 7-35) for resident adult exposure to the COPC in groundwater from ingestion, dermal contact, and inhalation of volatilized chemicals is 2E+02 (i.e., 200); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of 1,2-dichloroethene, arsenic, antimony, trichloroethene, and tetrachloroethene are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, liver, kidney, central nervous system, developmental, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 1E-02 (i.e., 1 in 100),

greater than the USEPA acceptable risk range. Ingestion of arsenic and vinyl chloride are the predominant contributors to the risk estimate.

The total hazard index (Table 7-35) for resident child exposure to the COPC in groundwater from ingestion, dermal contact, and inhalation of volatilized chemicals is 4E+02 (i.e., 400); this hazard index is greater than the USEPA acceptable level of 1.0, indicating a potential for adverse, noncarcinogenic health effects. Ingestion of 1,2-dichloroethene, arsenic, antimony, trichloroethene, and tetrachloroethene are the predominant contributors to the risk estimate. The toxic endpoint-specific hazard indices for circulatory system, liver, kidney, central nervous system, developmental, and skin effects are greater than the USEPA acceptable level. The total estimated cancer risk (Table 7-35) is about 7E-03 (i.e., 7 in 1,000), greater than the USEPA acceptable risk range. Ingestion arsenic and vinyl chloride are the predominant contributors to the risk estimate.

7.3.4.6 COPC Without Toxicity Criteria

As presented earlier, USEPA-derived toxicological criteria are not available to quantitatively assess the potential for human health risks for two PAHs and four inorganic chemicals. Possible health implications that may be associated with exposure to these chemicals are as follows:

<u>COPC in Soil and Sediment</u>

Benzo[g,h,i]perylene and phenanthrene: These two chemicals are among the 17 PAHs typically analyzed for and evaluated at hazardous waste sites; the 17 PAHs often occur together in the environment and many have similar environmental fate and toxicological characteristics (ATSDR, 1993b). However, reliable environmental fate and toxicological information exists for only a few of the 17 PAHs and the potential health effects of the other less well-studied PAHs must be inferred from this information (ATSDR, 1993c). The USEPA (1997a) regards both chemicals as not classifiable as to carcinogenicity.

As presented in Tables 7-19 and 7-20, benzo[g,h,i]perylene and phenanthrene were

detected in one or more soil samples in each area in concentrations within the range of other detected noncarcinogenic PAHs (e.g., fluoranthene). As presented in Table 7-24, benzo[g,h,i]perylene was also detected in one sediment sample from Parcel C and phenanthrene was also detected in one sediment sample from each of Parcels B and C. Since the other detected noncarcinogenic PAHs were not selected as COPC based on the concentration-toxicity screen, it is unlikely that benzo[g,h,i]perylene and phenanthrene in either soil or sediment would significantly increase the risk estimates.

Lead: Chronic exposure to low levels of lead may result in hematologic (blood and blood-forming), neurobehavioral, kidney, and other effects in humans (ATSDR, 1993b). Effects such as slowed nerve conduction velocities, altered testicular function, reduced hemoglobin production and other signs of impaired heme synthesis, and blood pressure effects have been observed in adults. Children, who represent a sensitive portion of the population, may experience an array of pathophysiological effects. Electrophysiological effects, impaired cognitive performance (as measured by IQ tests, performance in school, and other means), heme synthesis impairment, inhibition of pyrimidine and alanine synthesis, interference with vitamin D hormone synthesis, and early childhood growth reductions have been observed in children. In addition, factors influencing neurological development such as low birth weights and decreased gestational age and deficits in mental indices have been reported in infants.

Lead was detected in concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use (USEPA, 1994) or the soil lead guidance range of 750 to 1700 mg/Kg for industrial land use (USEPA, 1996b) in the following soil and sediment samples:

Area A:

Surface Soil:	SS-05 (688 mg/Kg)
	SS-07 (521 mg/Kg)

Area B:

Surface Soil:	SS-06 (551 mg/Kg)
	SS-08 (672 mg/Kg)

	SB-19 (775 mg/Kg)
	SB-20 (3,710 mg/Kg)

Area B & C:

Surface Soil:	SS-4 (1,980 mg/Kg)
	SS-12 (2,150 mg/Kg)
	SB-11 (1,960 mg/Kg)
	SB-14 (3,300 mg/Kg)
	SB-16 (853 mg/Kg)
	SB-17 (1,020 mg/Kg)
	TP-1 (19,600 mg/Kg)
	TP-3 (6,100 mg/Kg)
	TP-5 (2,980 mg/Kg)
	TP-8 (1,160 mg/Kg)
Deeper Soil:	SB-27 (570 mg/Kg)
	SB-28 (2,000 mg/Kg)
	SB-28B (419 mg/Kg)

Area C:

Surface Soil:	SS-10 (784 mg/Kg)
	SS-11 (3,040 mg/Kg)
	SB-24 (1,080 mg/Kg)
	SB-25 (2,730 mg/Kg)
	SED-02 (1,220 mg/Kg)
	SED-03 (5,140 mg/Kg)
Deeper Soil:	SB-21 (1,330 mg/Kg)
	SB-22 (2,080 mg/Kg)
	SB-23B (434 mg/Kg)

Parcel C:

Sediment:	SED-10 (1,950 mg/Kg)
	SED-11 (2,840 mg/Kg)

COPC in Groundwater

Calcium: There are no drinking water standards for calcium as calcium is relatively non-toxic and U.S. drinking water supplies have calcium levels that are below those that pose risks to human health. In fact, the presence of calcium may provide nutritional benefit as calcium is an essential mineral. Calcium intakes greater than 1,000 mg/day along with high Vitamin D intakes have been shown to raise calcium blood levels.

Calcium concentrations greater than the nutrient screening concentration of 400 mg/L were detected in samples from the following two monitoring wells during both sampling rounds:

MP-18 (at 457 and 482 mg/L)
MP-18D (at 511 and 554 mg/L)

Lead: Lead was detected in 46 of the 60 groundwater samples (to 0.836 mg/L), as well as in four of the five background groundwater samples (to 0.133 mg/L), at concentrations greater than the USEPA MCL action level of 0.015 mg/L for lead in drinking water at the tap..

Magnesium: Magnesium is an essential nutrient in humans involved as a cofactor in many vital enzymatic reactions and important in the maintenance of membrane electric potential. The kidney is the key organ in the homeostasis of magnesium, and disturbances of magnesium metabolism have been described in several renal diseases. Most magnesium compounds taken orally have minimal toxicity. (Clayton and Clayton, 1994). By the respiratory route, the few available data indicate moderate toxicity. There is no evidence that the inhalation of magnesium dust has led to lung injury. No reports of serious cases of magnesium poisoning among industrial workers have been reported. Magnesium concentrations less than those that impart an astringent taste typically pose no health problems and are likely to be beneficial to human health; consequently, there are no health-based limits for drinking water.

Magnesium concentrations greater than the nutrient screening concentration of 40 mg/L) were detected in samples from the following six monitoring wells during one or more sampling rounds:

GM-1 (at 45.9 mg/L)
GM-13 (at 56.9 and 56.3 mg/L)
MW-10D (at 54.0 and 51.1 mg/L)
MP-2D (at 127.0 and 102.0 mg/L)
MP-18D (at 227.0 and 247.0 mg/L)
MP-22D (at 127.0 mg/L)

Sodium: Physiologically, sodium is an essential element encountered as a salt in most foodstuffs. Although current studies are equivocal, earlier epidemiological studies have indicated that long-term excessive sodium intake is one of many factors associated with hypertension in humans (Carson et al., 1986; Clayton and Clayton, 1994). A high sodium:potassium ratio may be detrimental to persons susceptible to high blood pressure. Feeding high salt diets to laboratory animals leads to hypertension, especially if salt-sensitive species are started on the regime early in infancy. Chronic inhalation exposures may cause inflammation, ulcerate changes in the mouth, and bronchial and gastrointestinal disturbances (Clayton and Clayton, 1994).

Sodium concentrations greater than the nutrient screening concentration of 500 mg/L were detected in samples from the following three monitoring wells during both sampling rounds:

GM-14B (at 7,330 and 8,400 mg/L)
MP-18D (at 1,630 and 1,860 mg/L)
MP-22D (at 641 and 600 mg/L)

7.3.4.7 Uncertainty Analysis

Some uncertainty is inherent in the process of conducting predictive, quantitative human health evaluations. Environmental sampling and analysis, fate and transport modeling, and human exposure modeling are all prone to uncertainty, as are the available toxicity data used to characterize risks.

Uncertainty associated with environmental sampling is generally related to the limitations of the sampling in terms of the number and distribution of samples, while uncertainty associated with the analysis of samples is generally associated with systematic or random errors (e.g., false positive or negative results). Thus exposure may be overestimated or underestimated depending on how well each environmental medium is characterized.

While aspects of the exposure assessment methodology can result in overestimation or underestimation of long-term exposure, exposure is probably overestimated, overall, for

the potentially exposed populations evaluated. The exposure point concentrations used in the exposure assessment (i.e., the 95% UCL on the average concentration or the maximum detected concentration, without consideration of environmental migration, transformation, degradation, or loss) should result in overestimates of long-term exposure. As discussed in Appendix O, potential exposure to non-volatile chemicals of potential concern adsorbed to respirable particulates made airborne from wind or mechanical erosion is based on conservative air dispersion modeling that over predicts air concentrations.

Assumptions and model input parameters that result in reasonable maximum exposure estimates are used in the exposure assessment; the actual frequencies and durations of exposure would probably be less than evaluated so that long-term exposure should be overestimated. Model input parameters (e.g., permeability constants) which are influenced by a number of factors may result in overestimates of long-term exposure.

Potential exposure to chemicals in groundwater from dermal contact during showering (or bathing/washing) is based on data from unfiltered water samples and, as chemicals adsorbed to particulates in the water may be unavailable for dermal absorption, exposure may be overestimated.

The derivation of health effects criteria that form the basis of the risk characterization can result in overestimates or underestimates of potential health risks. In most cases, the criteria are derived from extrapolation from laboratory animal data to humans. RfDs and cancer slope factors for oral exposure are used as criteria to assess exposure from dermal absorption. While the criteria for oral exposure are adjusted for such use following USEPA guidance, oral absorption for the organic chemicals is assumed to be 100%; this may underestimate dermal contact risks for some chemicals. For those chemicals with specific oral absorption factors, consideration was not given to the absorption efficiency of the exposure vehicle used in the studies on which the toxicity factors are based; this may overestimate or underestimate dermal contact risks for some chemicals. Furthermore, for some chemicals, health criteria are insufficient to determine reference doses or slope factors for oral and/or inhalation exposure. As a result, the overall risks may be underestimated.

Central Tendency Analysis

As presented above, analysis of the soil, groundwater, surface water, and sediment pathways resulted in risks in excess of the USEPA acceptable levels for all populations evaluated. Per USEPA, Region II guidance, the pathways are reevaluated using central tendency exposure parameter values, where available, in place of the upper-bound values used in the RME analysis. This is accomplished by calculating the percent difference between the RME and the central tendency exposure paramter values used in the individual exposure route calculations for each population, where appropriate, and adjusting the RME risks accordingly. The exposure parameter values used in the central tendency analysis are presented in Table 7-36 and the reevaluated risk estimates are presented in Table 7-37. The revised exposure parameter values and reevaluated risks are described below. Except as noted, all the other risk estimates remain greater than the USEPA acceptable levels.

For current off-site resident exposure to respirable particulates, an exposure duration for adults of 9 years, representing the national median time spent at one residence (USEPA, 1989b), is used in the central tendency analysis. The hazard index for the off-site adult resident remains the same, but the total estimated cancer risk would be approximately three times less, at the upper bound of the USEPA acceptable risk range.

For current and future adolescent trespasser exposure to surface soil, surface water, and sediment, 50% of the ingestion and dermal contact exposures (i.e., FI = 0.5) and an exposure frequency of 50 days/year, representing exposure either twice per week during the warmer months or weekly throughout the year, are used in the central tendency analysis. The hazard indices and estimated cancer risks for ingestion of and dermal contact with surface soil and sediment would each be approximately five times less. The hazard indices and estimated cancer risks for dermal contact with surface water would be approximately two times less. This reduces the total pathway hazard index for exposure to surface soil at Area C to equal the USEPA acceptable level of 1.0 and reduces the total pathway cancer risks for exposure to surface soil at Areas B and C and surface water and sediment at Parcel C, to within the USEPA acceptable risk range.

For future Site worker exposure to surface soil, 50% of the ingestion and dermal contact exposures (i.e., FI = 0.5), an exposed body surface area of 2,000 cm^2, representing a "typical case" limited to the head and hands (USEPA, 1992a), and an exposure duration of 4 years, representing the 50th percentile time spent at a specific job (Bureau of Labor Statistics, 1987) are used in the central tendency analysis. The hazard indices for ingestion of and dermal contact with surface soil are approximately two and three times less, respectively. The estimated cancer risks for ingestion of and dermal contact with surface soil are approximately 13 and 16 times less, respectively. This reduces the total hazard index for the Site worker at Area A to below the USEPA acceptable level of 1.0 and reduces the total estimated cancer risks at Areas A and C to within the USEPA acceptable risk range.

For future construction worker exposure to all soils, 50% of the ingestion and dermal contact exposures (i.e., FI = 0.5), an exposed body surface area of 2,000 cm^2, representing a "typical case" limited to the head and hands (USEPA, 1992a), and an exposure frequency of 20 days/year is used in the central tendency analysis. The hazard indices and estimated cancer risks for ingestion, dermal contact, and inhalation exposures to all soils are approximately six, eight, and three times less, respectively. This reduces the total hazard index for the construction worker at Area A to below the USEPA acceptable level of 1.0 and reduces the total estimated cancer risk at Area C to within the USEPA acceptable risk range.

For future adult residents exposure to all soils, 50% of the ingestion and dermal contact exposures (i.e., FI = 0.5) and an exposure duration of 9 years, representing the national median time spent at one residence (USEPA, 1989b), are used in the central tendency analysis. The total hazard indices and total and estimated cancer risks are each approximately two times less; the hazard indices and cancer risks remain greater than the USEPA acceptable levels for exposure to all soils at Areas B, B&C, and C.

For future child resident exposure to all soils, 50% of the ingestion and dermal contact exposures (i.e., FI = 0.5) were assumed in the central tendency analysis. The total hazard indices and total estimated cancer risks are each approximately two times less; with the exception of the cancer risk for Area A, the hazard indices and cancer risks remain

greater than the USEPA acceptable levels for exposure to all soils at all areas.

For future Site worker exposure to groundwater, an ingestion rate of 0.7 l/day, an exposed body surface area of 2,000 cm^2, and an exposure duration of 4 years are used in the central tendency analysis; these values represent one-half the average adult tap water consumption rate (USEPA, 1989a, 1989b), a "typical case" limited to the head and hands (USEPA, 1992a), and the 50th percentile time spent at a specific job (Bureau of Labor Statistics, 1987), respectively. The hazard indices for ingestion and dermal contact exposure remain the same. The estimated cancer risks for ingestion and dermal contact exposures are approximately three and eight times less, respectively. The total estimated cancer risk is at the upper bound of the USEPA acceptable risk range.

For future adult resident exposure to groundwater, an ingestion rate of 1.4 l/day (about six 8-ounce glasses per day), an inhalation rate of 0.6 m^3/hour, an exposure time of 0.1 hours/day for inhalation while showering, and an exposure duration of 9 years are used in the central tendency analysis. These values represent the average adult tap water consumption rate (USEPA, 1989a, 1989b), an inhalation rate for all age groups while showering (USEPA, 1989b), the 50th percentile time spent showering (USEPA, 1989b) and the national median time spent at one residence (USEPA, 1989b), respectively. The hazard indices for ingestion and dermal contact remain the same while the estimated cancer risks are approximately three and eight times less, respectively. The total hazard index is not reduced. The total estimated cancer risk remains greater than the USEPA acceptable risk range.

For the resident child, an ingestion rate of 0.5 l/day (about four 4-ounce glasses per day), an inhalation rate of 0.6 m^3/hour, and an exposure time of 0.1 hours/day for inhalation while showering are used in the central tendency analysis. These values represent the total average daily consumption rate of water and water-based foods by a 2-year old child (USEPA, 1989a), an inhalation rate for all age groups while showering (USEPA, 1989c), and the 50th percentile time spent showering (USEPA, 1989b), respectively. The total hazard index and total estimated cancer risk, while lower than originally estimated, remain greater than the USEPA acceptable levels.

As indicated earlier, the current off-site resident exposure to respirable particulates

was reevaluated based on arithmetic average arsenic, cobalt, and manganese concentrations in surface soil at Areas B, B&C, and C. In calculating the arithmetic average concentrations, if the chemical was not detected in a sample, it was presumed to be present at ½ its limit of detection. The arithmetic average concentrations and the resulting estimated annual average concentrations in air are as follows:

Chemical	Soil Concentration (mg/Kg)			Annual Average Air Concentration (mg/m^3)
	Area B	Area B&C	Area C	
Arsenic	3.78E+02	1.01E+03	5.22E+02	1.05E-05
Cobalt	5.55E+02	5.67E+02	1.80E+02	6.46E-06
Manganese	1.18E+04	1.37E+04	1.09E+03	1.27E-04

The total pathway hazard indices, while reduced, remain greater than the USEPA acceptable level of 1.0 for the resident adult 3.0 (3E+00) and child 10 (1E+01) while the total pathway cancer risks are reduced to within the USEPA acceptable risk range for both the resident adult (2E-05) and child (2E-05).

7.3.5 Summary

The human health evaluation addresses the consequences of reasonable maximum exposure to COPC from hypothetical current and future exposure scenarios in the absence of remedial action at the Site. A summary of the risk estimates is presented in Table 7-35. Estimated risks that exceed the USEPA acceptable levels and the chemicals associated with those risks are discussed below by environmental medium.

7.3.5.1 Soil

All Areas

Potential exposure of current off-site residents to respirable particulates results in hazard indices for noncancer effects in excess of the USEPA acceptable level and estimated cancer risks at the upper bound of the USEPA acceptable risk range. The predominant

contributors to the hazard indices are manganese and cobalt (at annual average concentrations in air based on the maximum detected concentrations in surface soil at Areas B, B&C, and C). The predominant contributor to the cancer risks is arsenic (at an annual average concentration in air based on the maximum detected concentrations in surface soil at Areas B, B&C, and C).

Area A

Potential exposure to soil at Area A results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations except the future scenario adolescent trespasser and estimated cancer risks that exceed the USEPA acceptable risk range for the future scenario resident adult. The predominant contributor to hazard indices and cancer risks is arsenic and, for inhalation for the future scenario construction worker, cobalt. In addition, while not evaluated quantitatively, lead was detected in two of 28 samples at a concentration greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use.

Area B

Potential exposure to soil at Area B results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations and estimated cancer risks that exceed the USEPA acceptable risk range for the future scenario Site worker, resident adult, and resident child. The predominant contributor to hazard indices and cancer risks is arsenic, at the maximum detected concentration. Cobalt, antimony, and nickel (at the maximum detected concentrations), and manganese contribute to a lesser extent to the hazard index for inhalation for the future scenario construction worker. In addition, while not evaluated quantitatively, lead was detected in four of 12 samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in two of 12 samples at concentrations, one within and one greater than, the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

Area B&C

Potential exposure to soil at Area B&C results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations and estimated cancer risks that exceed the USEPA acceptable risk range for all populations except the future scenario construction worker. The predominant contributors to hazard indices are arsenic (at the maximum detected concentration), antimony (at the maximum detected concentration for surface soil), manganese and, for inhalation for the future scenario construction worker, cobalt. The predominant contributor to cancer risks is arsenic. In addition, while not evaluated quantitatively, lead was detected in 13 of 37 samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in three of 37 samples at concentrations within and eight of 37 samples at concentrations greater than the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

Area C

Potential exposure to soil at Area C results in hazard indices for noncancer effects in excess of the USEPA acceptable level for all populations and estimated cancer risks that exceed the USEPA acceptable risk range for the future scenario Site worker, resident adult, and resident child. The predominant contributors to hazard indices are arsenic and antimony, at the maximum detected concentrations. Manganese, cobalt (at the maximum detected concentration), and silver (at the maximum detected concentration) contribute to the hazard index for inhalation be future scenario construction workers. The predominant contributor to cancer risks is arsenic. In addition, while not evaluated quantitatively, lead was detected in nine of 15 samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in five of 15 samples at concentrations within and four of 15 samples at concentrations greater than the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

7.3.5.2 Surface Water and Sediment

Parcel B

Potential exposure of an adolescent trespasser to surface water and sediment on Parcel B results in a hazard index for noncancer effects in excess of the USEPA acceptable level. The predominant contributors to the hazard index are antimony, arsenic, cadmium, aluminum, and nickel at the maximum detected concentrations in surface water. While the total hazard index for dermal contact with surface water is greater than the USEPA acceptable level, the hazard quotients for the individual chemicals are all equal to (antimony) or less than the USEPA acceptable level.

Parcel C

Potential exposure of an adolescent trespasser to surface water and sediment on Parcel C results in a hazard index for noncancer effects in excess of the USEPA acceptable level. The predominant contributor to the hazard index is arsenic at the maximum detected concentration in sediment. In addition, while not evaluated quantitatively, lead was detected in both samples at concentrations greater than the USEPA interim soil lead guidance criterion of 400 mg/Kg for residential land use. Lead was detected in both samples at concentrations greater than the soil lead guidance range of 750 - 1700 mg/Kg for industrial land use.

7.3.5.3 Groundwater

Potential exposure of the future scenario Site worker, resident adult, and resident child to groundwater underlying the Site results in hazard indices for noncancer effects in excess of the USEPA acceptable level and estimated cancer risks that exceed the USEPA acceptable risk range. The predominant contributors to the hazard indices are 1,2-dichloroethene, arsenic, antimony, trichloroethene, and tetrachloroethene. The predominant contributors to the cancer risks are arsenic and vinyl chloride. While evaluated in the human health evaluation since groundwater is a sole source aquifer, potable use of the shallow groundwater underlying the Site in the future is unlikely due to the availability of a municipal water supply. In addition, while not evaluated quantitatively, lead was detected in 46 of 60 groundwater samples in concentrations greater than the USEPA MCL action level for lead

in drinking water.

7.4 HUMAN HEALTH EVALUATION: RADIOLOGICAL AND CHEMICAL RISKS

Carcinogenic risks associated with potential exposures to ROPC and COPC are estimated in Sections 7.2 and 7.3, respectively. The environmental models, risk assessment methodologies, and cancer slope factors used in the two analyses are unique to the ROPC and COPC to which they have been applied. However, despite the differences in the quantitative approach to assessing radiological and chemical carcinogenic risks, it is not inappropriate to sum the risks estimates for populations that may be exposed to both types of contaminants (USEPA, 1997). The resultant combined risks provide the best estimate of the total estimated carcinogenic impact of Site contaminants on potentially exposed populations.

The total estimated cancer risks are presented in Table 7-38. For the chemical risk evaluation, groundwater-related risks are combined with soil-related risks for the future scenario Site worker, resident adult, and resident child on an area-by-area basis. This was done to conform with the radiological risk evaluation. Potential exposures to the current scenario off-site resident adult, the current and future scenario adolescent trespasser at Area B&C, the future scenario construction worker at Area B&C, and the future scenario Site worker, resident adult, and resident child at all areas result in estimated total cancer risks greater than the USEPA acceptable risk range. The predominant contributor (i.e., radiological or chemical) and the predominant environmental medium (i.e., air, soil, or groundwater) to the total estimated cancer risks varies.

Non-carcinogenic risks do not result from exposure to the radiological contaminants present at the Site. Therefore, a combined radiological and chemical non-carcinogenic hazard can not be evaluated.

7.5 ECOLOGICAL ASSESSMENT

7.5.1 Objectives and Overview

Ecological risk assessments integrate information gathered from field investigations with toxicological information to decide whether contamination presents potential risks to ecological receptors. A baseline ecological risk assessment for the Site was performed following current guidance for ecological assessments at hazardous waste sites. This guidance includes:

- Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual (EPA/540/1-89/001) (USEPA, 1989).
- Framework for Ecological Risk Assessment (EPA/630/R-92/001) (USEPA, 1992).
- Proposed Guidelines for Ecological Risk Assessment (Federal Register, Vol. 61, No.175, Monday, September 9, 1996).

The objective of the ecological assessment is to evaluate environmental samples for site-related contaminants, and to estimate any potential risks these contaminants pose to the natural environment. The results of this assessment will determine if more detailed analyses are warranted. These may include toxicity testing of field-collected media, additional chemical analysis of media or biological tissues, modeling or a variety of bioassessment techniques.

According to current USEPA guidance (1992), the process of ecological risk assessment involves a preliminary step called problem formulation, which includes identification of the following:

- ecosystems potentially at risk,
- potential stressors, pathways, and effects,
- ecological endpoints, and
- a conceptual model.

Problem formulation is followed by the analysis phase, which includes:

- exposure assessment, and
- ecological effects assessment.

Risk characterization is the third and final phase, which includes:

- risk estimation
- risk description, and
- risk reporting (includes assessment of uncertainty and identification of data gaps).

This Ecological Assessment includes a risk characterization of chemical contaminants in surface water, sediment and surface soil for aquatic, semi-aquatic and terrestrial receptors. Also included is a separate risk characterization for radionuclides occurring in surface water, sediment and surface soil, for aquatic, semi-aquatic and terrestrial receptors.

7.5.2 Problem Formulation

Problem formulation is based on information collected during the remedial investigations (e.g., soil sample analysis, groundwater analysis). This phase of the ecological risk assessment is presented in four parts: (1) ecosystems of concern, (2) potential stressors, exposure pathways, and ecological effects, (3) ecological endpoints and (4) the conceptual model.

7.5.2.1 Ecosystems of Concern

The Site consists mostly of buildings and structures, with associated paved areas and dirt roads. There are, however, several vegetated areas on-site, and several surface impoundments as well. Vegetated areas include the northwest corner of the property on Parcel C' and Parcel C, the area to the north of the Benbow) Building on Parcel C, the area surrounding the Mud Pond/Mud Holes in the southwest portion of Parcel C, and the area east

of Dickson Lane and north of Herb Hill Road, in the vicinity of the landfill, tanks and radioactive black waste piles (Parcel B). Scarred vegetation was found to exist in the area north of the Reduction Building and in the vicinity of the Mud Pond/Mud Holes.

The surface impoundments on the Site include: two unlined settling ponds, referred to as the Mud Holes; a lined settling pond known as the Mud Pond, and three concrete oil recovery sumps. The Mud Pond/Mud Holes are located immediately south and southeast of the 500,000-gallon fuel oil tank along Garvies Point Road (Parcel C). The three concrete oil recovery sumps are located west of the Dice/Warehouse Building (Parcel A) and are connected via pipes to the Mud Pond/Mud Holes. The total area of these impoundments is estimated to be 11,760 square feet (NUS, 1990).

The nearest downslope surface water is Glen Cove Creek, which generally flows southwest into Hempstead Harbor, but is also affected by the tides. The creek is adjacent to the Site's southern boundary and receives runoff from the Site and from storm drains on Herb Hill Road. Glen Cove Creek is tidally influenced along its entire 0.75 mile length and ranges from approximately 30 feet wide upstream to approximately 1,000 feet wide at its mouth. There are limited biological resources present in the creek. Known species include barnacles, bluefish and blue crab (Ebasco, 1991).

Although no critical habitats of federally listed endangered species have been identified in the vicinity of the Site, Hempstead Harbor is a known waterfowl wintering area most noted for scaup, canvasback and black ducks, and is a nursery/feeding habitat for shrimp, striped bass, bluefish, Atlantic silverside, menhaden, winter flounder and blackfish. The Harbor has been designated as a "significant coastal fish and wildlife habitat" by the NYS Department of State under Policy 7 of the Waterfront Revitalization and Coastal Resources Act of 1981.

The state water quality classification for Hempstead Harbor north of Bar Beach is Class SA (suitable for shellfishing for market purposes and primary/secondary recreation). The state water quality classification for Glen Cove Creek is Class 1 (secondary contact recreation except for primary recreation and shellfishing). The waters of Long Island Sound, including Hempstead Harbor and Glen Cove Creek, have been closed to shellfish harvesting

for the last 20 years because of high concentrations of fecal coliform bacteria.

Wetland delineations were performed on October 14-15 and November 28-30, 1996. On-site jurisdictional wetlands were determined by following the U.S. Army Corps of Engineers (ACOE) 1987 Wetland Delineation Manual and were mapped accordingly. Based on the wetland delineation, four areas (Wetlands B, C1, C2 and C3) meet the federal criteria for wetland designation. These areas are described in more detail in Section 2.9 and Appendix G.

Another environmental resource in the vicinity of the Site is Garvies Point Preserve, located to the west of the Site along the shoreline of Hempstead Harbor and extending inland north of Glen Cove Creek. The Preserve is characterized as a mixed deciduous forest which steeply slopes to a wide sandy beach on its western perimeter (EBASCO, 1991). The deciduous forest supports a wide variety of bird species, both migrant and resident, and small mammals such as the eastern cottontail, gray squirrel and striped skunk.

7.5.2.2 Potential Stressors, Exposure Pathways, and Ecological Effects

Chemical stressors were identified within the Site and the contaminants of potential concern (COPC) and radionuclides of potential concern (ROPC) were selected. Selection of COPC and ROPC for ecological receptors was based on screening criteria, including maximum site-specific background concentrations and ecological risk-based values derived or obtained from published sources (e.g., ambient water quality criteria, sediment guideline values). The use of background concentrations and risk-based values to screen the data allows identification of COPC and ROPC to which ecological receptors may be highly sensitive.

Potential Stressors - Surface water samples were collected at five locations throughout the Site. Sediment samples were collected at the same locations as the surface water samples. No background surface water or sediment samples are available for the Site. Surface soil samples were collected at 58 locations throughout the Site. Background surface soil values for radionuclides represent on-site samples MP-5, MP-5B, MP-13, MP-13B, TP-6, MP-11D, MP-11DB, SS-13, SS-14, SS-15, SS-16, SS -17 and SS-18. Background surface

soil values for inorganics represent on-site samples SB-13, MP-11D, MP-5, MP-5B AND TP-6. Refer to Section 5-13 for locations of sampling points.

Contaminants detected in surface water were compared with available federal and New York State standards and guidance values to determine which chemicals may be of concern with respect to target wildlife receptors (Table 7-40). New York State Ambient Water Quality Standards and Guidance Values (NYSDEC, 1993) and USEPA Ambient Water Quality Criteria (AWQC) for chronic effects in fresh water (USEPA, 1991).

For sediments, New York State Sediment Criteria (NYSDEC, 1994) were utilized to determine which contaminants may be of concern with respect to aquatic wildlife receptors (Table 7-41). If New York State Sediment Criteria were not available for a particular contaminant, a criterion was calculated based on the Equilibrium Partitioning approach (EqP) (DiToro et al., 1991) for deriving sediment guideline values (SGVs). These criteria were calculated based on an average site sediment TOC (total organic carbon) content of 1.7%. The National Oceanic and Atmospheric Administration's Effects Ranges were also utilized as a point of comparison (NOAA, 1991). Effects Ranges were developed based upon compilation and analysis of available data on the effects of various chemicals in sediment on biota. The Effects Range-Low (ER-L) is a concentration at the low end of the range in which effects have been observed. The Effects Range-Median (ER-M) is a concentration approximately midway in the range of reported values associated with biological effects. Also presented in Table 7-41 are the Ontario Ministry of the Environment's "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" as additional benchmarks for comparison.

Maximum background soil concentrations for the Site were compared with maximum surface soil concentrations from the Site (Table 7-42), in selecting COPC and ROPC in surface soil.

If criteria, guideline values and maximum background were exceeded, and the frequency of detection of the chemicals was greater than 5%, the chemicals were chosen as chemicals of potential concern for this assessment. The compounds chosen as chemicals of potential concern for the Ecological Assessment are shown in Table 7-43.

Exposure Pathways - Several ecologically relevant exposure pathways for contaminants exist at the Site. Wildlife near the Site may have incidental contact with or ingest contaminants while foraging, nesting, or engaging in other activities in the terrestrial portions of the Site. Chemical contaminants can also adversely affect plants and animals in surrounding habitats via the food chain. Contaminants in surface water may be taken up by aquatic life as well as semi-aquatic and terrestrial wildlife.

Upon their release, some site contaminants may be persistent and may be transformed to more bioavailable forms and mobilized in the food chain. Mobilization of contaminants in the terrestrial food chain could occur through the following pathways:

- root uptake from contaminated soil by herbaceous plants,
- contact and absorption, incidental ingestion, and feeding on contaminated food by invertebrates,
- bioaccumulation from vegetation or animal prey at the base of the food chain by wildlife, and
- drinking of contaminated surface water by wildlife.

Like the terrestrial food chain, contaminants could be mobilized in the aquatic food chain through the following pathways:

- uptake and absorption, incidental ingestion, and feeding on contaminated food by aquatic invertebrates, fish, reptiles and amphibians,
- drinking of contaminated surface water by aquatic and semi-aquatic wildlife, and
- bioaccumulation from vegetation or animal prey at the base of the food chain by aquatic and semi-aquatic wildlife.

Based on these pathways, the following general classes of ecological receptors potentially might be exposed to contaminants at the Site:

- terrestrial plants growing around the Site,
- terrestrial invertebrates living in surface soils,

- birds that forage or nest within the Site,
- small mammals that reside and/or feed in the vicinity of the Site,
- other wildlife species (e.g., carnivores) that feed in the Site vicinity, and
- aquatic and semi-aquatic wildlife inhabiting or using the surface water impoundments on the Site.

Based on the potential pathways and receptors identified during field surveys, detrimental effects (i.e., reduced vigor or population decline) in vegetation, invertebrates, fish, small mammals, birds, and carnivores were selected as the assessment endpoints for the ecological risk assessment.

Ecological Effects - As discussed earlier, several Site contaminants are present in surface water, sediment and surface soil and exceed ecological criteria or background levels and therefore, may have adverse effects on biota in the vicinity of the Site. These COPC include:

- **Surface Water** - bis(2-ethylhexyl)phthalate, 4,4'-DDE, 4,4'-DDD, endrin, total PCBs, ^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th, aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, vanadium and zinc.
- **Sediment** - acetone, 4,4'-DDE, 4,4'-DDD, total PCBs, ^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th, aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, vanadium, zinc and cyanide.
- **Surface Soil** - acetone, benzene, 2-butanone, 2-hexanone, methylene chloride, 4-methyl-2-pentanone, tetrachloroethene, acenaphthene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i) perylene, benzo(a)pyrene, bis(2-ethylhexyl)phthalate, carbazole, chrysene, dibenz(a,h)anthracene, dibenzofuran, fluorene, fluoranthene, indeno(1,2,3-cd)pyrene, 2-methylnaphthalene, naphthalene, phenanthrene, pyrene, endrin, total PCBs, ^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th, aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, thallium, vanadium, zinc and cyanide.

Descriptions of the environmental fate and transport of these chemicals, as well as

bioaccumulation potential and toxicity, with regard to various aquatic and terrestrial organisms, are included as Appendix P.

7.5.2.3 Receptor Species

Receptor species chosen were considered representative of the local wildlife populations that would use and frequent the Site. The species were selected based on their potential exposure (i.e., Site usage, food habitats, home range size) and susceptibility to adverse effects of the Site contaminants.

Aquatic and Semi-Aquatic Receptor Species - Following is a brief description of the habitat requirements and diet of the aquatic and semi-aquatic receptor species selected for the Site. In addition, the reasons for selection of these species are discussed.

- **Aquatic Invertebrates, Fish, Reptiles and Amphibians.** The small surface water bodies on the Site may provide habitat for communities of benthic invertebrates, fish, reptiles (e.g., turtles) and/or amphibians (e.g., frogs). These groups occupy the lower end of the food chain and can be sensitive indicators of environmental contamination. Therefore, they were selected as assessment endpoints. The measurement endpoints for aquatic biota include published ambient surface water quality criteria or surface water toxicity reference values for each contaminant, as well as sediment screening values.

- **Mallard (*Anas platyrhynchos*).** The mallard is the most abundant of the United States ducks. It feeds mostly on aquatic plants, seeds, and aquatic invertebrates, depending on the season, and forages in ponds and wetlands by dabbling and filtering through sediments. Home range size has been measured between 270 and 1500 acres (USEPA, 1993).

  The mallard has been selected to represent the semi-aquatic avian community at the Site. It is a common game species likely to utilize the surface impoundments at the Site. This species represents omnivorous feeders, consuming both aquatic plants and invertebrates.

  Measurement endpoints for the mallard are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Meadow Vole (*Microtus pennsylvanicus*).** The meadow vole is the most widely distributed small grazing herbivore in North America and is found

over most of the northern half of the United States. The meadow vole tends to inhabit moist to wet habitats and is a strong swimmer. Meadow voles consume green succulent vegetation, sedges, seeds, roots, bark, fungi, insects and animal matter. Home ranges have been measured between 0.0005 and 0.2 acres (USEPA, 1993).

The meadow vole has been chosen to represent the small mammal community of the forested wetlands at the Site. This species represents herbivorous feeders, consuming primarily vegetation. Measurement endpoints for the vole are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Raccoon (*Procyon lotor*).** The raccoon is the most abundant and widespread medium-sized omnivore in North America. Raccoons are found near virtually every aquatic habitat, using surface waters for both drinking and foraging (USEPA, 1993). Omnivorous and opportunistic feeders, raccoons will change their activity period to adapt to the availability of food and water. Raccoons feed primarily on fleshy fruits, nuts, acorns, and corn but also eat grains, insects, frogs, crayfish and virtually any animal and vegetable matter. Home ranges have been measured between 96 and over 6,000 acres (USEPA, 1993).

  The raccoon has been chosen to represent the semi-aquatic mammal community at the Site. This species, known to inhabit the Site, represents omnivorous feeders, consuming both aquatic plants and invertebrates as well as other aquatic organisms.

  Measurement endpoints for the raccoon are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

Terrestrial Receptor Species

Following is a brief description of the habitat requirements and diet of the terrestrial receptor species selected for the Site. In addition, the reasons for selection of these species are discussed.

- **Herbaceous Vegetation.** Plants that occur in wooded and disturbed areas in the north-eastern United States are likely to occur at the Site. These plants include herbaceous species that serve as an important food source for songbirds, small mammals, and larger herbivores. The measurement endpoints for terrestrial vegetation are published phytotoxicity reference values for each COPC.

- **American Robin (*Turdus migratorius*).** The American robin occurs throughout most of the continental United States during the breeding season and winters in the southern half of the United States and in Mexico and Central America. Robins forage on the ground in open areas, along habitat edges, or the edges of streams. They forage by hopping along the ground in search of ground-dwelling invertebrates and by searching for fruit and foliage-dwelling insects in shrubs and low tree branches. Foraging home ranges of 0.4 to 2.0 acres have been measured (USEPA, 1993). In the months preceding and during the breeding season, robins feed mainly (greater than 90 percent by volume) on invertebrates and on some fruits; during the remainder of the year, their diet consists primarily (over 80 to 99 percent by volume) of fruits (USEPA, 1993).

  The robin has been selected to represent the songbird community at the Site. Although other small bird species are known to occur at the Site, habitat conditions for the robin at the Site are considered good. Also, as a receptor with an omnivorous diet that includes both plants and invertebrates, the robin represents herbivorous and insectivorous small birds in the Site vicinity.

  Measurement endpoints for the robin are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Deer Mouse (*Peromyscus maniculatus*).** The deer mouse is resident and common in nearly every dry-land habitat within its range, including short-grass prairies, grass-sage communities, coastal sage scrub, sand dunes, wet prairies, upland mixed and cedar forests, deciduous forests, ponderosa pine forests and other habitats (USEPA, 1993). Deer mice are omnivorous and highly opportunistic. They eat principally seeds, arthropods, some green vegetation, roots, fruits and fungi as available. Home ranges of 0.03 to 0.3 acres have been measured (USEPA, 1993).

  The deer mouse has been selected to represent the small mammal community at the Site. As an omnivorous species, the deer mouse represents herbivorous and insectivorous small mammals present at the base.

  Measurement endpoints for the deer mouse are derived from rodent toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

- **Red Fox (*Vulpes vulpes*).** Red foxes are present throughout the United States, except in the southeast, extreme southwest and parts of the central states. Red fox prey extensively on mice and voles but also feed on other

small mammals, insects, hares, game birds, poultry and occasionally seeds, berries and fruits (USEPA, 1993). The home range of this species varies between 141 and 8,447 acres (USEPA, 1993).

The red fox has been selected to represent the terrestrial carnivore community at the Site. Bald eagle and peregrine falcon are other potential receptor species, but the home ranges are much larger than that of the fox, and their use of the Site itself is not likely to be significant.

Measurement endpoints for the fox are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms.

7.5.2.4 Ecological Conceptual Site Model

Following recent USEPA guidance (USEPA, 1992), a conceptual model was developed to evaluate how chemical stressors from the Site may influence ecological components of the natural environment (Figure 7-3). This model illustrates the relationship between the ecosystem at risk, including the assessment receptor species, and the chemical/radiological stressors. In addition, the contaminated media, exposure routes, and environmental transport mechanisms are identified in the conceptual Site model.

Ecological receptors which are evaluated in the risk assessment include representative species of terrestrial habitats (herbaceous plants, small mammals, small birds and carnivores) that are likely to use the Site. Effects evaluated are based on published scientific studies and will include the estimated/calculated or predicted effects of the COPC and ROPC on the survival, growth, and reproduction of these receptors. Toxicity data used in the assessment are given in Appendix P.

7.5.3 Exposure Assessment

7.5.3.1 Exposure Point Concentrations

Exposure media of ecological concern at the Site include surface soils, surface water and sediment. Maximum exposure point concentrations were considered for terrestrial and semi-aquatic wildlife receptors, to provide a conservative estimate of exposure. A maximum exposure scenario was also considered for benthic invertebrates, other aquatic biota and

terrestrial vegetation, because they are either immobile or have limited mobility. In this case, the maximum value best represents the exposure received by the most exposed individual and therefore is a conservative estimate of the exposure experienced by the population. Exposure point concentrations (EPCs) which were calculated for the maximum exposure scenario are the maximum of the detected concentrations of COPC and ROPC in each medium. EPCs are given in Table 7-44.

7.5.3.2 Exposure Scenarios and Pathways

Exposure factors for the receptor species were derived or obtained from published sources (primarily the USEPA's Wildlife Exposure Factors Handbook, USEPA, 1993). Exposure durations of eight months per year were used for the American robin to account for the migratory behavior of this bird (one-third of the year is spent overwintering away from the Site). Exposure factors are given in Table 7-45.

To estimate exposure through the terrestrial food chain, bioaccumulation factors (BAFs) for soils were derived from published sources. Using these BAFs, tissue levels in potential prey items of the receptor species were calculated for the maximum scenario. Where BAFs were not available, the prey tissue concentration was assumed to be equal to the soil concentration. Plant and earthworm uptake factors are given in Table 7-46, and estimated tissue concentrations for plants and invertebrates are given in Table 7-47.

7.5.3.3 Exposure Estimates

Chemical Exposure - Estimated chemical exposures for terrestrial herbaceous vegetation and terrestrial invertebrates were derived from the maximum surface soil concentrations of the COPC. Dietary exposure and exposure from ingestion of soil and water for each wildlife species were calculated using equations derived from USEPA's "Wildlife Exposure Factors Handbook" (USEPA, 1993), as described below.

Semi-aquatic and Terrestrial Wildlife

Estimates of exposure to contaminants in soil or sediment via ingestion were made

for the mallard, raccoon, American robin, deer mouse and red fox by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$$EE_{soil/sed} = (C \times FS \times IR_{total} \times FR) / BW$$

where:

$EE_{soil/sed}$	=	Estimated exposure to soil or sediment (mg/Kg-day)
C	=	Maximum contaminant concentration in soil or sediment at the Site (mg/Kg dry weight)
FS	=	Fraction of soil or sediment in diet (as percentage of diet on a dry-weight basis divided by 100; unitless)
IR_{total}	=	Food ingestion rate on a dry-weight basis (Kg/day)
FR	=	Fraction of total food intake from the Site (size of site ÷ home range; unitless)
BW	=	Body weight (Kg)

The food ingestion rate on a dry-weight basis was estimated based on body weight (USEPA, 1993):

Birds: IR_{total} (Kg/day) = $0.0582\ BW^{0.651}$ (Kg)

Mammals: IR_{total} (Kg/day) = $0.0687\ BW^{0.822}$ (Kg)

Estimates of exposure to contaminants via dietary sources (e.g., vegetation and invertebrates) were made for the wildlife receptors by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$$EE_{diet} = \sum_{k=1}^{m} (C_k \times FR_k \times NIR_k)$$

where:

EE_{diet} = Estimated exposure from diet (e.g., in mg/Kg-day)

for the mallard, raccoon, American robin, deer mouse and red fox by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$$EE_{soil/sed} = (C \times FS \times IR_{total} \times FR) / BW$$

where:

$EE_{soil/sed}$	=	Estimated exposure to soil or sediment (mg/Kg-day)
C	=	Maximum contaminant concentration in soil or sediment at the Site (mg/Kg dry weight)
FS	=	Fraction of soil or sediment in diet (as percentage of diet on a dry-weight basis divided by 100; unitless)
IR_{total}	=	Food ingestion rate on a dry-weight basis (Kg/day)
FR	=	Fraction of total food intake from the Site (size of site ÷ home range; unitless)
BW	=	Body weight (Kg)

The food ingestion rate on a dry-weight basis was estimated based on body weight (USEPA, 1993):

Birds: IR_{total} (Kg/day) = $0.0582\ BW^{0.651}$ (Kg)

Mammals: IR_{total} (Kg/day) = $0.0687\ BW^{0.822}$ (Kg)

Estimates of exposure to contaminants via dietary sources (e.g., vegetation and invertebrates) were made for the wildlife receptors by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993), as follows:

$$EE_{diet} = \sum_{k=1}^{m} (C_k \times FR_k \times NIR_k)$$

where:

EE_{diet} = Estimated exposure from diet (e.g., in mg/Kg-day)

C_k	=	Maximum contaminant concentration in the kth type of food - vegetation, invertebrates and/or small mammals (e.g., in mg/Kg wet weight).
FR_k	=	Fraction of intake of the kth food type that is contaminated (unitless).
NIR	=	Normalized ingestion rate of the kth food type on a wet weight basis (e.g., in g/g-day).
m	=	Number of contaminated food types

Estimates of exposure to contaminants in surface water via ingestion were made for the receptors by using equations adapted from USEPA's Wildlife Exposure Factors Handbook (USEPA, 1993) as follows:

$$EE_{water} = C \times FR \times NIR$$

where:

EE_{water}	=	Estimated exposure through ingestion of water (e.g., in mg/Kg BW-day).
C	=	Maximum contaminant concentration in the contaminated water source (e.g., in mg/L).
FR	=	Fraction of total water ingestion from the contaminated water source (unitless).
NIR	=	Normalized water ingestion rate (i.e., fraction of body weight consumed as water per unit time typically in g/g-day).

The estimated exposure concentrations for the mallard and raccoon are given in Table 7-48, and the estimated exposure concentrations for the American robin, deer mouse and red fox are given in Table 7-49.

Radiological Exposure - Radiological exposure for aquatic organisms was calculated based on methodology contained in "Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment" (Baker and Soldat,

1992). Separate calculations were performed for internal and external dose rates. The internal total-body dose rate to an organism for N radionuclides is given as (Baker and Soldat, 1992):

$$R_c = \sum_{i=1}^{N} b_{i,c} E_{i,c}$$

where:

R_c = dose rate to total body of organism c (rad/d)

$E_{i,c}$ = effective absorbed energy rate for nuclide i per unit activity in organism c (Kg rad Ci^{-1} d^{-1})

$E_{i,c} = \epsilon_{i,c}$ MeV dis^{-1} x 3.70E+10 dis s^{-1} Ci^{-1} x 86,400 s d^{-1} x 1.602E-11 Kg rad MeV^{-1} = 5.12E+04 $\epsilon_{i,c}$

where ϵ is the effective absorbed energy for nuclide i in organism c.

$b_{i,c}$ = specific body burden of nuclide i in organism c (Ci Kg-1).

For a primary organism, such as an aquatic plant, invertebrate or fish,

$$b_{i,c} = C_{i,c} B_{i,c}$$

where $C_{i,c}$ is the concentration of nuclide i in water to which organism c is exposed (Ci m^{-3}), and $B_{i,c}$ is the bioaccumulation factor for nuclide i and organism c (m3 Kg^{-1}). Bioaccumulation factors and values for ϵ were taken from Baker and Soldat, 1992.

The external pathways for an aquatic organism include immersion in water and contact with bottom sediment. From Soldat, Robinson and Baker (1974), the water immersion dose rate in rad d^{-1} from N nuclides is (Baker and Soldat, 1992):

$$R_{imm} = \sum^{N} C_{i,c} DF_{imm,i} F_{exp}$$

$i = 1$

where $DF_{imm,i}$ is the water immersion dose factor for nuclide i, rad d^{-1} per Ci m^{-3} and F_{exp} is the exposure fraction (unitless). $DF_{imm,i}$ values for each radionuclide were taken from Baker and Soldat, 1992. The values for F_{exp} used were 1 for an aquatic plant (100% of the external dose is assumed to be from water immersion), 0.5 for an aquatic invertebrate (50% of the external dose is assumed to be from water immersion) and 0.75 for a fish (75% of the external dose is assumed to be from water immersion).

The model for the direct irradiation dose from bottom sediment or mud is similar to the shoreline dose equation of Soldat, Robinson, and Baker (1974). For N nuclides, the dose rate in rad d^{-1} is (Baker and Soldat, 1992):

$$R_{sed} = F_{sed} F_{ruf} F_{exp} \sum_{i=1}^{N} C_{i,c} DF_{gnd,i} (1-\exp^{-\lambda_r T_s})/\lambda_r$$

where:

F_{sed} =	sediment deposition transfer factor, 0.07 Ci m^{-2} d^{-1} Ci^{-1} m^3 (Soldat, Robinson, and Baker, 1974)
F_{ruf} =	geometry-roughness factor (unitless)
$DF_{gnd,i}$ =	ground irradiation dose factor for nuclide i, rad d^{-1} Ci^{-1} m
T_s =	time sediment is exposed to contaminated water, d
λ_r =	effective decay constant of nuclide in organism (d^{-1})

For this equation, T_s is assumed to be 1 year or 365 days. The geometry-roughness factor modifies the "infinite plane" dose factor to account for the height of the organism above the surface, the relative size of the contaminated area, and the roughness of the surface, which causes scattering of the photons emitted from the sediment surface. The roughness factor is assumed to be 0.2, which is the normal shore-width factor for humans standing on the

shore of a river (Baker and Soldat, 1992). The exposure fraction is the fraction of time the organism spends exposed to the medium. Values used for F_{exp} are 0 for the aquatic plant (0% of the external dose is assumed to be from sediment), 0.5 for the aquatic invertebrate (50% of the external dose is assumed to be from sediment) and 0.25 for the fish (25% of the external dose is assumed to be from sediment). The value for λ_r is taken to be that of "Standard Man" as derived from Publication 2 of the International Commission on Radiological Protection (ICRP, 1959), and as used in Baker and Soldat, 1992.

Estimation of radiation doses to semi-aquatic and terrestrial ecological receptors were conducted using equations adapted from the Hanford Site Ecological Risk Assessment (DOE, 1996), as follows:

$$\text{Dose (rad/d)} = (5.11 \times 10^{-5})\,(\text{MeV})(C)$$

where:

5.11×10^{-5} = Constant (rad d^{-1} pCi^{-1} g MeV^{-1} disintegration)

MeV = Mean energy of decay (MeV per disintegration)

C = Radionuclide concentration in organism (pCi/g dry weight).

The constant was derived as follows:

$$5.11 \times 10^{-5} = (A)(B)(C)(D)(E)(F)(G)$$

where:

A = 1 Ci/10^{12} pCi

B = 3.7×10^{10} disintegrations/Ci-sec

C = 3,600 sec/hr

D = 24 hr/d

E = 10^6 eV/MeV

F = 1.6×10^{-12} erg/eV

G = 1 rad-g/100 ergs.

The above equation is modified as follows, to calculate radiation dose to plants:

$$D_{Pr}\ (rad/d) = (5.11x10^{-5})(MeV_{Pr})(C_{Pr})$$

where:

MeV_{Pr} = Average effective energy of decay of radionuclide r in the plant

C_{Pr} = Concentration of radionuclide r in plant (pCi/g = $[C_{sr}][B_{vr}]$), where

C_{sr} = Concentration of radionuclide r in soil (pCi/g)

B_{vr} = Soil-to-plant concentration factor (unitless) for radionuclide r.

Expanding this equation to express radiation dose as a function of soil concentration,

$$D_{Pr}\ (rad/d) = (5.11 \times 10^{-5})(MeV_{Pr})(C_{sr})(B_{vr})$$

The derivation of the radiation dose to herbivores is similar to the derivation of chemical dose and the radiation dose to the plant. The estimated dose is:

$$D_{Hr}\ (rad/d) = (5.11 \times 10^{-5})(MeV_{Hr})(C_{Hr})$$

where the terms are defined in the same manner as for the plant and C_{Hr} (the radionuclide concentration in the receptor) is calculated similarly, yielding the following equation:

$$C_{Hr} = (C_{Pr})(IR_H)(FI_H)(B_{Hr})(0.4)(0.001)$$

where:

C_{Hr} = Contaminant concentration in herbivore (pCi/g wet weight)

C_{Pr} = Contaminant concentration in plant (pCi/g dry weight)

IR_H = Ingestion rate of plants by herbivore (g/day)

FI_H = Fraction ingested by a herbivore from a contaminated source (unitless) = 1.0

B_{Hr} = Plant-to-muscle transfer factor (day/Kg). (ingestion-to-beef transfer factors from "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture" [Baes et al., 1984] will be used)

0.4 = wet weight/dry weight conversion (DOE-RL 1994)

0.001= Kg/g (conversion factor for plant-to-beef transfer factors, which have units of days/Kg).

Expanding the equation yields:

$$D_{Hr} = (C_{Pr})(IR_H)(FI_H)(B_{Hr})(0.4)(0.001)(5.11 \times 10^{-5})(MeV_{Hr})$$

or, expanding further for C_{Pr} yields:

$$D_{Hr} = (C_{sr})(B_{vr})(IR_H)(FI_H)(B_{Hr})(0.4)(0.001)(5.11 \times 10^{-5})(MeV_{Hr})$$

The derivation of radiation doses for carnivores is similar to the derivation of doses for herbivores and chemical doses for carnivores. The concentration of radionuclides in a carnivore is calculated as:

$$C_{Cr} = (C_{Hr})(IR_C)(FI_C)(B_{mmr})$$

where:

C_{Cr} = Radionuclide concentration in carnivore (pCi/g wet weight)

C_{Hr} = Radionuclide concentration in herbivore (pCi/g wet weight)

IR_C = Ingestion rate of herbivores by carnivore (Kg/day)

FI_C = Fraction ingested by a carnivore from a contaminated source (unitless)

B_{mmr} = Muscle-to-muscle transfer factor (assumed to be 1.0)

The resulting equation for radiation dose, expanding the above equation is:

$$D_{Cr} = (C_{sr})(B_{vr})(0.4)(0.001)(FI_H)(IR_H)(B_{Hr})(5.11 \times 10^{-5})(MeV_{Cr})(IR_C)(FI_C)(B_{mmr})$$

Radiation doses to omnivores (e.g. raccoon) were calculated based upon the above

equations, taking into account the percentage of plant material and prey the omnivore ingests.

7.5.4 Ecological Effects Criteria

Toxicity reference values (TRVs) were derived for aquatic life, plants, terrestrial invertebrates and other wildlife as described below:

Aquatic Organisms - USEPA and New York State Ambient Water Quality Criteria (AWQC) or other criteria were used as TRVs to assess potential risks to aquatic organisms. AWQC are non-regulatory values based on scientific assessment of ecological effects. Other TRVs were taken from the available literature (e.g., Suter and Tsao, 1996) and include: USEPA Tier II Secondary Chronic Values (chronic values established with fewer data than are required for the National AWQC); lowest chronic values for aquatic biota reported in the literature; and other toxicity data such as LC_{50}s. The lowest available TRV for each COPC in surface water were used for the assessment. Radiation doses to aquatic organisms for each of the ROPC were compared with the benchmark dose of 1 rad/d suggested by the National Council on Radiation Protection and Measurements (NCRP, 1991) as protective of aquatic organisms.

Terrestrial Plants and Invertebrates - The TRVs used to evaluate the toxicity of a given COPC to terrestrial plants and soil invertebrates (e.g., earthworms) were derived from the available literature. Phytotoxic values represent the lowest values from toxicity studies conducted in the field or in greenhouse and growth chamber settings (Will and Suter, 1995a). Soil TRVs based on earthworm toxicity represent data provided by toxicity studies in the field or in laboratory settings (Will and Suter, 1995b).

Wildlife - TRVs for mammals and birds chosen as receptor species were derived based on methodology presented by Sample et al. (1996). This general method is based on USEPA methodology for deriving human toxicity values from animal data. In this method, experimentally derived No Observed Adverse Effect Levels (NOAELs) or Lowest Observed Adverse Effect Levels (LOAELs) are used to estimate NOAELs for wildlife by adjusting the dose according to differences in body size. For mammals, NOAELs for laboratory species

obtained from the literature were converted to receptor species NOAELs as follows (Sample et al., 1996):

$$NOAEL_r = NOAEL_t \, (bw_t/bw_r)^{1/4}$$

where:

$NOAEL_r$ = receptor species NOAEL

$NOAEL_t$ = test species NOAEL

bw_r = receptor body weight

bw_t = test species body weight

For birds, if a NOAEL was available for an avian test species, the equivalent NOAEL for an avian receptor species was calculated by using the adjustment factor for differences in body size (Sample et al., 1996) as follows:

$$NOAEL_r = NOAEL_t \, (bw_t / bw_r)^0 = NOAEL_t \, (1) = NOAEL_t$$

TRVs for mammals and birds are included in Tables 7-50 and 7-51, respectively. Radiation doses for each of the ROPC were compared with the benchmark dose of 0.1 rad/d suggested by the International Atomic Energy Agency (IAEA, 1992) as protective of terrestrial organisms.

7.5.5 Chemical Risk Characterization

The ecological risks posed by the COPC at the Site are identified and summarized in this risk characterization. Risk characterization involves two major steps: risk estimation and risk description (USEPA, 1992). The risks were estimated using general comparisons and hazard quotients (HQs) calculated with estimated exposure and toxicity reference values for each receptor species. The principal uncertainties of the assessment are discussed in Section 7.5.7. The risks are summarized and the ecological significance of the findings and recommendations for further study are presented in Section 7.5.8.

7.5.5.1 Aquatic Receptor Species

In comparing Site surface water and sediment concentrations to ecological criteria, the maximum concentrations detected at the Site and the lowest available TRV for each COPC were used to provide a conservative assessment of potential risk. The maximum concentrations were divided by the TRVs for each COPC to produce a Hazard Quotient (HQ). The Hazard Quotient Method characterizes possible ecological hazard as the ratio of the concentration in the environmental medium to the corresponding toxicity benchmark. If an HQ exceeds one, there is concern for possible adverse effects. The results of these comparisons are shown in Tables 7-52 and 7-53.

As shown in Table 7-52, the maximum concentrations of all of the surface water COPC exceeded the lowest available TRVs, with the exception of chromium. The Hazard Quotients (HQs) ranged from 0.37 for chromium to 9,100 for 4,4'-DDD. No TRVs were available for ^{226}Ra, ^{228}Ra, ^{230}Th or ^{232}Th. Therefore, no conclusions can be drawn regarding the potential risk to aquatic biota from these COPC.

As shown in Table 7-53, the HQs for all of the sediment COPC exceeded one. The HQs ranged from 2.34 for copper to 168 for arsenic. TRVs were not available for ^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{232}Th, barium, beryllium, magnesium, selenium, silver, vanadium and cyanide. Therefore, no conclusions can be drawn regarding the potential risk to aquatic biota from the presence of these COPC in sediment.

Although an investigation of Glen Cove Creek was not included as part of this RI, there exists the potential for surface water from the site to discharge into the creek. Surface water and sediment sampling was conducted in Glen Cove Creek in 1990 and 1995 for the Mattiace Petrochemical Site. The results of these sampling events are shown in Tables 7-54 and 7-55 and in Appendix Q. AWQC for marine waters were not available for many of the constituents detected in the creek. The maximum concentrations of tetrachloroethene, trichloroethene, gamma-chlordane, mercury, silver and zinc in surface water, however, exceeded the lowest available AWQC. Hazard quotients ranged from three for trichloroethene to 130,435 for silver, as shown in Table 7-54. Also, most of the constituents detected in sediment in the creek exceeded the sediment TRVs, as shown in Table 7-55.

Hazard quotients ranged from 0.03 for bis(2-ethylhexyl)phthalate to 266,667 for endosulfan sulfate. As shown above, concentrations of many of the COPC in on-site surface water and sediment also exceed TRVs. Any contribution of contaminants to Glen Cove Creek from the site can be considered detrimental to aquatic biota in the creek, considering the high HQs of constituents both on-site and in the creek.

There also exists the potential for groundwater from the site to discharge into the creek. Therefore, concentrations of chemicals in groundwater were compared with New York State and USEPA AWQC, as a conservative screening. Table 7-56 shows the results of this screening. HQs for the volatile compounds 1,1-dichloroethene (total), ethylbenzene, tetrachloroethene, toluene, 1,1,1-trichloroethane and trichloroethene exceeded one, and ranged from 5.13 (1,1,1-trichloroethane) to 155 (trichloroethene). The HQs for the semi-volatile compounds bis(2-ethylhexyl)phthalate, 1,2-dichlorobenzene, naphthalene and phenol exceeded one, and ranged from 1.1 (phenol) to 9.8 (naphthalene). HQs exceeded one for all of the pesticides except for aldrin, and ranged from 1.2 (gamma-BHC) to 565 (endrin). Likewise, HQs for all of the inorganic compounds (including cyanide) exceeded one, except for chromium and thallium, and ranged from 18.5 (selenium) to 127,241 (copper). It should be noted that this comparison does not take into account dilution upon entering Glen Cove Creek. For the semi-volatile compounds, it is likely that groundwater would be diluted enough upon discharge to the creek to bring these compounds below the AWQC. For the inorganics, particularly copper, with very high HQs, dilution is unlikely to significantly reduce risk to aquatic resources in the creek. This is especially true for creek sediments, which already contain high concentrations of chemicals. Also, since AWQC for marine waters were not available for various compounds, (shown as "NA" in Table 7-56) no conclusions can be drawn regarding their potential for affecting aquatic resources in Glen Cove Creek.

7.5.5.2 Semi-aquatic Receptor Species

In evaluating the potential risks of COPC to semi-aquatic wildlife, the total estimated exposures (EE_{total}) for the mallard and raccoon, shown in Table 7-48, were divided by each

COPC's toxicity reference value (Tables 7-50 and 7-51) to produce a Hazard Quotient (HQ) for each receptor (for each COPC). The results of this comparison are shown in Table 7-54. Calculations are given in Appendix P.

As shown in Table 7-54, HQs for all of the COPC (for which TRVs were available) exceeded one for the mallard. HQs ranged from 0.002 for uranium-238 to 2,350 for selenium. TRVs were not available for the mallard for acetone, radium, thorium, uranium, antimony, beryllium, cobalt, iron, magnesium, silver and cyanide.

For the raccoon, HQs for acetone, 4,4'-DDD, 4,4'-DDE, uranium, thorium, chromium, mercury and cyanide were below one, indicating no potential risk from these COPC. HQs for the remaining COPC (for which TRVs were available) were greater than one. HQs ranged from 0.007 for chromium to 39,800 for selenium. A TRV was not available for radium.

7.5.5.3 Terrestrial Receptor Species

Terrestrial plants and invertebrates (e.g., earthworms) inhabiting the soils at the Site have the potential to take up the COPC from the soil. In addition to potential toxic effects on these organisms themselves, there exists the possibility of movement of COPC through the food chain via consumption of plants and invertebrates. In evaluating toxic effects on terrestrial plants and invertebrates, the maximum soil concentrations detected at the Site were compared with appropriate TRVs taken from the literature, as discussed in Section 7.5.4. Although, in general, the top 12 inches of soil is the zone of greatest impacts to wildlife, the maximum value of all of the soil results (including samples taken at depths greater than 12 inches) were used to provide a conservative estimate of risk. The results of this comparison are shown in Table 7-55.

As shown in Table 7-55, the maximum concentrations of most of the soil COPC (for which TRVs were available) exceeded the plant TRVs, with the exception of acenaphthene, dibenzofuran and PCBs. HQs for plants ranged from 0.001 for dibenzofuran to 1,620 for chromium. The maximum concentrations of most of the soil COPC also exceeded the earthworm TRVs (where TRVs were available), with the exception of fluorene and endrin.

Earthworm HQs ranged from 0.007 for endrin to 4,050 for chromium.

In evaluating the potential risks of COPC to terrestrial wildlife, the total estimated exposures (EE_{total}) for each receptor, shown in Table 7-49 were divided by each COPC's toxicity reference values (Tables 7-50 and 7-51) to produce a Hazard Quotient (HQ) for each receptor, for each COPC. If an HQ exceeds one, there is concern for possible adverse effects. The results of this comparison are shown in Table 7-56. Calculations for the American robin, deer mouse and red fox are given in Appendix P.

As shown in Table 7-56, HQs for the American robin for endrin and uranium were less than one, indicating no potential risk from these COPC. HQs for the remaining COPC (for which TRVs were available) were greater than one. HQs for the American robin ranged from 0.6 for endrin to 2,380 for zinc. TRVs for the robin were not available for any of the volatile or semi-volatile COPCs, radium, thorium, antimony, beryllium, cobalt, iron, magnesium, silver, thallium or cyanide.

HQs for the deer mouse for acetone, benzene, 2-butanone, 2-hexanone, methylene chloride, 4-methyl-2-pentanone, tetrachloroethene, all of the semi-volatiles (except benzo(b)fluoranthene), endrin, uranium, thorium, chromium, mercury and cyanide were below one, indicating no potential risk for these COPC. The remaining COPC (for which TRVs were available) had HQs greater than one. HQs for the deer mouse ranged from 6.23E-08 for thorium-230 to 7,660 for arsenic. TRVs were not available for carbazole, dibenzofuran or radium.

For the red fox, HQs for acetone, benzene, 2-butanone, 2-hexanone, methylene chloride, 4-methyl-2-pentanone, tetrachloroethene, all of the semi-volatiles (except for benzo(b)fluoranthene and pyrene), uranium, thorium, chromium, mercury and cyanide were below one, indicating no potential risk for these COPC. The remaining COPC (for which TRVs were available) had HQs greater than one. Red fox HQs ranged from 1.17E-07 for thorium-230 to 14,400 for antimony. TRVs were not available for carbazole, dibenzofuran or radium.

7.5.6 Radiological Risk Characterization

The ecological risks posed by the ROPC at the Site are identified and summarized in this risk characterization. The risks were estimated using hazard quotients (HQs) calculated with estimated radiation dose and toxicity reference values for each receptor species. The principal uncertainties of the assessment are discussed in Section 7.5.7. The risks are summarized and the ecological significance of the findings and recommendations for further study are presented in Section 7.5.8.

7.5.6.1 Aquatic Receptor Species

In evaluating the potential ecological risk to aquatic species from the presence of radionuclides in surface water and sediment, the internal and external doses (in rad/d) were added. The total doses were compared to the TRV for radiological exposure (1 rad/d) as recommended by the NCRP (1991) as protective of aquatic organisms. The doses for the radionuclides detected at the Site (^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th and ^{232}Th) were calculated as well as the doses for the daughter products (^{234}U, ^{210}Pb and ^{228}Th). Results of this comparison are shown in Table 7-57. Calculations are given in Appendix P. HQs for all of the aquatic receptors (aquatic plant, aquatic invertebrate and fish) were below one for all of the ROPC, indicating no potential risk to aquatic organisms.

7.5.6.2 Semi-aquatic Receptor Species

In evaluating the potential ecological risk to semi-aquatic species from the presence of radionuclides in sediment, the internal dose (in rad/d) for each receptor was calculated. The internal doses were compared to the TRV for radiological exposure (0.1 rad/d) as recommended by the IAEA (1992) as protective of terrestrial organisms. The doses for the radionuclides detected at the Site (^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th and ^{232}Th) were calculated as well as the doses for the daughter products (^{234}U, ^{210}Pb and ^{228}Th). Results of this comparison are shown in Table 7-58. Calculations are given in Appendix P. HQs for all of the semi-aquatic receptors (plant, meadow vole and raccoon) were below one for all of the ROPC, indicating no potential risk to semi-aquatic organisms.

7.5.6.3 Terrestrial Receptor Species

In evaluating the potential ecological risk to terrestrial species from the presence of radionuclides in surface soil, the internal dose (in rad/d) for each receptor was calculated. The internal doses were compared to the TRV for radiological exposure (0.1 rad/d) as recommended by the IAEA (1992) as protective of terrestrial organisms. The doses for the radionuclides detected at the Site (^{238}U, ^{226}Ra, ^{228}Ra, ^{230}Th and ^{232}Th) were calculated as well as the doses for the daughter products (^{234}U, ^{210}Pb and ^{228}Th). Results of this comparison are shown in Table 7-59. Calculations are given in Appendix P. HQs for all of the terrestrial receptors (plant, deer mouse and red fox) were below one for all of the ROPC, indicating no potential risk to terrestrial organisms.

7.5.7 Uncertainty Analysis

Uncertainty is inherent in the process of conducting predictive risk assessments. Environmental sampling and analysis and exposure calculations are prone to uncertainty, as are the available toxicity data used to characterize risks.

Uncertainty associated with environmental sampling is generally related to the limitations of the sampling program in terms of the number and distribution of samples, while uncertainty associated with the analysis of the samples is generally related to systematic or random errors. Aspects of the current exposure assessment methodology can result in overestimation or underestimation of long-term exposure. For example, on Parcel A, many of the surface soil samples were collected from under pavement. This soil is not likely to be contacted by ecological receptors in the present usage of the Site, but may be contacted in the future, if pavement is removed. Soil samples which were collected from under pavement include the following: SB-01, SB-02, SB-03, SB-04, MP-21D, MP-17D, MP-2D, GM-2 (all on Parcel A); and MP-4D and GM-15 (on Parcel C).

Uncertainty is also inherent in the selection of receptor species. While the wildlife receptors chosen are considered to be appropriate for the Site, other species which were not chosen are likely to be present, and could possibly be more sensitive than the chosen receptors. The uncertainty involved with the selection of receptors is assumed to be low,

since the range of sensitivity for most species may be covered with the chosen receptors.

Another point of uncertainty lies in the assumption that each of the wildlife receptor species feeds only on food items found in the area of concern. For species with very small home ranges, this assumption is likely to be accurate. However, several of the receptors may consume food sources other than those considered in the assessment, the exclusion of which could either over- or underestimate the potential risk. It is also possible that receptors may not feed entirely within the Site, but may forage in other areas as well. In addition, the average weights and daily intakes used for the receptor species do not take into account smaller and larger individuals, and young of the species, which may be more or less sensitive to contaminants than the average-sized adult.

The use of plant and earthworm uptake factors in the exposure assessment may also result in over- or underestimating the potential risk. The amount of a contaminant which is taken up by plants and earthworms from soil depends, in part, on site-specific soil conditions such as organic content, soil type contaminant concentration and the presence of other chemicals in the soil.

In most cases, the NOAELs that form the basis of the assessments are derived by extrapolation of laboratory animal data to wildlife. There may be differences in sensitivity to chemicals between two species that adjusting for body weight may not account for. The lack of toxicity data for various chemicals also adds uncertainty to the assessment.

For surface soil, the maximum concentrations detected at the Site were used in the assessment. If the 95% UCL concentrations are used in estimating exposure for the American robin, deer mouse and red fox, the resulting HQs (and therefore, potential risks) are lower, as illustrated in Table 7-60. Calculations are given in Appendix P. Using the 95% UCLs for surface soil and the average surface water concentrations of COPC, the HQ for the American robin is less than one (no potential risk) for endrin. For the deer mouse, HQs for benzo(b)fluoranthene, pyrene, endrin, beryllium and mercury are less than one (no potential risk) using the 95% UCL concentrations rather than the maximum concentrations. For the red fox, HQs for benzo(b)fluoranthene, pyrene, endrin, beryllium and mercury are less than one.

Overall, a generally conservative approach was taken in the preceding evaluation, including:

- the use of maximum chemical concentrations
- the comparison of maximum chemical concentrations in surface soil with maximum soil background concentrations
- the selection of COPC for surface water and sediment based on exceedance of criteria or guideline values.

This approach is consistent with USEPA guidance (USEPA, 1994) which states that "it is important to minimize the chance of type II error (the likelihood that the actual risk is greater than that predicted)". It is therefore probable that this assessment tends to overestimate risk rather than underestimate risk to receptor species.

7.5.8 Conclusions and Recommendations

The results of the ecological assessment are presented in Tables 7-61 and 7-62. For the chemical risk characterization, all of the COPC (except for chromium) in surface water had HQs which exceeded one. In sediment, all of the COPC had HQs which were greater than one. HQs for the mallard were greater than one for all COPC except uranium-238. HQs for the raccoon exceeded one for PCBs and seventeen inorganic COPC. Terrestrial plant HQs were greater than one for all COPC except mercury and earthworm HQs for nine inorganic COPC exceeded one. For the American robin, HQs were greater than one for PCBs and thirteen inorganic COPC. HQs for the deer mouse and the red fox were greater than ***one*** for PCBs and eighteen inorganic COPC. Based on use of the 95% UCL soil concentrations, HQs for the robin exceeded one for PCBs and twelve inorganic COPC, HQs for the mouse exceeded one for PCBs and seventeen inorganic COPC and HQs for the fox excceded one for PCBs and seventeen inorganic COPC.

Most of the COPC shown in Table 7-62, particularly arsenic, copper, lead, nickel, selenium and zinc, exhibit high HQs for most of the receptors chosen for this Site. It is recommended that the potential risks to wildlife with respect to these COPC in surface water,

sediment and surface soil be considered during remedial efforts at the Site.

With regard to the radiological risk characterization, none of the radionuclides evaluated in the assessment showed potential risk in surface water, sediment or surface soil. No further investigation is recommended regarding these ROPC at the Site.

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8.0 SUMMARY AND CONCLUSIONS

8.1 SUMMARY

The source of much of the contamination at the Site is the tungsten ore residues that were previously left on-site or currently remain buried on-site. Prior to the start of this RI, approximately 3,000 - 4,000 cubic yards of the ore residues were present on the Site in drums, wooden crates and mounds both inside some of the buildings and outside on driveways and walkways, primarily on Parcel A, but also to a lesser extent on Parcel C. These ore residues were temporarily relocated to the Dickson Warehouse as part of the 1995-1996 IRAs described in Section 1.3.3. Ore residues remain on-site in middle portion of Parcel B that is believed to have been used as a disposal area and the "scarred" vegetation area in the northern portion of Parcel C that was also used as a disposal area for ore residues. Other primary contaminant sources include the Mud Pond and two Mud Holes which were used for disposal of process wastewater; underground storage tanks on Parcel A; and a 500,000-gallon aboveground fuel oil tank on Parcel C. Other secondary sources of contamination include the on-site storm sewer pipes and groundwater from three off-site sources: the Mattiace Petrochemical NPL site, the Konica Imaging, USA, Inc., property (formerly Powers-Chemco) and the Crown-Dykman site across Herb Hill Road from the main entrance to Parcel A.

The field investigation was designed to confirm contamination in areas with known or suspected contamination and characterize areas where there was little or no previous information. In areas of known or suspected contamination, "source area" soil borings, radiological borings and monitoring wells were located on the three. Areas where little or no information was available included soils the area between the Dickson Warehouse and the Benbow Building, the deeper groundwater zones in the Upper Glacial Aquifer and soils along the route of the storm sewer pipes.

8.1.1 Nature and Extent

8.1.1.1 Surface and Subsurface Soils

Many of the contaminants that were found occurred in areas that were known or suspected to have contamination. A recurring pattern is evident by examining where individual constituents

in each of the five main analytical parameter groups (e.g., inorganics, radionuclides, SVOCs, VOCs and pesticides/PCBs) were detected at concentrations exceeding either USEPA soil screening values or NYSDEC guidance values. The pattern that recurs is that several of the same areas repeatedly show exceedances for more than one constituent group. For example, in the middle portion of Parcel B, the concentration of SVOCs, pesticides/PCBs, inorganics and radionuclides all exceed regulatory guidance levels; in the upper and lower portions of Parcel C, the concentration of SVOCs, inorganics and radionuclides exceed regulatory guidance levels. Other areas which also exhibit exceedances but for only one or two analytical groups include: the northwest corner of Parcel A (outside of the fence) near the intersection of Herb Hill Road and Dickson Lane (inorganics and radionuclides); the bulkhead area (radionuclides); and the area between the Dickson Warehouse and the Benbow Building (inorganics and radionuclides). VOCs were only found in very low concentrations in the soils along Herb Hill Road on Parcel A and the lower portions of Parcel B.

8.1.1.2 Groundwater

A similar distribution pattern was also seen in the groundwater. The areas where contamination was found included an area on Parcel C and C′ north of the Mattaice Petrochemical Site (VOCs, SVOCs, pesticides/PCBs and inorganics); the lower portion of Parcel C in the vicinity of the 500,000-gallon aboveground fuel oil tank, Mud Pond and the two Mud Holes (VOCs, SVOCs, pesticides/PCBs, inorganics and radionuclides); and the middle portion of Parcel A/lower portion of Parcel B (VOCs, inorganics and radionuclides). Other areas where contamination was found included the middle portion of Parcel B (VOCs); the bulkhead area (SVOCs); the upper portion of Parcel C (radionuclides).

8.1.1.3 Surface Water

Surface water samples contained trace to low levels of volatiles, semi-volatiles and pesticides/PCBs. Surface water standards for many of the inorganics in samples collected from both the wetlands and ponds were exceeded. One surface water sample (SW-8) on Parcel B exceeded both the regulatory standard for ^{226}Ra and the combined standard for ^{226}Ra and ^{228}Ra.

8.1.1.4 Sediment

Sediment samples were collected from locations where surface water samples were collected. Sediment results for VOC, SVOC, inorganics, pesticides and PCBs were compared to the NYSDEC TAGM values; radiological parameters were compared to background concentrations. Most of the samples exceeded TAGM guidance values for the chemical constituents with the SVOCs and inorganics exhibiting the most exceedances. The concentration of each radionuclide in the two samples collected on Parcel B (SED-8 and SED-9) and one sample on the upper portion of Parcel C (SED-10) were all less than the site-specific background level.

8.1.1.5 Storm Sewer Sediment

Storm sewer sediment results for VOC, SVOC, inorganics, pesticides and PCBs were compared to the NYSDEC TAGM values; radiological parameters were compared to background concentrations. Similar to the sediment samples, most of the storm sewer samples exceeded TAGM guidance values for the chemical constituents with the SVOCs and inorganics exhibiting the most exceedances. The majority of all storm sewer sediment samples exceeded 1.5X the site-specific background concentration of the five radionuclides. The exception occurred in sample SED-DP-29 where the concentration of ^{232}Th and ^{226}Ra were below the site-specific background concentration.

8.1.2 Fate and Transport

Several processes appear to be responsible for the transport and fate of organic and inorganic compounds in the various environmental media at the Site. Evidence indicates that advection, dispersion and facilitated transport are major mechanism for transport of compounds. Preferential flow along flow paths adjacent to man-made subsurface infrastructure such as storm sewer lines amplifies the effect of these mechanisms. Biodegradation of some organic compounds, and sorption of organic and inorganic compounds with affinity for the surfaces of immobile soil particles seem to be important mechanisms for their attenuation.

The low frequency of detection of volatile organic compounds (VOCs) indicates that their transport and degradation are likely. Many of the VOCs detected were found at low concentration, and given the general biodegradability of these compounds, it is likely that biodegradation is a

mechanism for their removal. The data on semi-volatile organic compounds (SVOCs) indicate that lower molecular weight compounds are transported and biodegraded, but higher molecular weight compounds are sorbed and subsequently attenuated on immobile soil particles.

A comparison of data from filtered and unfiltered groundwater samples indicate that facilitated transport is a major mechanism for transport of metals. Complexation and solubilization leading to transport of metals by advection and dispersion appears to occur but to a lesser degree than facilitated transport. The transport mechanism affecting metals will also influence radionuclides but to a lesser extent due to the low solubility of the radionuclides.

8.1.3 Risk Assessment

Potential human health and ecological risks, currently and in the future, in the absence of any major action to control or mitigate radiological and chemical contamination, are evaluated in the Baseline Risk Assessment.

Human Health Evaluation

The human health evaluation addresses the consequences of reasonable maximum exposure to radionuclides and chemicals of potential concern from hypothetical current and future exposure scenarios in the absence of remedial action at the Site. Based on the analytical results, soil data are evaluated by subdividing the Site into four areas, Areas A, B, B&C, and C. Sediment data are evaluated by parcel, while groundwater data are evaluated site-wide. Potentially exposed populations in the current scenario include off-site residents and trespassers, while potentially exposed populations in the future scenario include site workers (assuming the Site is developed for industrial/commercial use), resident adults and children (assuming the Site is developed for residential use), and construction workers. Carcinogenic risks are estimated for potential exposure to the radionuclides of potential concern, the chemicals of potential concern, and both the radionuclides and the chemicals of potential concern. Noncarcinogenic risks are estimated for potential exposure to the chemicals of potential concern only as noncarcinogenic risks do not result from exposure to the radionuclides of potential concern.

Radiological Risk - Radionuclide analyses of soil samples indicate that thorium and uranium series radionuclides are present on all parcels at concentrations which exceed the range of natural background. For several of the current and future populations evaluated, the lifetime cancer risk due to exposure to these radioactive contaminants exceeds both the post-remediation risk range generally deemed acceptable at CERCLA sites as well as the dose-based risk levels currently used to evaluate the impact of residual radioactivity at facilities formerly licensed to possess radioactive materials. As reflected in the risk calculations, the most highly contaminated soils were found in Area B&C; however, samples containing elevated radionuclide concentrations were collected from all areas (and all parcels) of the Site. As radionuclide concentrations in sediments were within the background range, they do not pose any above background risk to current or future populations. It is unclear if radionuclides have migrated to groundwater. The sum of the ^{226}Ra and ^{228}Ra concentrations in several wells ranged from 5-20 pCi/L, which exceed the 5 pCi/L maximum contaminant level (MCL) for drinking water set by the USEPA. However, these include the background Konica well and background well MP-11D. Uranium-238 concentrations were, for the most part, less than 5 pCi/L, although three deep monitoring wells had approximately 30-80 pCi/L. Similarly, while most groundwater data for thorium were less than 1 pCi/L, three wells had ^{232}Th and ^{230}Th concentrations ranging from 3-9 pCi/L. These fluctuations in concentrations of naturally occurring radionuclides may reflect regional variability.

Chemical Risk - A number of inorganic chemicals in soil pose carcinogenic and noncarcinogenic risks for one or more potentially exposed population in excess of the USEPA acceptable levels, including:

- arsenic and cobalt in soil at Area A;
- arsenic, cobalt, antimony, nickel, and manganese in soil at Area B;
- arsenic, antimony, manganese, and cobalt in soil at Area B&C; and
- Arsenic, antimony, manganese, cobalt, and silver in soil at Area C.

In most cases, however, the estimated risks are based on potential exposure to the maximum detected concentrations of the inorganic chemicals. In addition, lead was detected in soil at all areas in concentrations in excess of the USEPA interim soil lead guidance criterion for residential land use and soil lead guidance range for industrial land use.

A number of inorganic chemicals in surface water and/or sediment pose carcinogenic and noncarcinogenic risks for trespassers in excess of the USEPA acceptable levels, including:

- antimony, arsenic, cadmium, aluminum, and nickel in surface water at Parcel B; and
- arsenic in sediment at Parcel C.

In all cases, the estimated risks are based on potential exposure to the maximum detected concentrations of the inorganic chemicals. In addition, lead was detected in sediment at Parcel C in concentrations in excess of the USEPA interim soil lead guidance criterion for residential land use and soil lead guidance range for industrial land use.

1,2-Dichloroethene, tetrachloroethene, trichloroethene, vinyl chloride, arsenic, and antimony in shallow groundwater underlying the Site would pose carcinogenic and noncarcinogenic risks in excess of the USEPA acceptable levels if this groundwater were to be used for potable purposes. However, while evaluated because groundwater is a sole source aquifer, potable use of the shallow groundwater underlying the site in the future is unlikely due to the availability of a municipal water supply.

Radiological and Chemical Risk - Despite the differences in the quantitative approach to assessing radiological and chemical carcinogenic risks, it is not inappropriate to sum the risks estimates for populations that may be exposed to both types of contaminants. The resultant combined risks provide the best estimate of the total estimated carcinogenic impact of site contaminants on potentially exposed populations. Potential exposures to the current scenario off-site resident adult, the current and future scenario adolescent trespasser at Area B&C, the future scenario construction worker at Area B&C, and the future scenario site worker, resident adult, and resident child at all areas result in estimated total cancer risks greater than the USEPA acceptable risk range. The predominant contributor (i.e., radiological or chemical) and the predominant environmental medium (i.e., air, soil, or groundwater) to the total estimated cancer risks varies.

Ecological Assessment

The ecological assessment addresses the consequences of exposure to COPC and ROPC to aquatic, semi-aquatic and terrestrial wildlife receptors. These receptors include: aquatic invertebrates, fish, reptiles and amphibians; mallard, meadow vole; raccoon; herbaceous terrestrial

vegetation; American robin; deer mouse and; red fox. Estimates of chemical and radiological exposure were made for the receptors, and the exposure concentrations were compared with toxicity reference values (TRVs) using the Hazard Quotient (HQ) method.

For the chemical risk characterization, most of the COPC in surface water had HQs that exceeded 1. In sediment, HQs for acetone, 4,4'-DDE, 4,4'-DDD, PCBs and twelve inorganic COPC were greater than 1. HQs for the mallard were greater than 1 for 4,4'-DDE, 4,4'-DDD, 4,4'-DDT and 13 inorganic COPC. HQs for the raccoon exceeded 1 for PCBs and 17 inorganic COPC. Terrestrial plant HQs were greater than 1 for 18 inorganic COPC and earthworm HQs were greater than 1 for nine inorganic COPC. For the American robin, HQs were greater than 1 for PCBs and 13 inorganic COPC. HQs for the deer mouse were greater than 1 for benzo(b)fluoranthene, PCBs and 18 inorganic COPC. HQs for the red fox were greater than 1 for benzo(b)fluoranthene, pyrene, endrin, PCBs and 18 inorganic COPC. Based on use of the 95% UCL soil concentrations, HQs for the robin exceeded 1 for twelve inorganic COPC, HQs for the mouse exceeded 1 for PCBs and 16 inorganic COPC and HQs for the fox exceeded 1 for PCBs and 17 inorganic COPC. Many of the COPC, particularly arsenic, copper, lead, nickel, selenium and zinc, exhibit high HQs for most of the receptors chosen for this site.

With regard to the radiological risk characterization, none of the ROPC evaluated in surface water, sediment or surface soil were found to pose risks.

It is recommended that the potential risks to wildlife with respect to COPC in surface water, sediment and surface soil be considered during remedial efforts at the Site. No further investigation is recommended for the ROPC at the Site, with regard to ecological receptors.

8.2 CONCLUSIONS AND RECOMMENDATIONS

8.2.1 Data Limitations and Recommendations for Future Work

The quality of the data collected during the RI at the Site is sufficient to have characterized the Site for the purposes of preparing a FS which will identify an environmentally sound and cost-effective Remedial Alternative(s). Additional studies may be necessary as part of the FS in order to properly Remedial Alternatives including:

- Additional soil and groundwater sampling and analysis to evaluate natural attenuation of contaminants at the site including analysis for dissolved oxygen, ORP, pH, nitrogen and phosphorus;
- Treatability studies for metal removal including chemically- and/or biologically-based remedial technologies;
- Treatability studies for solidification/stabilization of soil contaminated with hazardous or radiological waste, or residual tungsten ore prior to land disposal;
- Groundwater modeling to delineate groundwater contaminant plumes, and to predict fate and transport of contaminant plumes.

Following completion of the FS for this Site, is may be necessary to collect additional pre-design data to design and implement the selected Remedial Alternative(s). The information which will be required will vary, based on the nature of the selected Remedial Alternative(s). Depending on the selected Remedial Alternative, the following pre-design activities may be required:

- Sampling from selected perimeter wells to confirm the horizontal extent of the groundwater contaminant plume immediately prior to application of a remedy;
- Installation and sampling of additional monitoring wells to confirm the vertical extent of the contaminant plume immediately prior to application of a remedy;
- Installation of interceptor trenches or other passive collection systems.

8.2.2 Preliminary Remedial Action Objectives

As stated in the NCP, the selected Remedial Alternative should be protective of human health and the environment, maintain the protection over time, and minimize the amount of untreated waste (40 CFR, Part 300.430). CERCLA, Section 121, includes a preference for remedial actions that permanently and significantly reduce the volume, toxicity, or mobility of the hazardous substances, pollutants and contaminants as a principal element. CERCLA, Section 121, also requires that remedial actions meet any federal standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate requirements (ARARs). If state ARARs are more stringent than federal ARARs, then the state ARARs must be met. CERCLA, Section 121, also

identifies six circumstances in which ARARs can be waived. ARARs can be contaminant-specific, action-specific, or location-specific.

As outlined in the Work Plan (Malcolm Pirnie, 1993), the FS for the Site will evaluate a range of appropriate remedial alternatives for the Site. The first step of the FS will be to develop Remedial Action Objectives for the Site based on ARARs; non-ARARs which are to be considered materials (TBCs), including NYSDEC TAGMs; and the potential risks to human health and the environment posed by the Site. The Remedial Action Objectives will be as specific as possible without limiting the range of Remedial Alternatives which can be developed during the FS. Remedial Action Objectives will be developed for each media of concern, including surface and subsurface soils, groundwater, surface water and sediment. Objectives for remedial action will take into account protection of existing wildlife habitat and will balance reduction of chemical risk to wildlife receptors with physical risks such as potential destruction of habitat.

Based on the nature of the Site, Remedial Action Objectives are likely to include the items listed in the conclusions and recommendations section above.

- Excavation and disposal of ore residues on Parcels B and C;
- Removal and disposal of ore residues being stored in the Dickson Warehouse;
- Excavation of contaminated soils;
- Monitoring of natural attenuation of contaminants in soil and groundwater;
- Application of an in-situ remedy for soil and groundwater contamination to meet ARARs and to be protective of the human health and the environment.

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10.0 GLOSSARY

10.1 Abbreviations and Acronyms

ABBREVIATION/ACRONYM	
ABS	Absorption Rate
ACGIH	American Conference of Governmental and Industrial Hygienists
ACM	Asbestos Containing Material
ACOE	Army Corps of Engineers
AEA	Atomic Energy Act
AF	Soil-to-Skin Adherence Factor
ALARA	As Low As Reasonably Achievable
AOC	Administrative Order on Consent
APT	Ammonium Paratungstate
ARARs	Applicable or Relevant and Appropriate Requirements
ARCS	Alternative Remedial Contracting Strategy
ASTM	American Society of Testing Materials
AT	Averaging Time
ATSDR	Agency for Toxic Substance and Disease Registry
ATV	All-terrain vehicle
AWQC	Ambient Water Quality Criteria
BAFs	Bioaccumulation Factors
BEIR	Committee on the Biological Effects of Ionizing Radiation
BN	Bings-Norton
BNA	Base-Neutral/Acid Extractables
BOD	Biological Oxygen Demand
Bq	Becquerel
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
BW	Body Weight
CAA	Clean Air Act

CDI	Chronic Daily Intakes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulation
Ci	Curie
CLP	Contract Laboratory Program
cm	Centimeter
CMP	Coastal Management Plan
CO	Contracting Officer (USEPA)
COD	Chemical Oxyen Demand
COPC	Chemical of Potential Concern
CPF	Carcinogenic Potency Factor
CRQL	Contract Required Quantification Limit
DOE	Department of Energy
DOT	Department of Transportation
DQO	Data Quality Objectives
EA	Ecological Assessment
ED	Exposure Duration
EE_{total}	Total Estimated Exposures
EF	Exposure Frequency
EqP	Equilibrium Partitioning Approach
EPCs	Exposure Point Concentrations
ER-L	Effects Range-Low
ER-M	Effects Range-Medium
ESD	Environmental Services Division (USEPA)
ET	Exposure Time
FACW	Faculative Wetlands Plants
FAR	Federal Acquisition Regulation
FI	Fraction Ingested
FIT2	Field Investigation Team - USEPA Region II
FOL	Field Operations Leader

FOP	Field Operations Plan
FRC	Federal Radiation Council
FS	Feasibility Study
FSP	Field Sampling Plan
FUSRAP	Formerly Utilized Sites Remedial Action Program
GCDC	Glen Cove Development Corporation
GM	Geiger Mueller
G&M	Geraghty & Miller, Inc.
Gr	Gray
Hart	Fred C. Hart Associates, Inc.
HASP	Health and Safety Plan
HEA	Health Effects Assessments
HEAST	Health Effects Assessment Summary Tables
HQ	Hazard Quotients
HRS	Hazardous Ranking System
ICRP	International Commission on Radiological Protection
IR	Ingestion Rate
IRA	Interim Remedial Action
IRIS	Integrated Risk Information System
LLRWPA	Low Level Radioactive Waste Policy Act
LNAPL	Light Non-Aqueous Phase Liquid
LOAEL	Lowest Observed Adverse Effect Level
LSA	Low Specific Activity
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDC	Minimum Detectable Concentration
MeV	Mega-electron Volts
MPI	Malcolm Pirnie, Inc.
mrem	millirem
mR/h	milliRoentgen per hour
MSL	Mean Sea Level

NAAQS	National Ambient Air Quality Standards
NaOH	Sodium Hydroxide
NAPL	Non Aqueous Phase Liquid
NAS	National Academy of Sciences
NCDOH	Nassau County Department of Health
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NDL	The NDL Organization, Inc.
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NORM	Naturally Occurring Radioactive Material
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NRC	National Reconditioning Company
NRC	Nuclear Regulatory Commission
NTU	Nephelometric Turbidity Unit
NUS	Halliburton-NUS, Inc.
NWI	National Wetland Inventory
NYCRR	New York Codes, Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDOS	New York State Department of State
NYSWQS	New York State Water Quality Standards and Guidance Values
OBL	Obligate
OSC	On Scene Coordinator
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
OVA	Organic Vapor Analyzer
PA	Preliminary Assessment

PAH	Polycyclic Aromatic Hydrocarbons
PC	Permeability Coefficient
PCB	Polychlorinated Biphenyls
PCE	Perchloroethylene
pCi/g	picoCurie per gram
pCi/L	picoCurie per Liter
PIC	Pressurized Ion Chamber
PLM	Polarizing Light Microscopy
PMO	Program Management Office
POC	Principal Organic Contaminant
POTW	Publicly-Owned Treatment Works
PRAP	Preferred Remedial Alternative Plan
PRP	Potentially Responsible Party(ies)
PVC	Polyvinyl chloride
QAPjP	Quality Assurance Project Plan
QF	Quality Factor
Ra	Radium
RAB	Removal Action Branch (USEPA)
RAGS	Risk Assessment Guidance (USEPA)
RAS	Routine Analytical Services
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Daily Allowance
R	Roentgen
rem	rem
RfC	Reference Concentration
RfD	Reference Dose
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
RMPP	Radon Measurement Proficiency Program
ROD	Record of Decision
ROPC	Radionuclide of Potential Concern

RPM	Remedial Project Manager
RSCC	Regional Sample Control Center
RTP	RTP Environmental Associates, Inc.
SA	Surface Area
SARA	Superfund Amendments and Reauthorization Act of 1986
SAS	Special Analytical Services
SBE	Small Business Enterprise
SDBE	Small Disadvantaged Business Enterprise
SDWA	Safe Drinking Water Act
SF	Slope Factor
SFMP	Remote Surplus Facilities Management Program
SGVs	Sediment Guideline Values
SHPO	State Historic Preservation Officer
SM	Site Manager
SMO	Sample Management Office
SMP	Site Management Plan
SOP	Standard Operating Procedure(s)
SPT	Standard Penetration Test
SPDES	State Pollution Discharge Elimination System
SSL	Soil Screening Level
Sv	Sievert
SVOC	Semi-Volatile Organic Chemical
TAGM	Technical Assistance Guidance Memorandum (NYSDEC)
TAL	Target Analyte List
TBC	"To Be Considered" Material
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
TDS	Total Dissolved Solids
TEM	Transmission Electron Microscopy
TERM	Technically Enhanced Radioactive Material
Th	Thorium

TIC	Tentatively Identified Compounds
TLV	Threshold Limit Value
TOC	Total Organic Carbon
TRVs	Toxic Reference Values
TSS	Total Suspended Solids
TSCA	Toxic Substance Control Act
µg/Kg	microgram per Kilogram
µg/L	microgram per Liter
µR/h	microRoentgen per hour
U	Uranium
UCL	95% Upper Confidence Limit
UMTRCA	Uranium Mill Tailing Radiation Control Act
USACOE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	Volatile Organic Compounds
WAM	Work Assignment Manager
WCC	Wah Chang Corporation
WCSRC	Wah Chang Smelting and Refining Corporation
WET	Wetlands Evaluation Technique
WL	Working Level

10.2 Radiological Terms

Action level:

A derived, media-specific concentration or activity level for a hazardous substance that (1) is based on a primary dose or risk limit and (2) triggers a response, such as further investigation or cleanup, if exceeded. See *investigation level.*

Activity:

See *radioactivity.*

ALARA (acronym for As Low As Reasonably Achievable):

A basic concept of radiation protection which specifies that exposure to ionizing radiation and releases of radioactive materials should be reduced as far below regulatory limits as is reasonably achievable considering economic, technological, and societal factors, among others. Reducing exposure at a site to *ALARA* strikes a balance between what is possible through additional remediation and the use of additional resources to achieve a lower level. A determination of *ALARA* is a site-specific analysis that is open to interpretation, because it depends on approaches or circumstances that may differ between regulatory agencies. An *ALARA* recommendation should not be interpreted as a set limit or level. An example of one approach to performing a site-specific *ALARA* analysis can be found in Appendix G of the NRC draft report NUREG-1500 (Daily, et al., 1994).

Alpha particle:

A positively charged particle emitted by some radioactive materials undergoing *radioactive decay.*

Background radiation:

Radiation from cosmic sources; *naturally occurring radioactive material,* including radon (except as a decay product of *source* or *special nuclear material)*; and global fallout as it exists in the environment from the testing of nuclear explosive devices or from nuclear accidents like Chernobyl which contribute to *background radiation* and are not under the control of the licensee. *Background radiation* does not include radiation from *source, byproduct,* or *special nuclear materials* regulated by the NRC.

Becquerel (Bq):

The International System (SI) unit of activity equal to one nuclear transformation (disintegration) per second. 1 *Bq* = 2.7×10^{-11} *Curies (Ci)* = 27.03 picocuries (pCi).

Beta particle:

An electron emitted from the nucleus during *radioactive decay.*

Biased sample or measurement:

See *judgement sample* or *measurement.*

Chain of custody:

An unbroken trail of accountability--supported by documentation and signatures--that ensures the physical security of samples, data, and records.

Cleanup:

Actions taken to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release of a hazardous substance to the environment. Cleanup is sometimes used interchangeably with the terms *remedial action,* response action, or *removal action.*

Confidence interval:

A range of values for which there is a specified probability (e.g., 80%, 90%, 95%) that this set contains the true value of an estimated parameter.

Contamination:

The presence of *residual radioactivity* in excess of levels which are acceptable for release of a *site* or facility for *unrestricted use.*

Core sample:

A soil sample taken by core drilling.

Corrective action:

An action taken to deal with a release or threat of release of a hazardous substance that could adversely affect humans or the environment or both. Corrective action is sometimes used interchangeably with the terms *remedial action*, response action, or *cleanup.*

Curie (Ci):

The customary unit of radioactivity. One *curie* (Ci) is equal to 37 billion disintegrations per second (3.7×10^{10} dps = 3.7×10^{10} *Bq),* which is approximately equal to the decay of one gram of ^{226}Ra. Fractions of a *curie,* e.g. picocurie (pCi) or 10^{-12} Ci and microcurie (μCi) or 10^{-6} Ci, are levels typically encountered in *decommissioning.*

Decay:

See *radioactive decay.*

Decontamination:

The removal of radiological contaminants from, or their neutralization on, a person, object or area to within levels established by governing regulatory agencies. *Decontamination* is sometimes used interchangeably with *remediation,* remedial action, and *cleanup.*

Direct measurement:

Radioactivity measurement obtained by placing the detector against the surface or in the media being surveyed. The resulting radioactivity level is read out directly.

Dose commitment:

The dose that an organ or tissue would receive during a specified period of time (e.g., 50 or 70 years) as a result of intake (as by ingestion or inhalation) or one or more radionuclides from a given release.

Dose equivalent (dose):

A quantity that expresses all radiations on a common scale for calculating the effective absorbed dose. This quantity is the product of absorbed dose (rads) multiplied by a quality factor and any other modifying factors. Dose is measured in *Sv* or *rem.*

Duplicate:

One of two independent samples collected in such a manner that they are equally representative of the parameter(s) of interest at a given point in space and time.

Exposure pathway:

The route by which radioactivity travels through the environment to eventually cause a radiation exposure to a person or group.

Exposure rate:

The amount of ionization produced per unit time in air by X-rays or gamma rays. The unit of exposure rate is roentgens/hour (R/h); for decommissioning activities the typical units are microroentgens per hour (μR/h), i.e. 10^{-6} R/h.

External radiation:

Radiation from a source outside the body.

Gamma (γ) radiation:

Penetrating high-energy, short-wavelength electromagnetic radiation (similar to X-rays) emitted during *radioactive decay.* Gamma rays are very penetrating and require dense materials (such as lead or uranium) for shielding.

Indistinguishable from background:

The term indistinguishable form background means that the detectable concentration distribution of a radionuclide is not statistically different form the background concentration distribution of that radionuclide in the vicinity of the site or, in the case of structures, in similar materials using adequate measurement technology, survey, and statistical techniques.

Infiltration rate:

The rate at which a quantity of a hazardous substance moves from one environmental medium to another--e.g., the rate at which a quantity of a radionuclide moves from a source into and through a volume of soil or solution.

Inventory:

Total residual quantity of formerly licensed radioactive material at a site.

Investigation level:

A radionuclide specific level of radioactivity that results in additional investigation when it is exceeded. See *action level.*

Lower limit of detection (L_D):

The smallest amount of radiation or radioactivity that statistically yields a net result above the method background. The critical detection level, L_c, is the lower bound on the 95% detection interval defined for L_D and is the level at which there is a 5% chance of calling a background value "greater than background". This value should be used when actually counting samples or making direct radiation measurements. Any response above this level should be considered as above background; i.e., a net positive result. This will ensure 95% detection capability for L_D. A 95% confidence interval should be calculated for all responses greater than L_c.

Minimum detectable concentration (MDC):

The minimum detectable concentration (MDC) is the *a priori* activity level that a specific instrument and technique can be expected to detect 95% of the time. When stating the detection capability of an instrument, this value should be used. The *MDC* is the detection limit. L_D, multiplied by an appropriate conversion factor to give units of activity.

Missing or unusable data:

Data (measurements) that are mislabeled, lost, or do not meet quality control standards. *Less-than data* are not considered to be missing or unusable data. See *R*.

Naturally occurring radionuclides:

Radionuclides and their associated progeny produced during the formation of the earth or by interactions of terrestrial matter with cosmic rays.

Precision:

A measure of mutual agreement among individual measurements, usually under prescribed similar conditions, expressed generally in terms of the *arithmetic standard deviation*.

Qualified data:

Any data modified or adjusted as part of statistical or mathematical evaluation, data *validation*, or data *verification* operations.

Quality:

The totality of features and characteristics of a product or service that bear on its ability to meet the stated or implied needs and expectations of the user.

Quality assurance (QA):

An integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the client.

Quality Assurance Project Plan (QAPP):

A formal document describing in comprehensive detail the necessary *QA, QC*, and other technical activities that must be implemented to ensure that the results of the work performed satisfies the stated performance criteria.

Quality control (QC):

The overall system of technical activities that measure the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the client. *QC* includes operational techniques and activities that are used to fulfill requirements for *quality*.

R:

The rate of missing or unusable measurements expected to occur for samples collected in *reference areas or survey units*. See *missing* or *unusable data*. See n_f (Not to be confused with the symbol of the radiation exposure unit Roentgen.)

Radioactive decay:

The spontaneous transformation of an unstable atom into one or more different nuclides accompanied by either the emission of energy and/or particles from the nucleus, nuclear capture or ejection of orbital electrons, or fission. Unstable atoms decay into a more stable state, eventually reaching a form that does not decay further or has a very long *half-life*.

Radioactivity:

The mean number of nuclear transformations occurring in a given quantity of radioactive material per unit time. The International System (SI) unit of radioactivity is the *Becquerel (Bq)*. The customary unit is the *Curie (Ci)*.

Radiological survey:

Measurements of radiation levels associated with a *site* together with appropriate documentation and data evaluation.

Radionuclide:

An unstable nuclide that undergoes *radioactive decay*.

Rem (radiation equivalent man):

The conventional unit of *dose equivalent*. The corresponding International System (SI) unit is the *Sievert* (Sv): 1 Sv + 100 rem.

Remediation:

The process and associated activities resulting in removal of contamination from a site. Remediation is sometimes used interchangeably with the terms remedial action, response action, or *decontamination.*

Replicate:

A repeated analysis of the same sample or repeated measurement at the same location.

Representative measurement:

A measurement that is selected using a procedure in such a way that it, in combination with other representative measurements, will give an accurate representation of the phenomenon being studied.

Representativeness:

A measure of the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

Reproducibility:

A measure of precision, usually expressed as a variance, that measures the variability among measurement results of the same sample or location by different analysts.

Residual radioactivity:

Radioactivity in structures, materials, soils, groundwater, and other media at a site resulting form activities under the licensee's control. This includes radioactivity from all licensed and unlicensed sources used by the licensee, but excludes background radioactivity. It also includes radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR Part 20.

Restoration:

Actions to return a remediated area to a usable state following decontamination.

Sample:

A part or selection from a medium located in a *survey unit* or *reference area* that represents the quality or quantity of a given parameter or nature of the whole area or unit; a portion serving as a specimen.

Scanning:

An evaluation technique performed by moving a detection device over a surface at a specified speed and distance above the surface to detect elevated levels of radiation.

Sievert (Sv):

The special name for the International System (SI) unit of *dose equivalent.* 1 Sv = 100 *rem* = 1 Joule per kilogram.

Site:

Any installation, facility, or discrete, physically separate parcel of land, or any building or structure or portion thereof, that is being considered for release.

Soil:

The top layer of the earth's surface, consisting of rock and mineral particles mixed with organic matter. A particular kind of earth or ground -- e.g., sandy soil.

Soil activity (soil concentration):

The level of radioactivity present in soil and expressed in units of activity per soil mass (typically Bq/kg or pCi/g).

Split:

A sample that has been homogenized and divided into two or more aliquots for subsequent analysis.

Subsurface soil sample:

A soil sample taken deeper than 15 cm below the soil surface.

Surface contamination:

Residual radioactivity found on building or equipment surfaces and expressed in units of activity per surface area (Bq/m^2 or $dpm/100\ cm^2$).

Surface soil sample:

A soil sample taken form the first 15 cm of surface soil.

Survey:

A systematic evaluation and documentation of radiological measurements with a correctly calibrated instrument or instruments that meet the sensitivity required by the objective of the evaluation.

Survey plan:

A plan for determining the radiological characteristics of a *site*.

Survey unit:

A geographical area of specified size and shape at a remediated site for which a separate decision will be made whether the unit attains the site-specific reference-based cleanup standard for the designated pollution parameter. *Survey units* are generally formed by grouping contiguous site areas with a similar use history and the same classification of contamination potential. Survey units are established to facilitate the survey process and the statistical analysis of survey data.

Working level:

A special unit of radon exposure defined as any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of

potential alpha energy. This value is approximately equal to the alpha energy released from the decay of progeny in equilibrium with 100 pCi of ^{222}Ra.

Validation:

Confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. In design and development, validation concerns the process of examining a product or result to determine conformance to user needs.

Verification:

Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled. In design and development, validation concerns the process of examining a result of a given activity to determine conformance to the stated requirements for that activity.

10.3 Baseline Risk Assessment Terms

Acute Effect:

A toxic effect resulting from exposure to one dose or multiple doses occurring within a short period of time.

Adsorption:

The adhesion of chemicals in a thin layer of molecules to the surfaces of solid bodies (e.g., soil) with which they come in contact.

Assessment Endpoint:

An explicit expression of the environmental value that is to be protected.

Avian:

Of, relating to, or derived from birds.

Baseline Risk Assessment:

An assessment (see Risk Assessment below) conducted to evaluate health risks in the absence of any action to remediate (or clean up) a site.

Benthic:

Of, relating to, or occurring at the bottom of a body of water.

Bioaccumulation:

The net uptake of chemicals by organisms directly from water and/or through consumption of food.

Carcinogen:

A chemical that is capable of increasing the risk of cancer.

Carcinogenesis:

The production of cancer, very likely a series of steps. The carcinogenic event so modifies the genetic material or molecular control mechanisms of the affected cells that they give rise to a population of altered cells, which eventually form a malignant tumor.

Carnivore:

A flesh-eating animal.

Central Tendency Analysis:

An analysis of risks estimated for the average or median individual exposure or dose for the exposed population conducted as an alternative to the Reasonable Maximum Exposure (RME) analysis. It is based on average exposure point concentrations in the different environmental media and 50th percentile exposure parameters. The analysis provides alternative risk estimates which, when compared to the RME risk estimates, allows risks to be characterized as a range. In so doing, the comparison provides a measure of the uncertainty in the baseline risk assessment process.

Chemical of Potential Concern (COPC):

A chemical selected for detailed evaluation in the risk assessment that is representative of the chemical contamination at the site and the health risks posed by those chemicals.

Chronic Daily Intake (CDI):

Rate of exposure to a chemical, expressed as the amount of the chemical people contact each day, averaged over the period of exposure (units = milligrams of chemical per kilogram body weight per day = mg/Kg/d).

Chronic Effect:

A toxic effect resulting from exposure to multiple doses over an extended period of time, typically many years or a lifetime.

Critical Effect:

In the spectrum of toxicity produced by a chemical, the adverse effect that occurs at the lowest dose. As the dose is increased from a no effect level, the critical effect is the first adverse effect to occur.

Data Evaluation:

The component of the risk assessment where relevant site data are compiled and analyzed to select radionuclides and chemicals of potential concern.

Dose:

The amount of a chemical to which a person is exposed (units = milligrams of chemical per kilogram body weight per day = mg/Kg/d). In laboratory studies, the dose is the amount of the test chemical given to each animal every day. USEPA Exposure Assessment Guidelines (57 FR 22888 - 22938, 29 May 92) make the following distinctions:

Absorbed Dose: The amount of the chemical that crosses the outer boundary of the body (e.g., as with dermal exposure) and is available for interaction with biologically significant receptors.
Applied Dose: The amount of a chemical at the absorption barrier of the body (e.g., the lung or the digestive tract) available for absorption.

Dose-Response Relationship:
The quantitative relationship between the amount of exposure to a chemical and the extent of toxic effect produced by that exposure.

Epidemiological Study:
Study of human populations to identify causes of disease. Epidemiology studies often compare the health status of a group of persons who have been exposed to a suspect chemical with that of a comparable, but unexposed, group.

Equilibrium Partitioning (EqP) Approach:
The equilibrium partitioning (EqP) approach to sediment classification focuses on predicting the chemical interaction among sediment, interstitial water (i.e., the water between sediment particles), and contaminants. Chemically contaminated sediments are expected to cause adverse biological effects if the predicted interstitial water concentration for a given contaminant exceeds the chronic water quality criterion for that contaminant.

Excess Lifetime Risk:
The additional or extra risk incurred over the lifetime of an individual. Approximately 20% - 30% of the population will develop cancer during a lifetime; this is the background cancer rate. Excess risk is that level of risk which is in addition to the background rate.

Exposure:
Contact of an organism (human or animal) with a chemical agent. Exposure is quantified as the amount of the chemical coming into contact with the outer boundary of the body. Most of the time, the chemical is contained in air, water, soil or a commercial/industrial product and exposure to the chemical is a result of exposure to the media containing the chemical.

USEPA Exposure Assessment Guidelines (57 FR 22888 - 22938, 29 May 92) provide the following definition: Exposure to a chemical is the contact of that chemical with the external side of the boundary separating the "outside of the body" from the "inside of the body".

Exposure Assessment:
The component of risk assessment that involves determining or estimating the magnitude, frequency, duration, and route of exposure to a chemical in the environment. The exposure assessment considers the nature and size of the exposed population and can focus on past, current, or future exposures, based on different land uses, consumer usage and/or human activity patterns.

USEPA Exposure Assessment Guidelines (57 FR 2288 - 22938, 29 May 92) state that an exposure assessment describes the intensity, frequency and duration of contact, and often evaluates the rates at which the chemical crosses the outer boundary of the body, the resulting amount of the chemical that actually crosses the boundary, and the amount absorbed.

Exposure Pathway:

The physical course a chemical in the environment takes from its source to the point of human exposure. Soil or ground water can represent exposure pathways.

Exposure Point Concentration:

The estimated concentration of radionuclides and chemicals of potential concern at the location or point of contact between an organism and radionuclides or chemicals of potential concern. The exposure point concentration is estimated, for the period of exposure, using site data.

Exposure Route:

The way an environmental chemical enters the body (e.g., ingestion, inhalation, dermal absorption) after contact with a contaminated environmental medium (e.g., soil). Alternatively, the means by which an experimental animal is given a test chemical for evaluation of its toxic properties.

Exposure Scenario:

A set of facts and assumptions about how exposure to an environmental chemical takes place. The exposure scenario aids the risk assessor in quantifying the magnitude of exposure. An exposure scenario is usually defined in terms of human activity related to a specific land use (e.g., residential, occupational, recreational) or consumer activity (e.g., pesticide use, dry cleaning patronage).

Genotoxic:

Damaging to the genetic material (i.e., DNA) of cells in the body.

Gram:

A unit of measure for weight (mass) in the metric system. One gram is equivalent to 0.035 ounces; there are 28 grams in one ounce.

Hazard Quotient:

The ratio of an exposure level of a chemical (usually expressed as the chronic daily intake) to the reference dose or reference concentration for the chemical. The frequency and duration of exposure must be taken into account in estimating the exposure level used in evaluating the hazard quotient.

Herbaceous Vegetation:

Seed plants that lack woody tissue and die to the ground at the end of a growing season.

Herbivore:

A plant-eating animal.

Human Health Risk:

The likelihood (or probability) that an exposure or series of exposures to environmental chemicals may have or will affect the health of the exposed individuals; this health effect may be temporary or permanent.

Incidence:

The number of new cases of disease or a toxic effect in a population during a specified period of time. In a laboratory carcinogenicity study - the percentage of animals with tumors.

Individual Risk:

The probability that a theoretical individual person will experience an adverse effect - most often used in relation to cancer risk.

Intake:

A measure of exposure expressed as the mass of a chemical in contract with the exchange boundary of an individual's body. Intake is expressed in terms of the mass per unit body weight per day (milligrams of chemical per kilogram body weight per day = mg/Kg/d).

USEPA Exposure Assessment Guidelines (57 FR 22888- 22938, 29 May 92) provides the following definition: The process by which a substance crosses the outer boundary of an organism without passing an absorption barrier.

Invertebrate:

An animal lacking a spinal column.

Kilogram:

One thousand grams. One kilogram is equivalent to 2.2 pounds.

Lifetime Average Daily Dose:

Rate of exposure to a chemical, expressed as the amount of the chemical people contact each day, averaged over an entire lifetime (units = milligrams of compound per kilogram body weight per day = mg/Kg/d).

Limited Evidence:

In relation to the Weight of Evidence classification scheme for carcinogens - a collection of facts and accepted scientific inferences which suggest that an agent may be causing an effect, but this suggestion is not strong enough to be considered established fact. Limited evidence indicates that other plausible factors cannot be ruled out as causes.

Linearized Multistage Model (LMS):

The USEPA's default low dose extrapolation model (see below). This is a conservative predictor of cancer risks based on a biological model of cancer initiation and

development. At low (environmentally-relevant) doses the LMS model is linear and predicts an excess cancer risk for any exposure level above zero. In the absence of scientific evidence to the contrary, the USEPA bases cancer risk estimates on an upper bound to the low-dose cancer potency predicted by the LMS model.

Lognormal Distribution:

Data that are distributed such that when plotted show a skewed graph.

Low Dose Extrapolation:

The process of predicting response rates to very low (environmentally-relevant) doses from observed response rates at high (laboratory) doses used in carcinogenicity studies. High-to-low dose extrapolation involves mathematically modeling the biologic processes in carcinogenesis to allow prediction of response rates many orders of magnitude below those observed in the laboratory.

Lowest Observed Adverse Effect Level (LOAEL):

The lowest concentration of a material used in a toxicity test that produces a statistically significant adverse effect on the exposed population of test organisms as compared with the controls.

Microgram (μg):

One-millionth of one gram ($1\mu g = 3.5x10^5$ oz. = 0.000000035 oz.). Also equivalent to one-thousand of one milligram.

Milligram (mg):

One-thousandth of one gram (1 mg $= 3.5x10^5$ oz. = 0.000035 oz.). Also equivalent to one thousand micrograms.

Modifying Factor:

An uncertainty factor used in derivation of reference doses (RfDs) or reference concentrations (RfCs) from experimental data. The modifying factor is set greater than zero and less than or equal to ten; its magnitude reflects professional judgement regarding the quality of the data used for the assessment (e.g., number of species tested, completeness of the overall database).

95% Upper Confidence Limit (95% UCL):

No Data:

In relation to the Weight of Evidence classification scheme for carcinogens - a category of human and animal evidence in which no studies are available to permit one to draw conclusions as to the induction of a carcinogenic effect.

No Evidence:

In relation to the Weight of Evidence classification scheme for carcinogens - a situation in which there is no increased incidence of cancer in at least two well-designed and will-conducted animal studies of adequate power and dose in different species.

No Observed Adverse Effect Level (NOAEL):

In a dose-response experiment, the highest experimental dose at which there was no statistically or biologically significant increase in a toxic effect of the chemical being tested.

Normal Distribution:

Data that are distributed such that when plotted show a bell-shaped graph.

Omnivore:

An animal which consumes both flesh and plants.

One-Hit Model:

Mathematical model based on the biological theory that a single interaction ("hit") of some minimum amount of a carcinogen at a cellular target (e.g., DNA) can initiate an irreversible series of events eventually leading to a tumor.

Phytotoxic:

Toxic to plants.

Potency:

The strength of a chemical at producing a toxic effect, especially cancer. The cancer slope factor is a measure of a carcinogen's potency; the greater the slope factor, the higher the cancer risk for a given level of exposure.

Radionuclide of Potential Concern (ROPC):

A radionuclide selected for detailed evaluation in the risk assessment that is representative of the radiological contamination at the site and the health risks posed by those chemicals.

RAGS:

Shorthand for the USEPA's Risk Assessment Guidance for Superfund which provides the basic guidance for conducting baseline risk assessments.

Reasonable Maximum Exposure (RME):

The usual exposure conditions recommended for evaluation in a risk assessment by the USEPA. RME is to represent the highest exposure that may reasonably be expected to occur at the site, that is, one that is well above the average case of exposure by within the range of possibility. In practice, RME is evaluated by considering average concentrations of the chemicals (or radionuclides) of concern and upper bound (i.e., 90th or 95th percentile) exposure parameters.

Receptor:

The entity (e.g. organism, population, community, ecosystem) that might be adversely affected by contact with or exposure to a substance of concern.

Reference Concentration (RfC):

An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of the daily inhalation exposure level to the human population (including sensitive subpopulations) that is likely to be without appreciable risk of deleterious effects during a lifetime. The RfC is expressed in units of milligrams of chemical per cubic meter of air (mg/m^3).

Reference Dose (RfD):

An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without appreciable risk of deleterious effects during a lifetime. The RfD is expressed in units of milligrams of chemical per kilogram body weight per day (mg/Kg-day).

Respirable Particulates:

Particles (e.g., soil particles) that when suspended in air are of a size (i.e., usually less than 10 microns in mean aerodynamic diameter) that may penetrate into the deeper portions of the respiratory system of the body when inhaled.

RESRAD:

A computer model developed by researchers at Argonne National Laboratory for calculating exposure pathway-specific radiation dose equivalents and carcinogenic risk resulting from exposure to radioactive materials in soil.

RESRAD-Baseline:

A related computer model developed by researchers at Argonne National Laboratory which uses user-supplied, environmental medium-specific radionuclide concentrations in environmental media other than soil and, following RAGS methodology, calculates carcinogenic risk.

Risk:

Probability of injury, disease, or death under specific circumstances. In quantitative terms, risk is expressed in values ranging from zero (no possibility of harm) to one (a certainty that harm will occur). The following are some examples of the manner in which risk is expressed:

1E-4	$= 1x10^{-4}$	= 1/10,000	= 0.0001	= risk of one in ten thousand
1E-5	$= 1x10^{-5}$	= 1/100,000	= 0.00001	= risk of one in one hundred thousand
1E-6	$= 1x10^{-5}$	= 1/1,000,000	= 0.000001	= risk of one in one million
1.3E-4	$= 1.3x10^{-4}$	= 1.3/10,000	= 1/7700	= 0.00013 = risk of one in seven thousand seven hundred

Risk Assessment:

The process of evaluating the probability of injury, disease or death from exposure to chemicals in the environment. Risk assessment usually involves evaluating the toxic properties of a chemical and the conditions of human exposure to it both to ascertain the likelihood that exposed humans will be adversely affected, and to characterize the nature of the effects they may experience.

Risk Characterization:

Final component of risk assessment that involves integration of the data and analysis involved in data evaluation, exposure assessment, and toxicity assessment to determine the likelihood that humans will experience any of the various forms of toxicity associated with the chemical being assessed.

Route of Exposure:

See Exposure Route.

Slope Factor:

The slope of the dose-response curve in the very low dose range (typically between zero and approximately one percent response). The slope factor is a measure of the cancer potency of a chemical for use with exposures expressed in terms of dose as milligrams of chemical per kilogram body weight per day. The cancer slope factor is a plausible upperbound estimate of the probability of developing cancer from a unit exposure to the chemical being assessed. The slope factor is used to generate an upperbound estimate of excess cancer risk from a lifetime average daily dose expressed in mg/Kg/d.

Species:

A group of closely related, morphologically similar individuals which interbreed.

Stressor:

Any physical, chemical or biological entity that can induce an adverse response.

Sufficient Evidence:

In relation to the Weight of Evidence classification scheme for carcinogens - a collection of facts and scientific evidence which is definitive enough to establish that the adverse effect is caused by the agent in question.

Systemic Toxicity:

Toxic effects observed at a site or sites distant from the entry point of a chemical into the body. The chemical must be absorbed and distributed throughout the body to its site of toxic action. Most chemicals that produce systemic do not cause a similar degree of injury in all organs; they usually produce toxicity in only one or two organs (these are referred to as the target organs).

Target Organ:

See Systemic Toxicity.

Threshold Dose:

The dose or level of exposure to a chemical below which no toxic effect occurs. Toxicity only becomes apparent when exposure exceeds the threshold. The implication of a threshold is that there are levels of exposure below which there is no risk of health impairment.

ToxicityAssessment:

Also termed the dose-response assessment, the component of risk assessment that describes the quantitative relationship between the amount of exposure to a chemical and the extent of toxic effects or disease. This involves evaluating toxicity information and characterizing the quantitative relationship between the chemical dose administered or received and the incidence of toxic effects in the exposed population (human or laboratory animals). From the quantitative dose-response relationship, toxicity values are derived that are used in the risk characterization step to estimate the likelihood of adverse effects occurring in humans at different exposure levels.

Toxicity Criterion:

A numerical expression of a chemical's dose-response relationship for use in risk assessment. The most common toxicity values are reference doses and reference concentrations (for assessment of non-cancer toxicity) and cancer slope factors (for assessment of cancer risk).

Uncertainty Factors:

Factors used in derivation of reference doses (RfDs) or reference concentrations (RfCs) form experimental data. The RfD/RfC is set by dividing a NOAEL ro LOAEL by uncertainty factors to account for:

(a) the variation in susceptibility among individuals of the human population;

(b) the uncertainty in extrapolating animal data to the case of humans;

(c) the uncertainty in extrapolating from data obtained in a less-than-lifetime study to a lifetime exposure level; and

(d) the uncertainty in using LOAEL data rather than NOAEL data.

Usually these factors are set equal to ten for each applicable area of uncertainty and are multiplied together, thus the total uncertainty adjustment may range form 10-fold to 10,000-fold.

Upperbound Estimate:

An estimate that is thought to be higher than a true, but unmeasurable, value. In cancer risk assessment, the upperbound risk estimate is thought to be a plausible upper limit to the risk that is consistent with a proposed mechanism of carcinogenesis. It is recognized that the true value of risk is likely to be lower than the upperbound estimate.

Weight-of-Evidence:

A USEPA classification system for characterizing the extent to which the available data indicate that an agent is a human carcinogen.