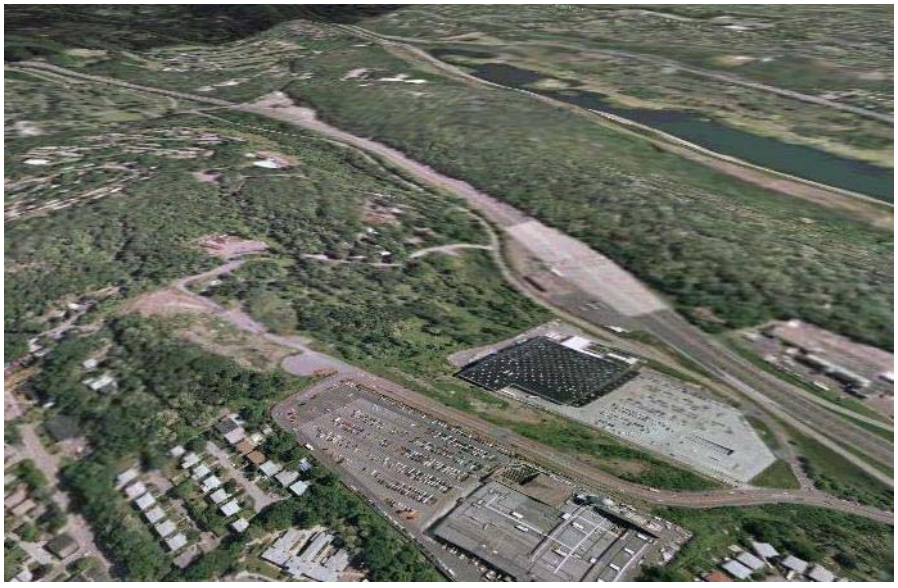
Work Plan
BCP Site # C360066



Brownfield Cleanup Program
Remedial Investigation
Austin Avenue Landfill
City of Yonkers, New York

March 2006

WORK PLAN

BROWNFIELD REMEDIAL INVESTIGATION
AUSTIN AVENUE LANDFILL
CITY OF YONKERS
WESTCHESTER COUNTY, NEW YORK

Prepared for

YONKERS INDUSTRIAL DEVELOPMENT AGENCY

Prepared by

S&W Redevelopment

of North America, LLC
430 East Genesee Street
Syracuse, New York 13202

March 2006

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SECTION 1 - INTRODUCTION

1.1 BACKGROUND

The Austin Avenue Landfill was formerly owned and operated by the City of Yonkers, and consists of approximately 20-acres containing primarily incinerator ash and bulky waste, including trees, brush, and building debris. The landfill began receiving waste in the 1960's, and continued operation into the 1970s. The landfill had ceased operating by 1979, at which time the City of Yonkers entered into a consent order with the New York State Department of Environmental Conservation (NYSDEC) to properly close the former landfill. The landfill property was transferred to Westchester County in 1979, and is currently owned by the Westchester County Industrial Development Agency (IDA).

In 2004, the Yonkers Industrial Development Agency (YIDA) completed an application on behalf of the Westchester County IDA, for entry into the New York State Brownfield Cleanup Program (BCP). The "site", as defined under the Brownfield Cleanup Agreement (BCA Site No. C360066), consists of Westchester County, City of Yonkers Tax Parcel Section 3, Block 3244, Lot 1.

The site's location is shown on Figure 1-1. It is bounded by Corporate Drive to the west, Austin Avenue to the north, and Sprain Road to the east (Figure 1-2). Adjoining properties include a Home Depot store to the south, a Stew Leonard's dairy/grocery store to the southwest, and wooded largely vacant land to the north (Figure 1-2). The site is currently vacant, with a natural vegetative cover.

In order to support the proposed future use of the property, a voluntary Remedial Investigation (RI) will be completed at the site in accordance with a Brownfield Cleanup Agreement (BCA). This Work Plan sets forth the scope and methods that will be followed during the course of the RI program. RI objectives and methods have been developed in accordance with the New York State Department of Environmental Conservation's (NYSDEC) *Brownfield Program Cleanup Guidance* (NYSDEC May 2004), and relevant provisions of draft DER-10 *Technical Guidance for Site Investigation and Remediation* (NYSDEC, December 2002).

1.2 SITE DESCRIPTION

The site consists of 20-acres located on the south side of Austin Avenue, just west of Sprain Brook Road and the New York State Thruway in Yonkers, New York (Figure 1-1). The former Austin Avenue landfill is situated on the site, and contains primarily incinerator ash as well as bulky waste, including trees, brush and building debris. The site is currently vacant, and since the landfill closed it has become covered by invasive vegetation, consisting of various species of grasses and shrubs. The natural topography of the site is steep, with a vertical drop of more than 100 feet from a ridge at the western site boundary to Sprain Brook, which is a distance of approximately 1,200 feet.

The landfill sits on the wall of a narrow valley drained by Sprain Brook, which is a Class D stream that flows from north to south at the eastern site boundary.

The principal rock unit at the site is Manhattan Schist, a metamorphic rock unit that is highly resistant to weathering and erosion. Along the western side of the site, bedrock is typically less than 5 feet below ground surface, but to the east towards the brook the depth to bedrock increases to over 50 feet.

Much of the site consists of fill material of the former landfill, consisting of the above noted ash and waste. Between the toe of the landfill and the brook are layers of fairly well sorted and stratified drift, with grain sizes ranging from gravel to clay.

1.3 REMEDIAL INVESTIGATION OBJECTIVES

In accordance with NYSDEC's *Brownfield Program Cleanup Guidance*, the objective of the Remedial Investigation (RI) will be to define the nature and extent of on-site contamination and conduct sufficient investigation to conduct an on and off-site qualitative exposure assessment. This Work Plan proposes an approach for conducting an RI which is aimed at the above stated objective. The goal will be to define the horizontal and vertical extent of contamination, and identify specific contaminant sources. The results of the investigation will be reviewed to determine whether the stated objective has been achieved, or whether additional investigation is needed.

The following supporting documents are also included in this plan:

Appendix A – Quality Assurance Project Plan

Appendix B – Site Health and Safety Plan

Appendix C – Community Air Monitoring Plan

Appendix D – Remedial Investigation Work Plan Fact Sheet

In addition, a Citizen Participation Plan (CPP) has been prepared as a separate document.

SECTION 2.0 - PREVIOUS SITE INVESTIGATIONS

A number of previous site investigations have been conducted at the Austin Avenue landfill site to characterize the nature of the waste material and the impacts it has had on local groundwater and surface water quality. The following sections summarize the scope and findings for three previous investigations conducted within the BCP site.

2.1 - 1976 LANDFILL STUDY

In 1976, the landfill site was investigated by Geraghty & Miller, Inc. (G&M) as part of a larger study of landfills in Westchester County. G&M utilized five (5) temporary well points (W-1 through W-5) to measure groundwater elevations and collect groundwater samples, and collected water samples from Sprain Brook (Figure 2-1). The investigation results were presented in a report dated June 1977. The section of the report that concerned the Austin Avenue landfill indicated that groundwater impacts from the landfill were evidenced by elevated levels of iron, manganese, chloride and nitrate (Table 2-1). Although the report suggested that low levels of organic compounds might be present, there was no quantitative evidence to support that suggestion; laboratory analysis indicated that if organic compounds were present, they were at concentrations too low to be measured. In addition, the overall findings and conclusions of the report stated that "Evidence of disposal of hazardous chemical wastes were not found at any landfill inspected".

Ground water beneath the property was determined by G&M to flow to the east, eventually discharging to Sprain Brook. Samples collected from Sprain Brook showed no significant impact to surface water quality with respect to the constituents detected in the ground water (iron, manganese, chloride and nitrate).

The G&M report concluded that impact from the landfill on ground-water and surface-water quality was "not significant".

2.2 - 1995 GROUNDWATER/SURFACE WATER STUDY

In 1995, Leggette, Brashears, & Graham, Inc. (LB&G) investigated surface water and groundwater quality at the landfill, which included a review of previously collected data, the installation of four (4) overburden and three (3) bedrock groundwater monitoring

wells, the collection of groundwater samples from the monitoring wells, and collection of surface water samples from Sprain Brook. The locations of the overburden and bedrock wells are shown on Figure 2-2.

Analytical results are summarized on Tables 2-2 and 2-3. Groundwater samples obtained from the overburden and bedrock monitoring wells did not contain polychorinated biphenyls (PCBs) or volatile organic compounds (VOCs). Elevated levels of some naturally-occurring metals were detected in the groundwater samples, specifically iron, manganese and some trace metals. Surface water samples from Sprain Brook showed no evidence of significant landfill-related contamination. Overall, these findings are similar to those of the 1976 study.

2.3 - 2000 ASH FILL & METHANE GAS STUDY

In September 2000, an investigation was conducted to further characterize the chemical composition of the ash at the landfill, and to define the potential for methane generation in the central portion of the landfill. Eight (8) ash fill samples were collected from the landfill for the purpose of waste characterization. The samples were numbered HA-1 through HA-8 and their locations are shown on Figure 2-3. The ash samples were collected from 0.5 and 2 feet below grade (bg) except for sample HA-6, which was collected from the face of a road cut, located between the Stew Leonard's parking lot and the site. Laboratory analysis results are summarized on Table 2-4.

In addition, twenty four (24) locations were monitored for the presence of methane gas, using a portable combustible gas indicator. The sampling locations are shown on Figure 2-4. The monitoring was conducted by driving a steel rod 1.5 to 3 ft bg to create a pilot hole.

Key findings of the 2000 study were that:

1. the ash fill that currently exists at the site was not a hazardous waste, based on analysis for total and leachable (TCLP) priority pollutant metals, and TCLP polycyclic aromatic hydrocarbons (PAHs). Although several leachable metals were detected by TCLP analysis, including cadmium, chromium, copper, lead, nickel, and zinc, their concentrations were well below applicable TCLP toxicity limits for hazardous waste.

2. methane generation is not a significant problem in the former ash landfill. Only two of 24 sample locations (see Table 2-5) had methane levels above 10 percent lower explosive limit (LEL).

2.4 - SUMMARY OF PREVIOUS FINDINGS

The findings of previous investigation indicate measurable, but subtle, groundwater impact with respect to inorganic constituents, including iron, manganese, chloride and nitrate, and little or no evidence of methane gas. These findings are consistent with inorganic material typical of an ash landfill. The leachate produced by ash landfills usually lacks soluble organic compounds, and the absence of putrescible waste material prevents the formation of methane gas. This means that the impacts from an ash landfill, if any, are best measured in terms of the inorganic parameters present in the ash.

Looking at groundwater data for inorganic parameters, it is apparent that landfill impacts must be very isolated, since the various sampling locations at the landfill have distinct chemical "fingerprints". Figure 2-5 shows the chemical distinction between groundwater samples taken from the overburden and bedrock monitoring wells installed in the 1995 investigation. If leachate impacts were widespread, the groundwater samples would have similar chemical characteristics, in common with the chemical fingerprint of leachate. Because the chemical fingerprints for the different sampling locations are noticeably different, it is concluded that leachate contamination is not widespread.

SECTION 3 - REMEDIAL INVESTIGATION APPROACH

The Remedial Investigation (RI) program will include the following main elements:

- Delineation/characterization of the solid waste mass
- groundwater investigation
- explosive gas monitoring
- qualitative human health exposure assessment
- fish and wildlife resource evaluation

The first four elements above will be completed as part of the RI field program. All laboratory analysis for the RI will be provided by a NYSDOH ELAP-certified laboratory. The human health exposure assessment and fish and wildlife resource evaluation will be conducted as part of the data evaluation process. An RI Report will be prepared to provide a detailed account of the work completed in accordance with this Work Plan, including field methods and observations, laboratory analysis results of samples taken, a description of the nature and extent of contamination relative to human health exposure and wildlife resources, and recommendations for additional investigation (if any). The findings of the RI, as presented in the RI Report, will form the basis for assessing and screening remedial alternatives under the BCP.

The following sections describe the specific RI tasks that will be carried out.

3.1 DELINEATION OF WASTE

Test pits will be dug using a rubber tired backhoe around the perimeter of the waste area on the site. The objective will be to delineate the edge and of the landfilled waste, by direct visual observation of the test pits.

A two-day effort is planned for this task, consisting of approximately 15 to 20 test pits. Figure 3-1 shows possible test pit locations, but the actual locations and number of pits will be determined in the field, based on a joint determination by NYSDEC and SWRNA regarding whether the delineation has been achieved.

A SWRNA hydrogeologist will visually examine the fill and soil that are encountered at each test pit location, and record observations in a test pit log. The description of waste

material in the logs will include the apparent type of waste (e.g. incinerator ash, building demolition debris, yard waste, etc), as well as visible evidence of staining or odors that could signal the presence of contamination. During the digging of the test pits, SWRNA field personnel will also use a photionization detector to measure total volatile organic compounds (VOCs) that may emanate into air from the waste. PID readings will be recorded in the test pit log.

Although the principal objective of the test pits will be to delineate waste material, samples of waste may be taken for analysis if it is determined by visual observation, odor, and/or PID screening that contamination may be present in the waste. The general rule for collecting samples will be based on PID readings greater than 100 ppm above background, or notable discoloration and/or odor. For general planning, SWRNA will be prepared to collect up to five (5) representative samples of waste material for laboratory analysis. The screening procedure to select samples for analysis will be to collect one waste sample from each test pit, based on PID readings and field observations, and temporarily place the sample in a sealed ziplock bag while the other pits are being dug. After all of the test pits are completed, the five samples that seem to exhibit the greatest potential for contamination will be selected for laboratory analysis. These five samples will be analyzed for TCLP (toxicity characteristic leaching procedure) VOCs, TCLP semivolatile organic compounds (SVOCs), TCLP target analyte list (TAL) metals, pesticides, and PCBs.

3.2 GROUNDWATER INVESTIGATION

The groundwater investigation completed for this RI will focus on shallow (overburden) groundwater, for a number of reasons:

- Previous groundwater samples from bedrock wells indicate no evidence of landfill contamination in bedrock groundwater.
- The drill log for bedrock well RW-3 indicates that bedrock under the site has a very low water-bearing capacity, as evidenceD by a modest well yield in the uppermost fracture zone (~1.5 gpm)
- The uppermost fracture zone was not encountered in RW-3 until 63 feet below grade, which is almost 30 feet below the overburden/bedrock interface. It appears unlikely that shallow overburden groundwater at the site is in contact with this groundwater flow zone in the bedrock.

- Groundwater contamination downgradient of the landfill, if any exists, is more likely to be present in the shallow groundwater because Sprain Brook is believed to represent a groundwater discharge zone, in which groundwater has an upward gradient.

In short, there is strong evidence to support that bedrock groundwater has not been impacted by the landfill, and that the physical character of bedrock precludes such contamination.

The investigation of shallow groundwater will utilize existing monitoring wells to the extent possible, plus the installation of additional overburden wells at the site.

3.2.1 Existing Monitoring Well Assessment. SWRNA will examine the two (2) existing overburden wells at the site (MW-3 and MW-4, see Figure 3-1) to determine their condition for use. The depth of each well will be checked to determine if sediments have accumulated which may plug the screen. It will then be determined whether a sampling device such as a bailer can be lowered into the well without obstruction. The wells will be purged of at 3 to 5 volumes to visually examine the clarity of water and the presence of sediments or foreign debris. These wells will be replaced if necessary, if it is determined that sediment accumulation has plugged the well screen, or if there is evidence of casing damage.

Each replacement well will be installed to a maximum depth of 25 feet, using 4 ¼-inch hollow stem auger (HSA) methods. Split spoon samples would not be collected for the replacements wells, because the soil profile at the replacement well locations has already been established by the boring logs from the original wells.

The replacement wells, if any are needed, will be constructed of two-inch diameter PVC, with ten (10) feet of 0.01 inch slot screen. A sand filter pack will be placed outside the screen, from the bottom of the boring to at least 2 feet above the top of the screen. A bentonite seal will be installed on top of the sand pack, and the remaining annulus will be backfilled with cement grout. A stick-up protective casing will be installed with a locking lid to protect the well riser pipe. Following installation, the replacement wells will be properly developed to remove suspended sediments.

The existing and/or replacement wells will be included in the groundwater sampling program described in Section 3.2.3 below.

3.2.2 Monitoring Well Installation. Eight (8) additional overburden monitoring wells will be installed at the site to supplement the previously installed monitoring wells. The proposed locations are shown on Figure 3-1. The 8 proposed wells will be installed to obtain shallow groundwater samples from the water table. Three monitoring wells are proposed near the downgradient boundary of the site, between the edge of refuse and the drainage swale. Three are proposed cross gradient of the site, at the site's northern boundary along Austin Avenue, beyond which residential properties are located. Two monitoring wells are proposed along the western site boundary, adjacent to Corporate Drive.

The proposed monitoring wells will be constructed of two-inch diameter PVC, with ten (10) feet of 0.01 inch slot screen. The well screens will therefore straddle the water table, with at least three feet above the water table and seven feet below. A sand filter pack will be placed outside the screen, from the bottom of the boring to at least 2 feet above the top of the screen. A bentonite seal will be installed on top of the sand pack, and the remaining annulus will be backfilled with cement grout. A stick-up protective casing will be installed with a locking lid to protect the well riser pipe. Following installation, the newly installed monitoring wells will be properly developed to remove suspended sediments.

The actual number and design of the monitoring wells will be determined by the depth to the water table and bedrock. It is possible that bedrock in the western portion of the site, may be too shallow to permit the installation of overburden water table wells. The installation of the wells is therefore contingent upon an adequate depth to bedrock to permit their installation. It is proposed that monitoring wells not be installed in any borehole in which bedrock is less than 3 feet below ground surface, which is the minimum depth to accommodate one foot of well screen, with at least 1.5 feet of sand pack, one foot of bentonite, and ½ foot of cement to set a protective casing.

3.2.3 Groundwater Sampling and Analysis. Two groundwater sampling events will be completed, spaced three months (i.e. one calendar quarter) apart. Groundwater samples will be collected from the eight (8) overburden monitoring wells at the site,

including the three newly installed wells and the two existing and/or replaced monitoring wells.

Prior to sampling, the depth to groundwater will be measured and recorded, and each well will then be purged of three (3) volumes of water. Field parameters will be measured, including pH, Eh, turbidity, and specific conductance.

Groundwater samples will be collected and analyzed for VOCs (8260), SVOCs (8270), TAL metals (6010/7471/7470), pesticides, and PCBs.

3.3 EXPLOSIVE GAS MONITORING

Previous sampling for methane indicates very little methane is being produced by the landfill, which is consistent with the non-degradable nature of municipal waste incinerator ash. As indicated on Figure 2-4, only two of 24 temporary gas probes had methane levels above 10 percent lower explosive limit (LEL). In addition, three of four permanent gas wells that were sampled along the southern site boundary in 1999 contained no detectable methane, whereas the fourth well sampled contained only a trace (1 percent LEL).

In addition to there being little or no measurable methane, subsurface conditions at the site are not conducive to widespread migration of landfill gas due to natural subsurface barriers. Along the eastern site boundary, in the direction of groundwater flow, Sprain Brook is a local discharge area that creates a natural barrier to gas migration east of the site. Along the western edge of the site, bedrock is very shallow – at less than 5 feet deep – and outcrops are present in this area. Thus, the unsaturated soil zone through which gas may migrate is bounded by surface water in the east and bedrock in the west. Because of these barriers, gas monitoring will target the eastern portions of the landfill's northern and southern flanks, where both bedrock and groundwater are adequately deep to permit gas migration.

A limited perimeter survey will be conducted, which will focus on the northern and southern landfill perimeters where off-site migration of landfill gas, if any, is most likely to occur. A gas survey for the interior portion of the site is not recommended, because gas abatement measures can be integrated into the construction and redevelopment plan for new buildings at the site.

Ten (10) methane samples will be collected, five each along the site's northern and southern perimeters. Because gas monitoring wells are already present along the southern boundary, five (5) additional gas monitoring wells will be installed along the northern site boundary (Figure 3-2). In the event that one or more of the existing gas wells along the southern boundary are damaged or destroyed, they will be replaced. Gas monitoring wells will be installed at least five feet deep, provided that the depth to groundwater and bedrock are greater than five feet.

A portable multi-gas meter will be used to measure methane, in both total percent and percent LEL, as well as oxygen and hydrogen sulfide gas, at the 10 locations.

3.4 WASTE HANDLING

Waste materials generated during the RI will include soil cutting from soil borings, groundwater from well development, and rinsate from decontamination of field sampling equipment.

Soil boring cuttings will be staged on plastic and covered with plastic on site. Following receipt of laboratory analysis results for soil samples taken during the RI, it will be determined whether these soils may remain at the site as fill, or whether off site disposal may be required. The RI Report will provide recommendations concerning the disposition of staged soils.

Groundwater produced from well development and purging will be disposed of at ground surface at each location, or contained in drums as conditions warrant. Groundwater will be disposed of at ground surface provided that there is no visible, olfactory, or PID evidence of contamination. (Note that previous laboratory analysis indicates very little evidence of groundwater contamination at the site). If there is reason to suspect contamination based on PID screening and/or direct observation, groundwater will be placed in drums and staged on site prior to disposal at a permitted facility.

A decontamination area will be established in a site area near Corporate Drive. The area will be located to ensure that rinse water from decontamination does no affect any of the proposed sampling areas. Rinse water from decontamination will be containerized if field observations (PID, visual, olfactory) indicate contamination is likely to be present.

If little or no indication of contamination is present in soil and groundwater, then rinse water may be discharged at ground surface.

3.5 HUMAN HEALTH EXPOSURE ASSESSMENT

Site data will be evaluated to determine whether human receptors, both on site and off site, are potentially exposed. The assessment will be conducted in accordance with Appendix 3B of NYSDEC's DER-10 Technical Guidance. The purpose of the exposure assessment will be to qualitatively determine the route, intensity, frequency, and duration of actual or potential exposures of humans to site-related chemicals. The assessment will also describe the nature and size of the population potentially exposed to the contaminants.

3.6 FISH AND WILDLIFE RESOURCE EVALUATION

A Fish and Wildlife Resource Evaluation will be completed to provide an initial screening of potentially affected fish and wildlife resources in connection with the site. The first step of the FWRIA process, resource characterization, will be completed as part of the site investigation scope. Resource characterization includes the following basic steps:

- Identify fish and wildlife resources for the area within a one-half mile radius of the site, based on NYSDEC records and knowledge of the site area.
- Identify contaminant migration patterns that may potentially expose fish and wildlife resources to site-related contaminants.
- Identify specific contaminants of ecological concern
- Draw conclusions regarding potential adverse effects.

The findings of the initial FWRIA phase will be used to determine whether it is likely that the site has a negative effect on local wildlife and related habitats.

3.7 DATA USABILITY STUDY REPORT (DUSR)

Following the completion of the laboratory analysis program, a Data Usability Study Report (DUSR) will be completed, in accordance with BCP QA/QC requirements, and

included as part of the RI Report. The DUSR is carried out to evaluate the quality control measures that were implemented during the field and laboratory analytical programs, with the objective of determining whether the reported analytical data are representative and usable for decision making. The DUSR will evaluate whether the data are technically defensible (i.e. were all analytical requirements met and documented). Data usability analysis reviews the site data to determine whether they are adequate to draw conclusions regarding the nature and extent of contamination.

The following items are reviewed as part of the DUSR:

- Completeness (number of samples collected and analyzed compared to plans)
- Chain of custody determined to be complete and accurate
- Holding times
- Instrument calibration
- Relative percent difference between field duplicates
- Reasonableness of data (e.g. relationships between total and soluble analytes)
- Blank contamination

3.8 REMEDIAL INVESTIGATION REPORT

Following the completion of the proposed sampling, analysis, and data evaluation, a Remedial Investigation (RI) Report will be prepared that presents the findings of the investigation. The following information will be included in the RI Report.

3.8.1 Technical Overview. The technical overview will be a narrative discussion of methods and results. Work completed under the approved RI Work Plan will be described, including the methods used for sample collection and laboratory analysis. Any departures from the approved scope of work or methods used will be noted, along with the rationale for such departures. The technical overview will provide enough information to define the nature and extent of contamination at the site, identifying sources of contamination, the specific contaminants of concern, and hydrogeologic and chemical characteristics that govern contaminant fate and transport.

At the heart of the technical overview will be the development of a conceptual site model. The site model will provide a framework to guide the analysis of chemicals of concern in the environment. A well defined conceptual site model identifies and describes:

- The sources of contamination
- The nature and extent of contamination
- The dominant fate and transport characteristics of the site
- Potential exposure pathways
- Potentially impacted receptors

3.8.2 SCGs. Standards, criteria and guidance (SCGs) that pertain to the sampled site media will be identified and listed in summary tables, along with the analytical results for each medium. Instances where sample analysis results exceed a relevant SCG will be indicated on the tables, and discussed in the technical overview.

3.8.3 Human Health Exposure Assessment. A description of potential exposure scenarios, both present and in the future, will be presented in the context of the site's existing and future contemplated use. The assessment will address exposure scenarios both on- and off site, and will include:

- Identification of on-site and off-site human receptors that may potentially be exposed to site contaminants;
- Identification of the specific contaminated media (soil, fill, groundwater, air) to which potential human receptors may be exposed;
- Identification of specific contaminants within the identified media, to which potential human receptors may be exposed;
- Identification of the potential exposure routes (i.e. direct contact, inhalation, ingestion) pertaining to the identified contaminated media.

3.8.4 Fish and Wildlife Resources. Area fish and wildlife resources will be identified, and the overall habitat value for the site will be discussed. The site's affect on the overall habitat value for the area, based on current conditions (i.e. buildings and paved areas) and the site's future anticipated use, will be presented. Fish and wildlife resources will be defined in terms of the following criteria:

- The presence of any endangered, threatened, or special concern species or rare plants and their habitats
- The presence of NYSDEC designated significant habitats or rare NYS ecological communities
- The presence of tidal or freshwater wetlands
- The presence of habitable streams, ponds, lakes, lagoons, or other attractive surface water features

- The variety of covertypes at the site and surrounding areas, including forest, grassland or grassy field, parkland, woodland, shrubby areas, and urban areas.

Any lack of resources that may be due to site contamination will be identified.

3.8.5 Conclusions/Recommendations. The results of the RI will be summarized, which will clearly identify source areas and potential exposure paths in relation to human and ecological receptors.

A Remedial Alternatives Analysis Report will be submitted along with the RI Report, which will evaluate appropriate remedial options based on the RI results. The Remedial Alternatives Analysis Report will include a Remedial Action Work Plan that describes the implementation of the selected remedy for the site. The principal objectives of the remedial approach will be to minimize on-site contact between site contaminants and human and ecological receptors, and to prevent future off site migration that may lead to off site exposure of human and ecological receptors to site related contaminants.

3.8.6 Supporting Data and Information. To support the presentation of RI information, the following items will be appended to the RI Report:

- Site photographs
- Soil boring logs
- Site maps, including a groundwater contour map, and text box figures depicting analytical results
- Laboratory analysis results
- DUSR

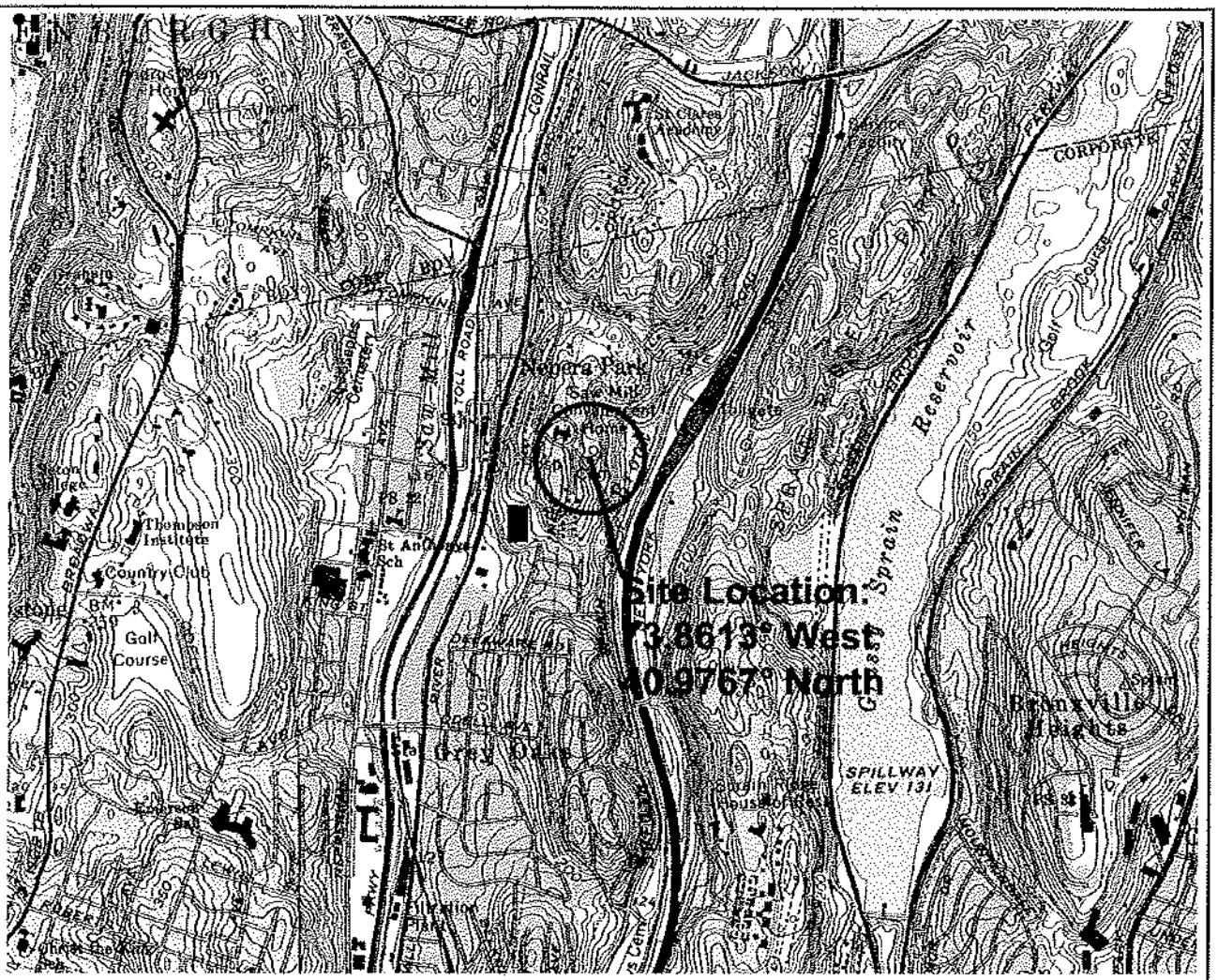
SECTION 4 PROJECT SCHEDULE

The RI sampling and analysis program proposed herein will be implemented following NYSDEC approval. RI field sampling work can be scheduled to begin within two weeks of NYSDEC approval, with the objective of beginning investigation field work in the spring of 2006. A project schedule is included below. Specific public participation milestones will be described in the Citizen Participation Plan.

It is estimated that field work will require two weeks to complete, and laboratory analysis will be complete within four weeks of the end of field work.

The RI Report/Remedial Action Work Plan will be submitted for NYSDEC review within four (4) months of the start of field work.

Figures



SCALE in FEET

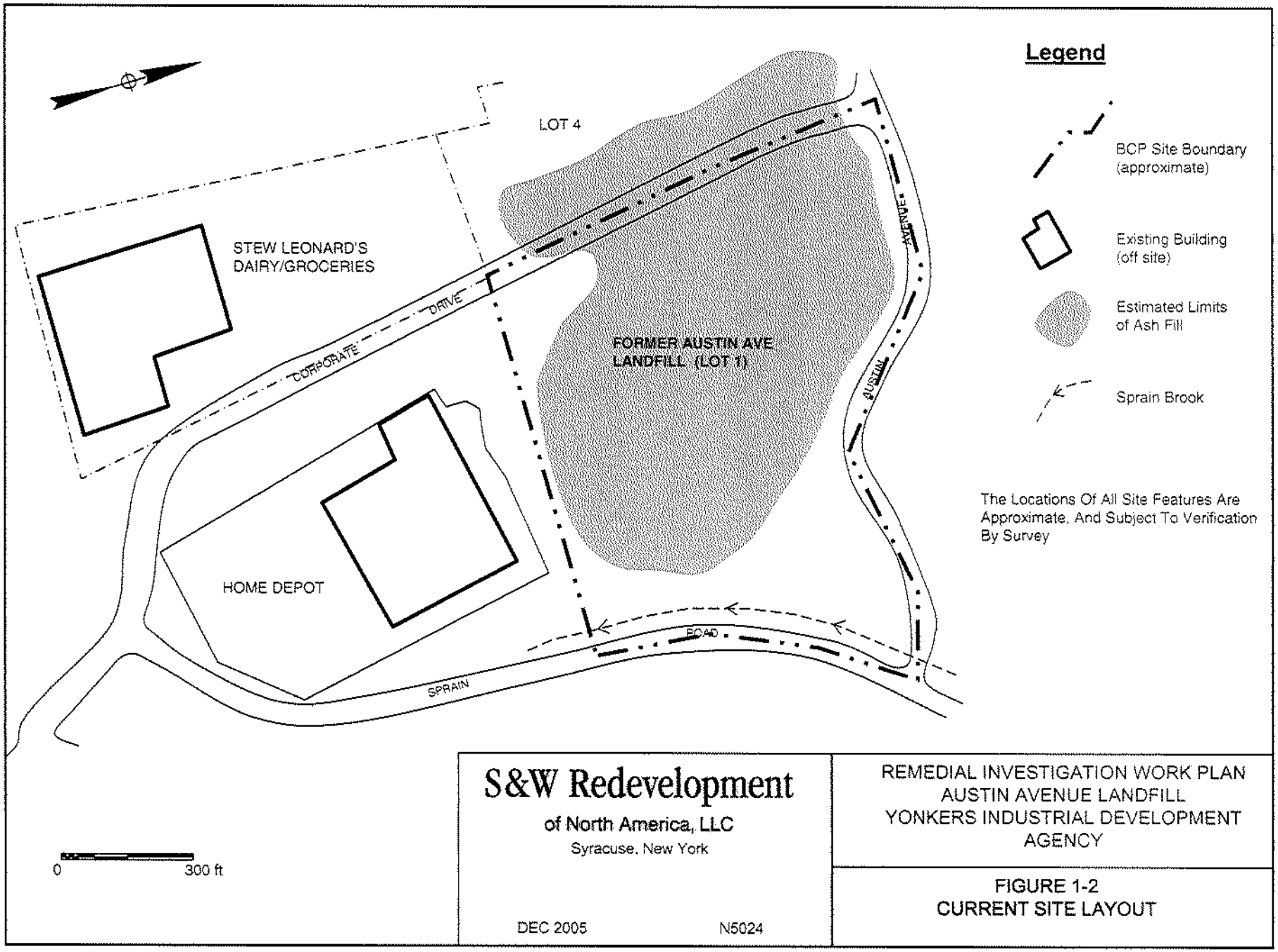
1,000 0 1,000 3,000 5,000

Contour Interval: 10 Feet

Map Taken From: USGS 7.5 Minute Series Topographic Quadrangle Mount Vernon and Yonkers (1966 Photorevised 1979) (www.nysgis.state.ny.us/quads/usgsdrg.htm)

QUADRANGLE LOCATION

S&W Redevelopment of North America, LLC Syracuse, New York	REMEDIAL INVESTIGATION WORK PLAN AUSTIN AVENUE LANDFILL YONKERS INDUSTRIAL DEVELOPMENT AGENCY
DEC 2005 N5024	FIGURE 1-1 SITE LOCATION



S&W Redevelopment

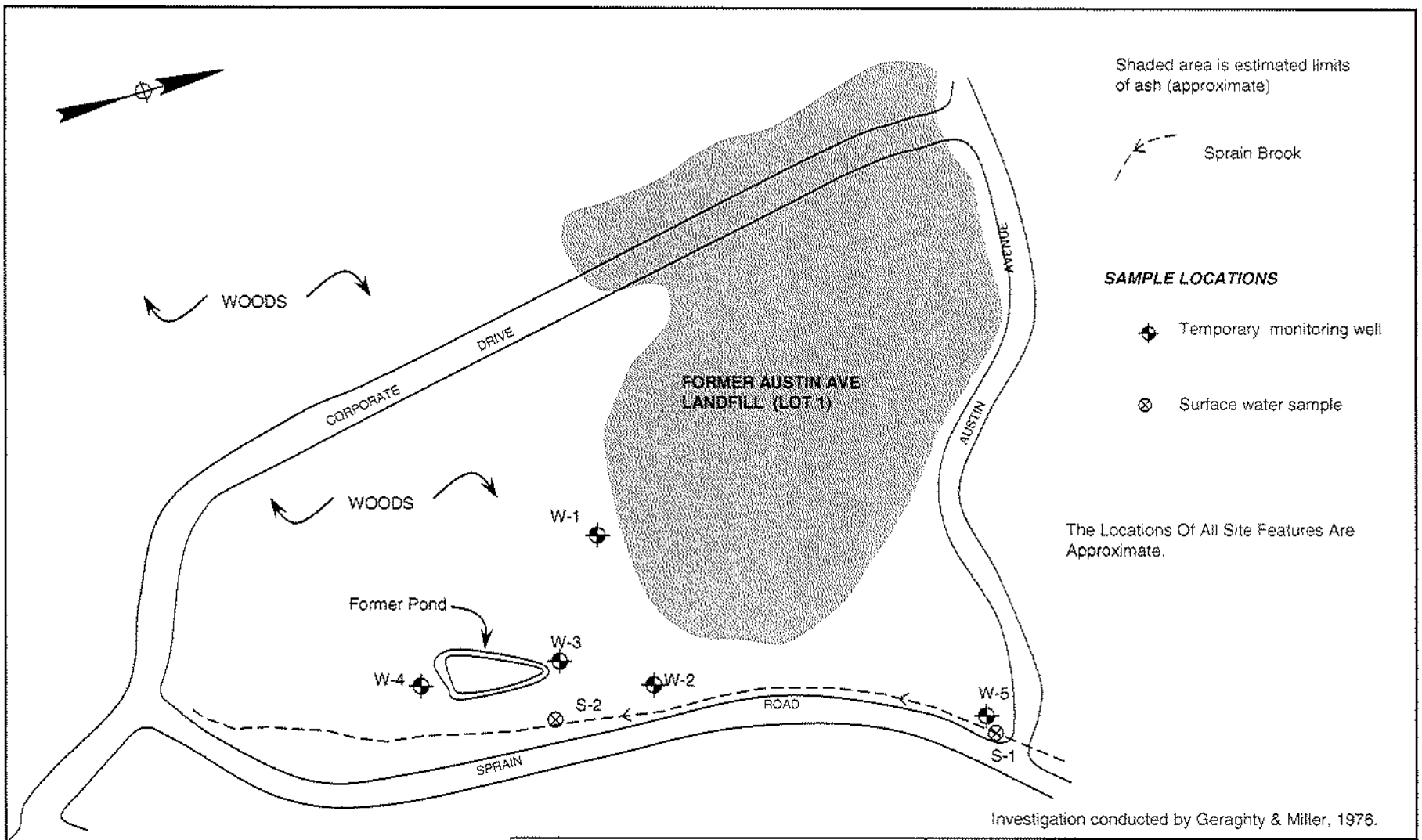
of North America, LLC

Syracuse, New York

DEC 2005 N5024

REMEDIAL INVESTIGATION WORK PLAN
AUSTIN AVENUE LANDFILL
YONKERS INDUSTRIAL DEVELOPMENT
AGENCY

FIGURE 1-2
CURRENT SITE LAYOUT



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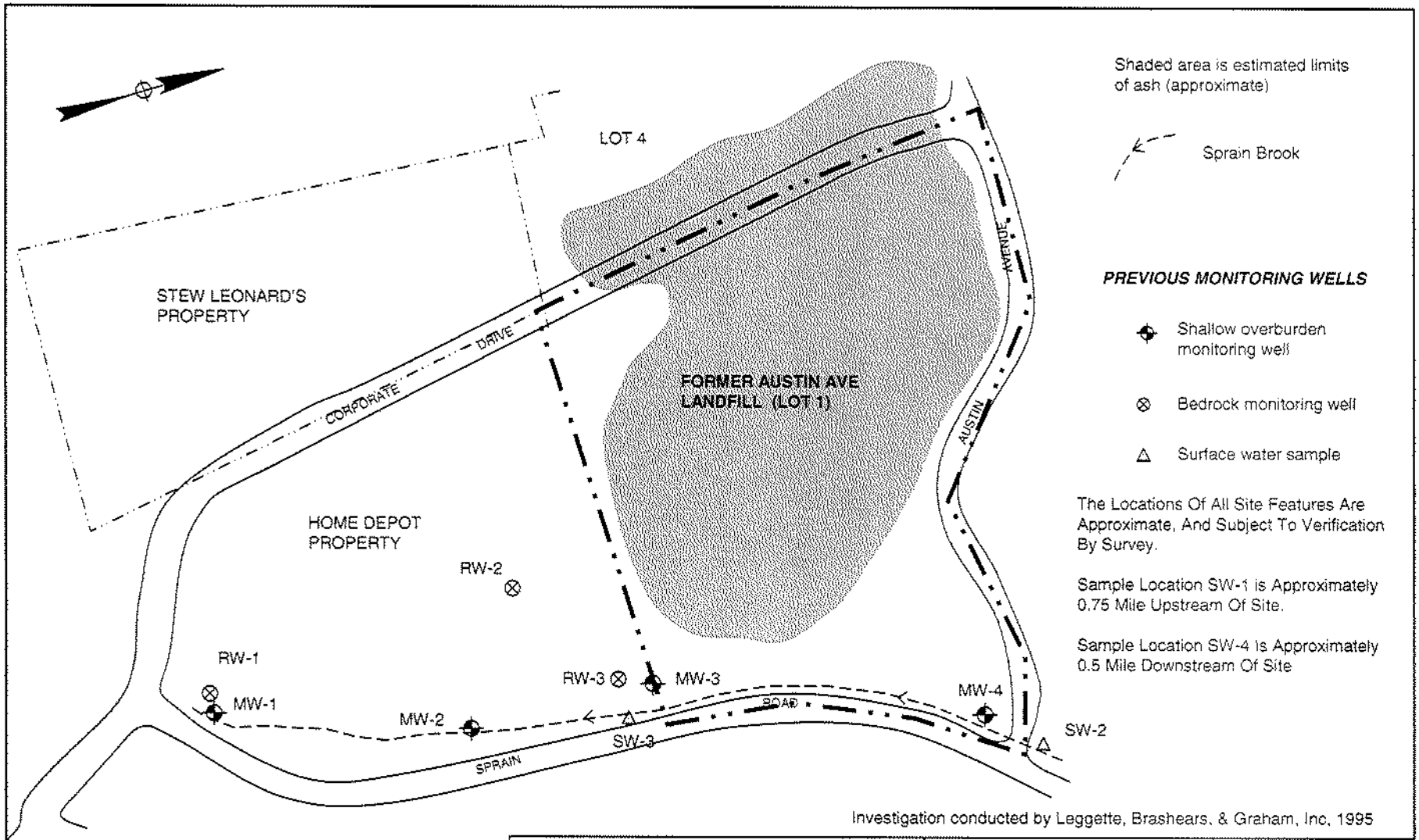
Syracuse, New York

DEC 2005 N5024

REMEDIAL INVESTIGATION WORK PLAN
AUSTIN AVENUE LANDFILL
YONKERS INDUSTRIAL DEVELOPMENT AGENCY

FIGURE 2-1
PREVIOUS INVESTIGATIONS, 1976



Investigation conducted by Leggette, Brashears, & Graham, Inc. 1995

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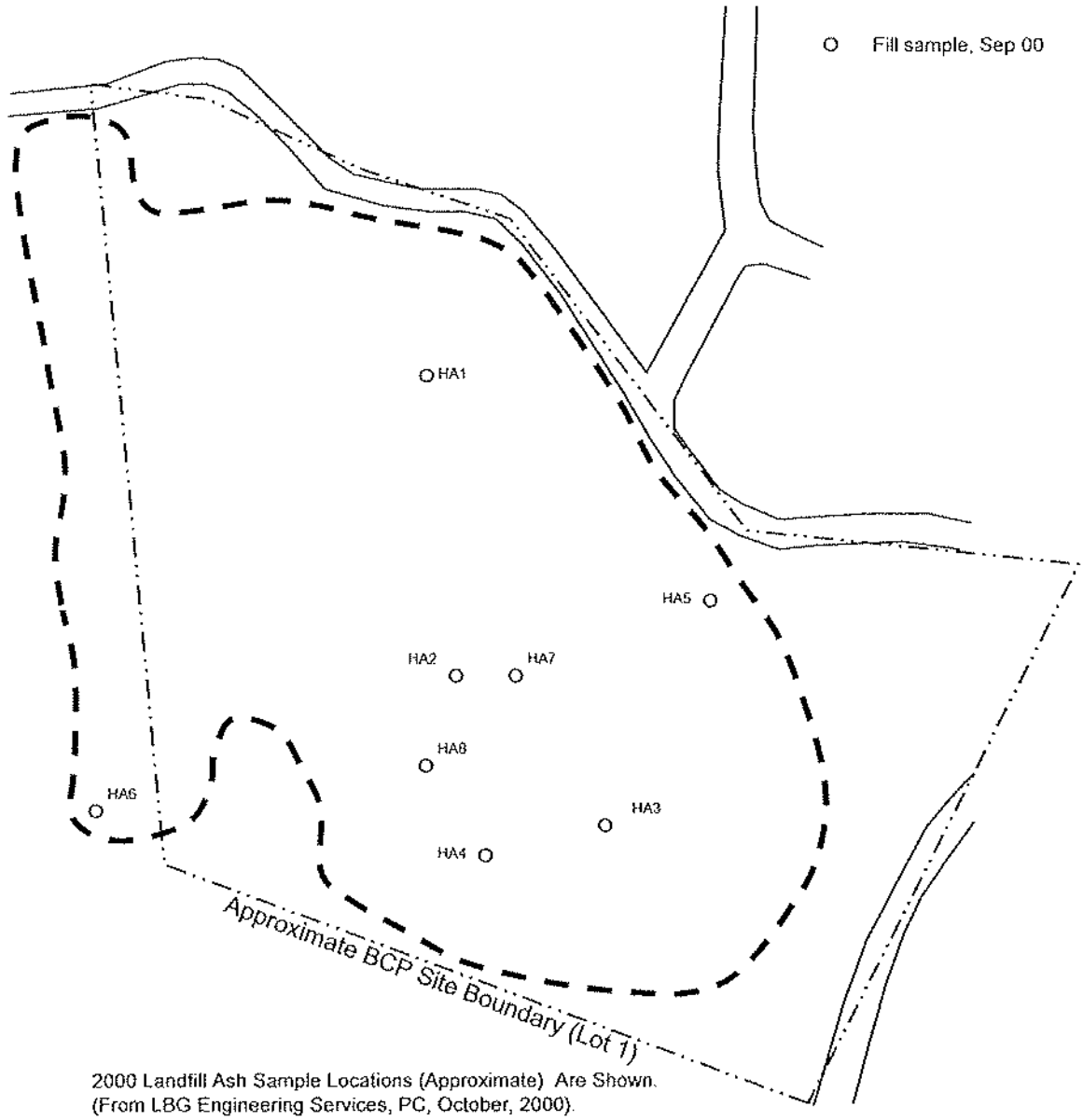
REMEDIAL INVESTIGATION WORK PLAN
AUSTIN AVENUE LANDFILL
YONKERS INDUSTRIAL DEVELOPMENT AGENCY

FIGURE 2-2
PREVIOUS INVESTIGATIONS, 1995



2000 Landfill Ash Sample Locations (Approximate) Are Shown.
(From LBG Engineering Services, PC, October, 2000).

0 200 ft

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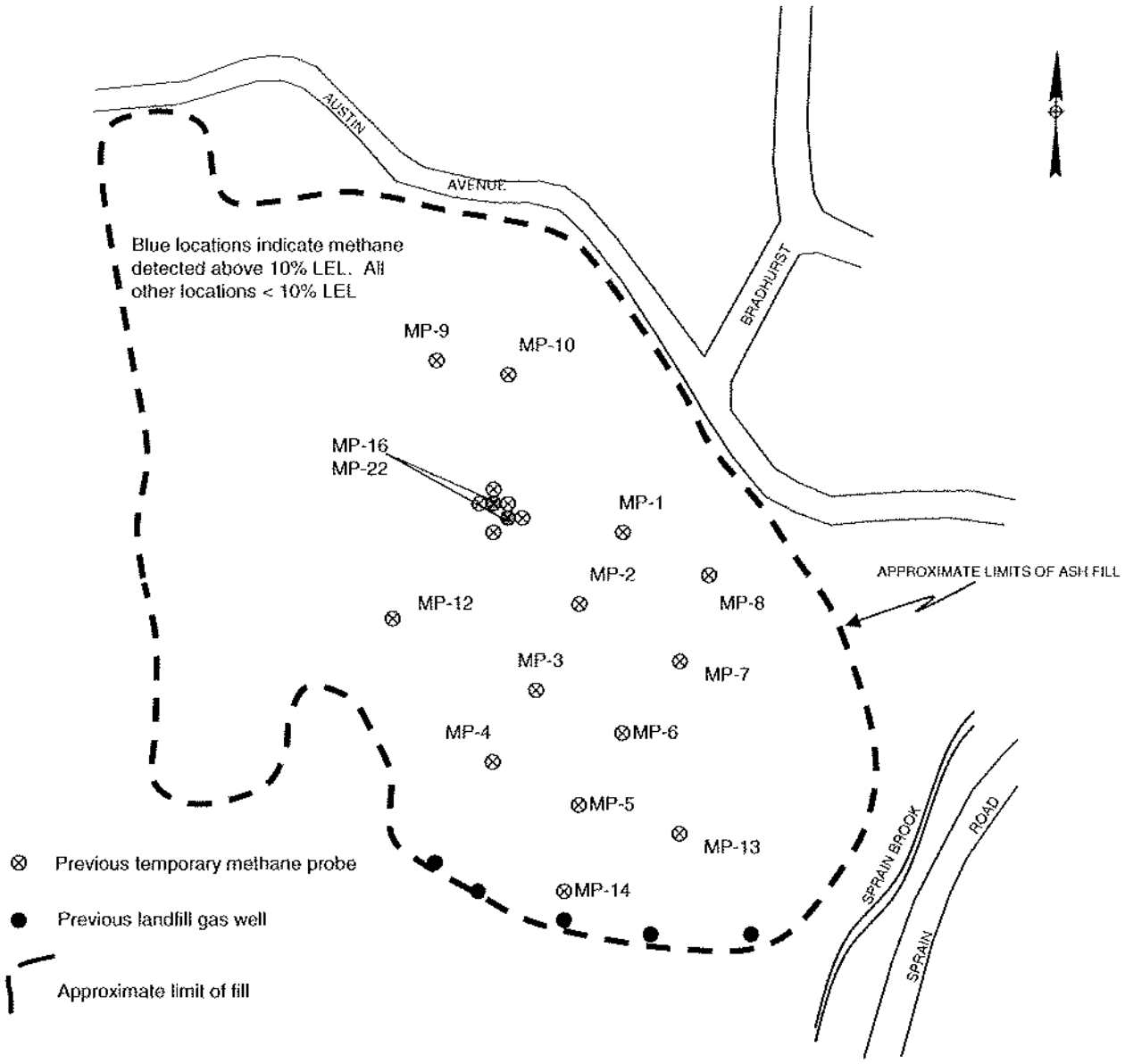
FIGURE 2-3
ASH FILL SAMPLE LOCATIONS (2000)



2000 Landfill Gas Sample Locations (Approximate) Are Shown. Only Two (2) Locations Had Readings Greater Than 5% LEL. (From LBG Engineering Services, PC, October, 2000).

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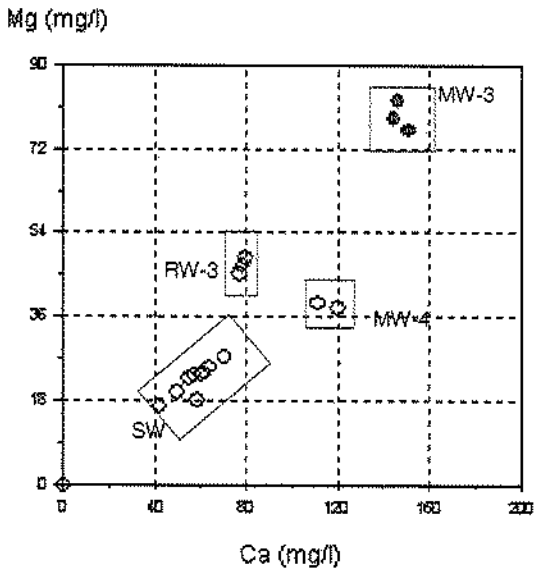
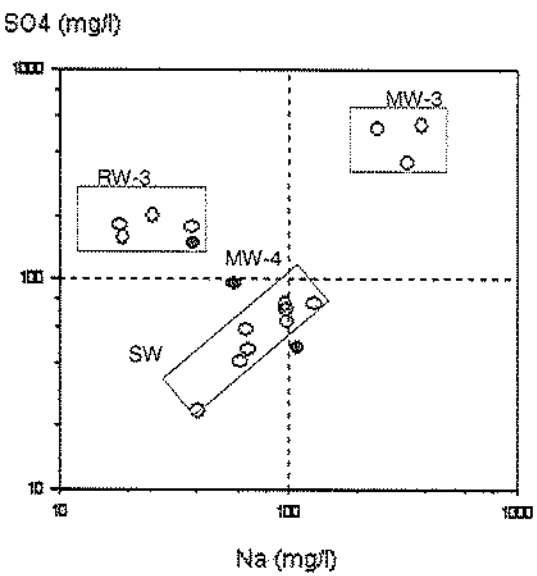
FIGURE 2-4
LANDFILL GAS PROGRAM (2000)



A plot of magnesium (Mg) versus calcium (Ca) shows distinct chemical groupings, or "fingerprints". The fingerprint for groundwater samples from MW-3 is clearly different than the fingerprints for MW-4, the bedrock well (RW-3), or surface water (SW), respectively.



A plot of sulfate (SO4) versus sodium (Na) also shows distinct chemical fingerprints. Note that groundwater quality in MW-4 has a degree of chemical similarity with both surface water and bedrock.

Each group of samples has a unique chemical fingerprint. This means that if contamination is present (landfill leachate, for example) it cannot be affecting more than one group, because the contamination would produce similar chemical fingerprints in the affected groups.

This data indicates that leachate contamination, if present, must be very isolated, since it evidently does not affect more than one group of samples. The proposed Remedial Investigation will be conducted To substantiate this conclusion.

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FIGURE 2-5
WATER QUALITY DATA
CHEMICAL FINGERPRINTS

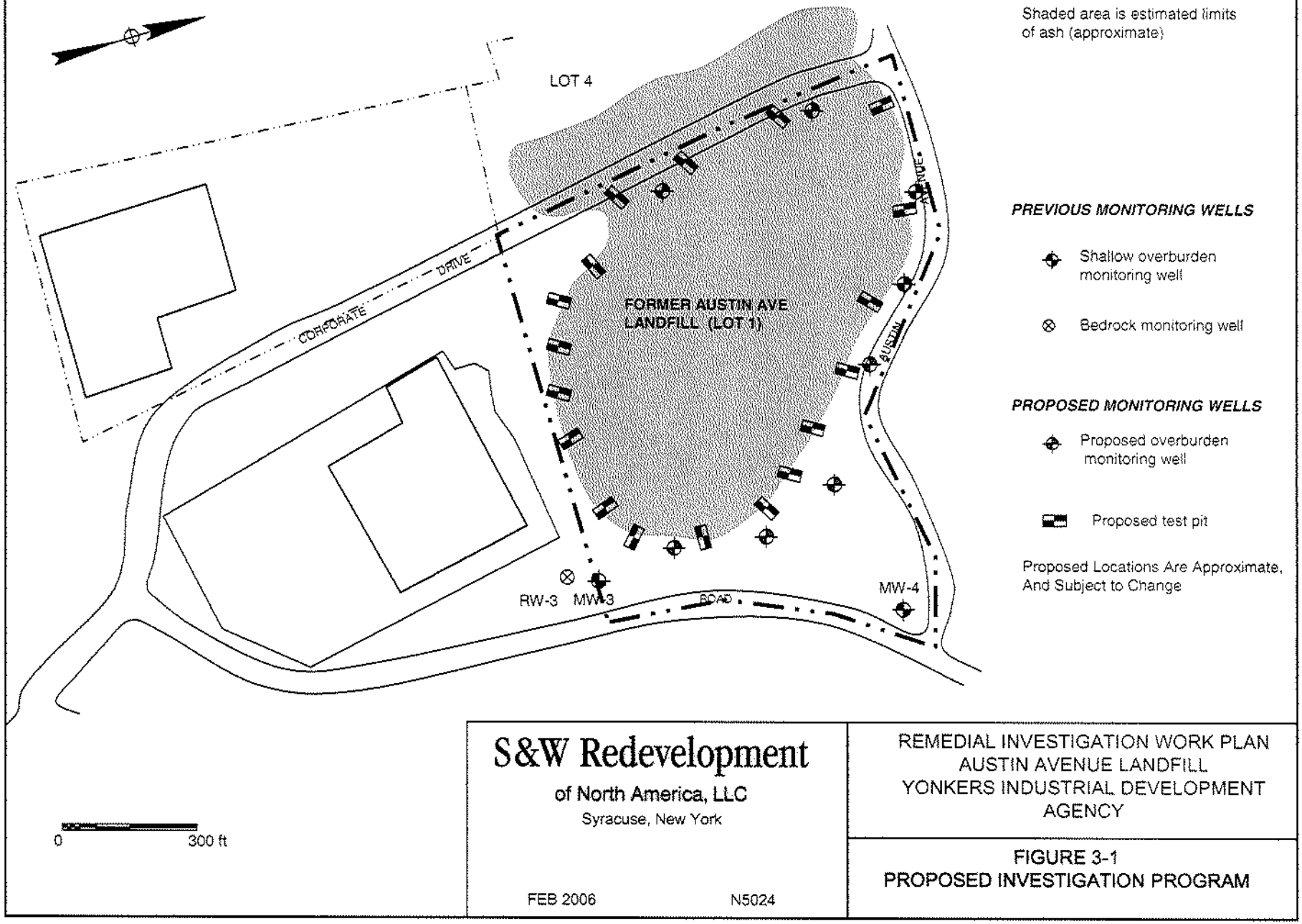

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FIGURE 3-1
PROPOSED INVESTIGATION PROGRAM

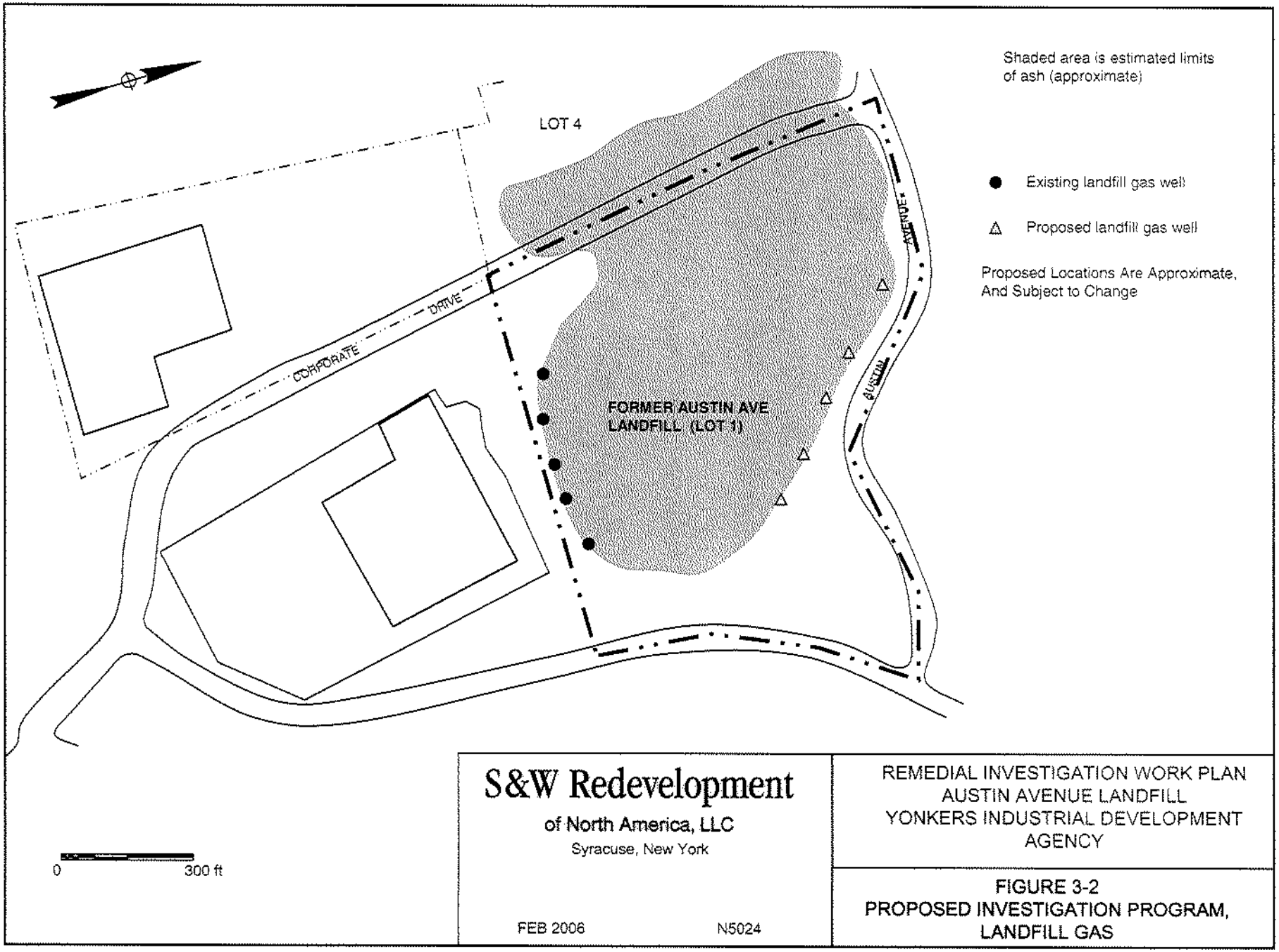

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FIGURE 3-2
PROPOSED INVESTIGATION PROGRAM, LANDFILL GAS

Tables

Table 2-1. December 1976 Water Sample Results, Austin Avenue Landfill. Remedial Investigation Work Plan. YIDA.

General Chem (mg/L)	W-1	W-2	W-3	W-4	W-5	S-1	S-2
chloride	21	39	201	18	168	370	369
nitrate	U	U	14	0.86	0.33	0.64	0.48
ammonia	28	9.6	1	0.86	1.5	2.3	6.8
chemical oxygen demand	270	105	23	12	32	25	24
pH (std units)	6.4	6.4	6.6		7	7.6	7
specific conductance (umhos/cm)	10500	5400	1650		750	1000	1200
temperature (F)	80	50	50		54	34	34
dissolved oxygen						12.5	13
Metals (mg/L)							
cadmium	U	U	U		U		
chromium	0.01	0.01	U		U		
copper	U	U	U		U		
iron	27	15	0.41	5.2	4.6	1.2	1
managanese	6.7	20	0.02	1.2	0.24	0.8	1
lead	0.1	0.1	0.1		0.1		
zinc	3.2	1.3	0.59		0.63		
Organics (mg/L)							
PCBs	U	U	U		U		
total halogenated pesticides	U	U	U		U		
heavy volatile organics	U	U	U		U		
light volatile organics	U	U	U		U		

Data as presented by Geraghty & Miller, Inc., June 1977 - *Hydrogeologic Investigation of Selected Landfills in Westchester County, New York*.

W-1 through W-5 represent groundwater samples from temporary wells.

S-1 and S-2 represent surface water samples from Sprain Brook.

U = undetected (i.e. below detection limits)

Blank cells indicate paramater was not analyzed

Sample locations shown on Figure 2-1.

Table 2-2. 1995 Water Sample Results, General Chemistry (Inorganics), Austin Avenue Landfill. Remedial Investigation Work Plan. YIDA.

Parameter (mg/L)	MW-1	MW-2	MW-3	MW-4	RW-1	RW-2	RW-3	SW-1	SW-2	SW-3	SW-4
pH (standard units)	6.25	6.56	6.77	6.1	9.02	7.07	7.24	7.05	6.22	7.29	7.42
specific conductance (umhos/cm)	343	1070	933	1180	155	2040	1120	626	1140	1333	862
chemical oxygen demand		20	35		U	67	7.8				20
alkalinity		190	182		70	478	144				132
phosphate		1.46	0.3		0.5	0.59	1.9				U
sulfate		280	90		46.8	138	178				38.4
chloride	U	17	106	12	9.5	324	124	176	285	475	150
nitrate		2.01	13.1		1.05	1.2	0.757				0.955
nitrite		0.14	0.01		0.08	0.01	0.04				0.05
ammonia		1.13	1.02		1.9	10.4	1.13				0.36
depth to water (feet)	12.49	11.33	10.66	7.99	18.2	13.12	12.38				
total well depth (feet)	17.87	17.5	17.7	19.83	204	204	83				

Data as presented by Leggette, Brashears, & Graham, Inc. April 1995 - *Austin Avenue Landfill Surface and Groundwater Investigation*.

and May 1995 - *Supplemental Investigation of Bedrock Groundwater Quality*.

MW-1 through MW-4 represent shallow overburden groundwater samples.

RW-1 through RW-3 represent bedrock groundwater samples.

U = undetected (i.e. below detection limits)

Blank cells indicate paramater was not analyzed

Sample locations shown on Figure 2-2.

Table 2-3. 1995 Water Sample Results, Metals, Austin Avenue Landfill. Remedial Investigation Work Plan. YIDA.

Parameter (mg/L)	MW-1	MW-2	MW-3	MW-4	RW-1	RW-2	RW-3	SW-1	SW-2	SW-3	SW-4
antimony	0.02	0.014	0.014	U	U	U	U	0.01	U	U	U
arsenic	U	U	U	0.104	U	U	U	U	U	U	U
beryllium	U	U	U	26	U	U	U	U	U	U	U
cadmium	U	U	U	0.02	U	U	U	U	U	U	U
chromium	U	U	U	0.88	U	U	U	U	U	U	U
copper	U	U	U	1.31	0.007	0.012	0.006	U	U	U	U
lead	U	U	U	2.22	U	U	U	U	U	U	U
nickel	U	U	U	0.68	U	0.016	U	U	U	U	U
selenium	0.011	U	U	U	U	U	U	U	U	U	U
zinc	U	U	U	2.48	0.027	0.051	0.032	0.059	U	U	0.077
sodium	11.6	14.8	73.5	15.6	25.5	166	37.8	73.5	114	162	178
iron	0.25	0.05	0.08	580	U	U	U	U	0.14	0.1	0.73
manganese	1.47	7.35	3.57	16.5	U	U	U	0.14	0.51	0.46	0.73

Data as presented by Leggette, Brashears, & Graham, Inc. April 1995 - *Austin Avenue Landfill Surface and Groundwater Investigation*, and May 1995 - *Supplemental Investigation of Bedrock Groundwater Quality*.

MW-1 through MW-4 represent shallow overburden groundwater samples.

RW-1 through RW-3 represent bedrock groundwater samples.

U = undetected (i.e. below detection limits)

Blank cells indicate paramater was not analyzed

Sample locations shown on Figure 2-2.

Table 2-4. 2000 Ash (Fill) Sample Results, Metals, Austin Avenue Landfill. Remedial Investigation Work Plan. YIDA.

Total Metals

Parameter (mg/Kg)	HA-1	HA-2	HA-3	HA-4	HA-5	HA-6	HA-7	HA-8
antimony	U	U	U	U	U	U	U	U
arsenic	5.29	4.47	7.44	4.22	4.6	U	2.87	1.55
beryllium	U	U	U	U	U	U	U	U
cadmium	0.66	U	3.25	3.27	0.89	4.18	6.85	8.02
chromium	20.4	4.97	44.1	32.5	21.2	72.7	126	53.6
copper	149	41.9	1010	325	63.6	419	210	1270
lead	483	76.3	1230	1320	516	1120	4190	3170
nickel	80	13	61	42.4	23.1	179	90.3	110
selenium	2.19	U	U	U	2.93	U	U	U
silver	1.56	U	4.31	U	U	1.14	4.41	13.8
thallium	U	U	U	U	U	U	U	U
zinc	287	139	1050	1230	370	470	1480	2760
mercury	0.506	0.439	1.237	1.636	0.661	0.528	0.373	1.791

TCLP Metals

Parameter (mg/L)	HA-1	HA-2	HA-3	HA-4	HA-5	HA-6	HA-7	HA-8	TCLP Limit
antimony	U	U	U	U	U	U	U	U	NL
arsenic	U	U	U	U	U	U	U	U	5
beryllium	U	U	U	U	U	U	U	U	NL
cadmium	U	U	0.013	0.022	0.006	0.025	0.035	0.023	1
chromium	0.005	U	0.006	U	U	U	U	U	5
copper	0.274	0.073	0.167	0.148	0.031	0.143	0.341	2.25	NL
lead	0.376	0.053	0.279	0.282	1.96	0.575	2.52	0.466	5
nickel	0.039	0.029	0.043	0.019	0.014	0.059	0.052	0.038	NL
selenium	U	U	U	U	U	U	U	U	1
silver	U	U	U	U	U	U	U	U	5
thallium	U	U	U	U	U	U	U	U	NL
zinc	1.94	3	3.69	3.67	2.26	1.89	3.96	9.61	NL
mercury	U	U	U	U	U	U	U	U	0.2

Data as presented by Leggette, Brashears, & Graham, Inc. October 2000 - *Supplemental Site Characterization Activities Former Austin Avenue Landfill*.

U = undetected (i.e. below detection limits)

Blank cells indicate paramater was not analyzed

Sample locations shown on Figure 2-3.

TCLP Limit - concentration above which a material is considered hazardous. NL indicates no limit has been set.

Table 2-5. 2000 Gas Sample Results, (Methane), Austin Avenue Landfill. Remedial Investigation Work Plan. YIDA.

Sample I.D	Approximate depth (ft)	% LEL Methane
MP-1	1.5	0.5
MP-2	2	1
MP-3	2.5	0.5
MP-4	2	0.5
MP-5	3	0.5
MP-6	3	0.5
MP-7	3	0.5
MP-8	NS	NS
MP-9	1.5	0
MP-10	1	0
MP-11	1.5	3.5
MP-12	2	0.5
MP-13	2	0.5
MP-14	2.5	1
MP-15	2	1
MP-16	2.5	>50
MP-17	2	1.5
MP-18	1	5
MP-19	2	1
MP-20	2	0.5
MP-21	2	1
MP-22	2	>50
MP-23	1.5	7.5
MP-24	1.5	1.5

Data as presented by Leggette, Brashears, & Graham, Inc. October 2000 - *Supplemental Site Characterization Activities Former Austin Avenue Landfill*.

Sample locations shown on Figure 2-4.

LEL = Lower Explosive Limit for methane gas, which is 5% methane in air (by volume)

NS indicates no sample taken

APPENDICES

Appendix A
Quality Assurance Project Plan

QUALITY ASSURANCE PROJECT PLAN
TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1

PROJECT DESCRIPTION

The Austin Avenue Landfill was formerly owned and operated by the City of Yonkers, and consists of approximately 20-acres containing primarily incinerator ash and bulky waste, including trees, brush, and building debris. The landfill began receiving waste in the 1960's, and continued operation into the 1970s. The landfill had ceased operating by 1979, at which time the City of Yonkers entered into a consent order with the New York State Department of Environmental Conservation (NYSDEC) to properly close the former landfill. The landfill property was transferred to Westchester County in 1979, and is currently owned by the Westchester County Industrial Development Agency (IDA).

In 2004, the Yonkers Industrial Development Agency (YIDA) completed an application on behalf of the Westchester County IDA, for entry into the New York State Brownfield Cleanup Program (BCP). The "site", as defined under the Brownfield Cleanup Agreement (BCA Site No. C360066), consists of Westchester County, City of Yonkers Tax Parcel Section 3, Block 3244, Lot 1.

Under the BCP, a Brownfield Site Investigation must be completed in accordance with NYSDEC's *Technical Guidance for Site Investigation and Remediation* (DER-10), to provide a systematic assessment of environmental conditions on the property. This Quality Assurance Project Plan sets forth the quality assurance measures for completing the Brownfield Site Investigation.

SECTION 2

PROJECT ORGANIZATION

The organization of the key project management and field sampling teams, and areas of responsibility are shown presented below.

Project Principal	David W. Stoner, C.P.G.	Provide technical and administrative oversight and guidance throughout the project, assist in securing company resources, participate in technical review of deliverables, and attend key meetings as needed.
Principal Engineer	Damian J. Vanetti, P.E.	Provide technical guidance and review of reports, analytical data. Will have key involvement in screening and development of remedial alternatives.
Project Manager	Daniel P. Ours, C.P.G.	Responsible for maintaining the day-to-day schedule for completing the fieldwork and deliverables according to program objectives.
Field Team Leader	Jeffrey L. Kiggins	Responsible for coordinating and directing field efforts of S&W staff and subcontractors

SECTION 3

QA/QC OBJECTIVES FOR MEASUREMENT OF DATA

In cases where NYSDOH ELAP Certification exists for a specific group or category of parameters, the laboratories performing analysis in connection with this project will have appropriate NYSDOH ELAP Certification. For analysis of samples where Analytical Service Protocol (ASP, June 2000) Category B deliverables are required, NYSDOH ELAP CLP certification is required.

Detection limits set by NYSDEC-ASP (June 2000) will be used for all sample analyses unless otherwise noted. If NYSDEC-ASP-dictated detection limits prove insufficient to assess project goals (i.e., comparison to drinking water standards or attainment of ARARs), then ASP Special Analytical Services (SAS) or other appropriate methods will be utilized.

The quality assurance/quality control objectives for all measurement data include completeness, representativeness, comparability, precision and accuracy.

COMPLETENESS

The analyses performed must be appropriate and inclusive. The parameters selected for analysis are chosen to meet the objectives of the study.

Completeness of the analyses will be assessed by comparing the number of parameters intended to be analyzed with the number of parameters successfully determined and validated. Data must meet QC acceptance criteria for 100 percent or more of requested determinations.

REPRESENTATIVENESS

Samples must be taken of the population and, where appropriate, the population will be characterized statistically to express the degree to which the data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process, or environmental condition.

Non-dedicated sampling devices will be cleaned between sampling points by washing and rinsing with pesticide-grade methanol, followed by a thorough rinse with distilled water. Specific cleaning

techniques are described in the Field Sampling Procedure. Two types of blank samples will accompany each sample set where Target Compound List (TCL) volatiles are to be analyzed (water matrix only). A trip blank, consisting of a 40 ml VOA vial of organic-free water prepared by the laboratory, will accompany each set of sample bottles from the laboratory to the field and back. This bottle will remain sealed throughout the shipment and sampling process. This blank will be analyzed for TCL volatile organic compounds along with the groundwater samples to ensure that contamination with TCL volatile compounds has not occurred during the bottle preparation, shipment and sampling phase of the project. In order to check for contaminant carryover when non-dedicated sampling equipment is used, a rinsate blank will be submitted to the laboratory. This blank will also be analyzed for TCL volatile organic compounds. The TCL compounds are identified in the United States Environmental Protection Agency (USEPA) Contract Laboratory Program dated 7/85 or as periodically updated.

The analysis results obtained from the determination of identical parameters in field duplicate samples can be used to further assess the representativeness of the sample data.

COMPARABILITY

Consistency in the acquisition, preparation, handling and analysis of samples is necessary in order for the results to be compared where appropriate. Additionally, the results obtained from analyses of the samples will be compared with the results obtained in previous studies, if available.

To ensure the comparability of analytical results with those obtained in previous or future testing, all samples will be analyzed by NYSDEC-approved methods. The NYSDEC-ASP mandated holding times for various analyses will be strictly adhered to.

PRECISION AND ACCURACY

The validity of the data produced will be assessed for precision and accuracy. Analytical methods which will be used include gas chromatography/mass spectrometry (GC/MS), gas chromatography (GC), colorimetry, atomic spectroscopy, gravimetric and titrametric techniques. The following outlines the procedures for evaluating precision and accuracy, routine monitoring procedures, and corrective actions to maintain analytical quality control. All data evaluations will be consistent with NYSDEC-ASP procedures. Data will be 100 percent compliant with NYSDEC-ASP requirements.

The requirements of QA/QC are both method specific and matrix dependent. The procedures to be used are described on this basis in Sections 6 and 9. The number of duplicate, spiked and blank samples analyzed will be dependent upon the total number of samples of each matrix to be analyzed, but there will be at least one split per matrix. The inclusion and frequency of analysis of field blanks and trip blanks will be on the order of one per each site. Samples to be analyzed for volatile organic compounds will be accompanied by trip and field blanks (water matrix) or field blanks (soil, sediment matrice).

Quality assurance audit samples will be prepared and submitted by the laboratory QA manager for each analytical procedure used. The degree of accuracy and the recovery of analyte to be expected for the analysis of QA samples and spiked samples is dependent upon the matrix, method of analysis, and compound or element being determined. The concentration of the analyte relative to the detection limit is also a major factor in determining the accuracy of the measurement. The lower end of the analytical range for most analyses is generally accepted to be five times the detection limit. At or above this level, the determination and spike recoveries for metals in water samples will be expected to range from 75 to 125 percent. The recovery of organic surrogate compounds and matrix spiking compounds determined by GC/MS will be compared to the guidelines for recovery of individual compounds as established by the United States Environmental Protection Agency Contract Laboratory Program dated 7/85 or as periodically updated.

The quality of results obtained for inorganic ion and demand parameters will be assessed by comparison of QC data with laboratory control charts for each test.

SECTION 4

SAMPLING PROCEDURES

SAMPLING PROGRAM

The soil sampling program will include the collection of soil samples from split spoon sampling devices retrieved from soil borings. Groundwater samples will be collected from groundwater monitoring wells, and gas samples will be collected from gas monitoring wells. Surface soil and fill samples will also be collected.

Figures Q.4-1 and Q4.2 show the locations from which samples will be collected at the site. Table 4-1 presents a summary of the sample matrices, analysis methods, containers, preservation requirements, duplicates, MS/MSDs, and holding times for the sampling program.

A. **Drilling/Soil Sampling Procedures.** Test borings shall be completed using the hollow stem auger drilling method or rotary drilling method to a depth specified by the SWRNA geologist.

If a hollow stem auger drilling method is to be utilized for monitoring well completion, the minimum inside diameter of the augers shall be 4-1/4 inches.

Samples of the encountered surface materials shall be collected at a minimum of every 5 feet and/or change in material or at the discretion of the geologist. The sampling method employed shall be ASTM D-1586/Split Barrel Sampling using a standard 2-foot long, 2-inch outside diameter split-spoon sampler with a 140-pound hammer. Upon retrieval of the sampling barrel, the collected sample shall be placed in glass jars and labeled, stored on site (on ice in a cooler if necessary), and transmitted to the appropriate testing laboratory or storage facility. Chain-of-custody procedures will be practiced following Section 15, EPA-600/4-82-029, Handbook for Sampling and Sample Preservation of Water and Waste Waters.

A geologist will be on site during the drilling operations to fully describe each soil sample, following the New York State DOT Soil Description Procedure, and to retain representative portions of each sample.

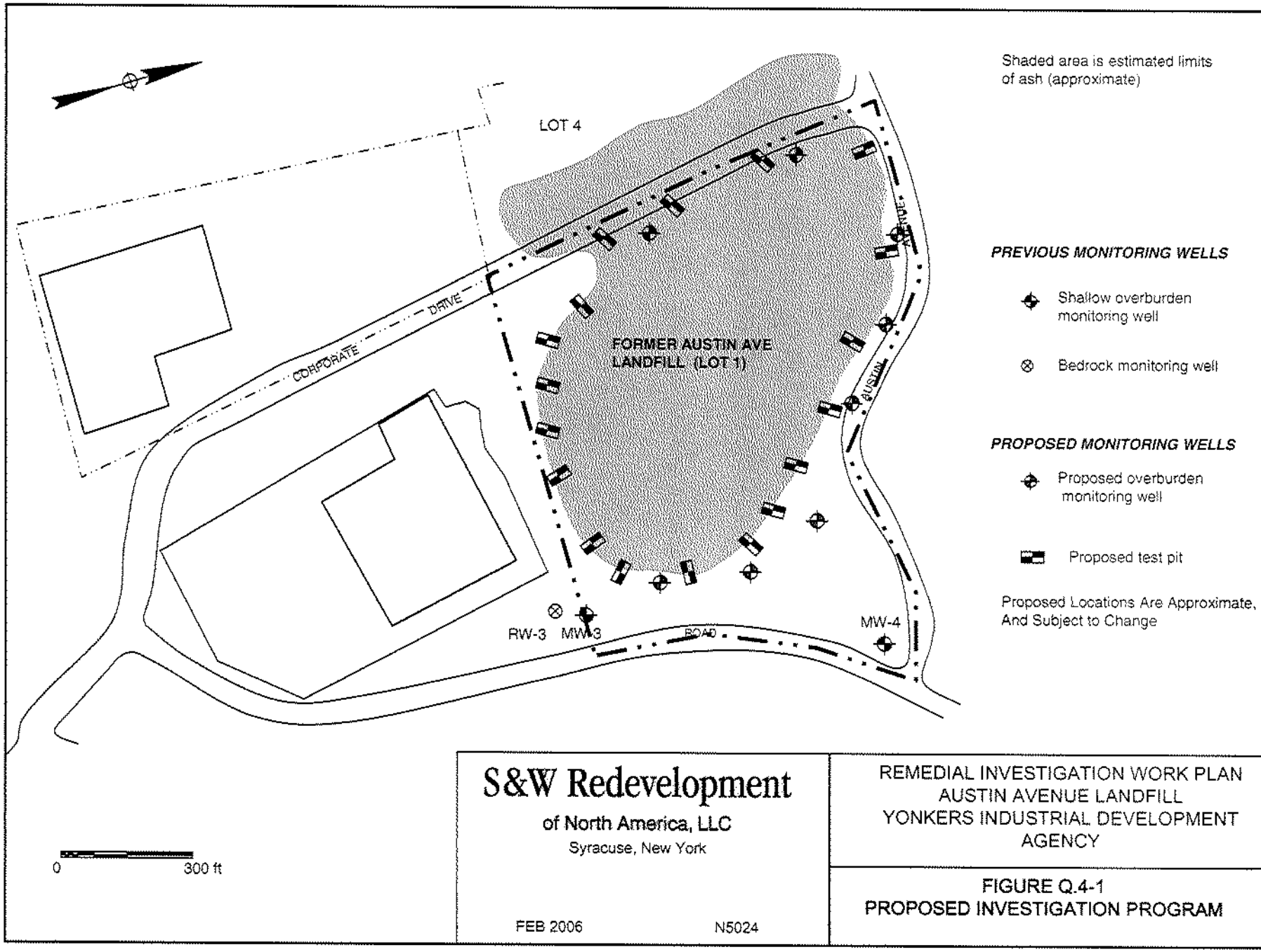

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FIGURE Q.4-1
PROPOSED INVESTIGATION PROGRAM

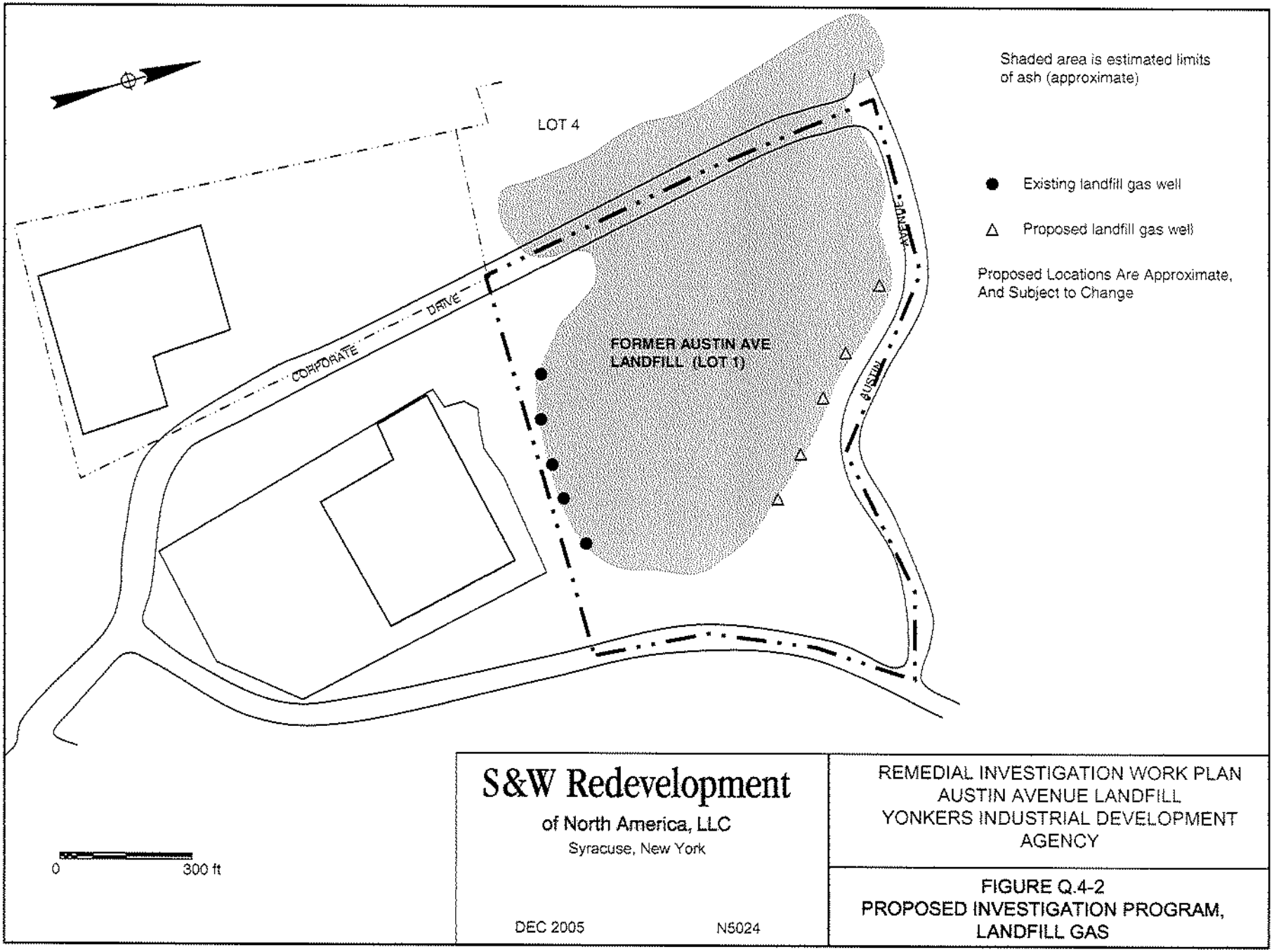

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FIGURE Q.4-2
PROPOSED INVESTIGATION PROGRAM, LANDFILL GAS

The drilling contractor will be responsible for obtaining accurate and representative samples, informing the geologist of changes in drilling pressure, keeping a separate general log of soils encountered including blow counts [i.e., the number of blows from a soil sampling drive weight (140 pounds)] required to drive the split-spoon sampler in 6-inch increments and installing monitoring wells to levels directed by the supervising geologist following specifications further outlined in this protocol.

B. Monitoring Well Completion. Initial downgradient monitoring wells will be constructed of 10 feet of .010-inch slot size PVC well screen and riser casing that will extend from the screened interval to 2 to 3 feet above existing grade. The selection of stainless steel or PVC for supplemental wells will depend on groundwater quality results from the initial wells. Other materials utilized for completion will be washed silica sand (Q-Rock No. 4 or approved equivalent) bentonite grout, Portland cement, and a protective steel locking well casing and cap with locks.

The monitoring well installation method for wells installed within unconsolidated sediments shall be to place the screen and riser assembly into the casing once the screen interval has been selected. At that time, a washed silica sand pack will be placed around the well screen if required to prevent screen plugging. If a sand pack is not warranted, the auger string will be pulled back to allow the native aquifer material to collapse 2 to 3 feet above the top of the screen. Bentonite pellets will then be added to the annulus between the casing and the inside auger to insure proper sealing. Cement/bentonite grout will continue to be added during the extraction of the augers until the entire aquifer thickness has been sufficiently sealed off from horizontal and/or vertical flow above the screened interval. During placement of sand and bentonite pellets, frequent measurements will be made to check the height of the sand pack and thickness of bentonite layers by a weighted drop tape measure.

A vented protective steel casing shall be located over the standpipe extending 2 feet below grade and 2 to 3 feet above grade, secured by a Portland cement seal. The cement seal shall extend laterally at least 1 foot in all directions from the protective casing and shall slope gently away to drain water away from the well. A vented steel cap will be fitted on the protective casing. The cap shall be constructed so it may be secured with a steel lock.

C. Well Development. All monitoring wells will be developed or cleared of all fine-grained materials and sediments that have settled in or around the well during installation so that the screen

is transmitting representative portions of the groundwater. The development will be by one of two methods, pumping or bailing groundwater from the well until it yields relatively sediment-free water.

A decontaminated pump or bailer will be used and subsequently decontaminated after each use following procedures outlined in the Decontamination Protocol. Pumping or bailing will cease when the turbidity falls below 50 NTUs or until specific conductivity, pH, and temperature are stable (i.e., consecutive readings are within 10 percent with no overall upward or downward trends in measurements). The decision to stop well development at a turbidity level above 50 NTUs is made only after consultation with the NYSDEC. Well development water will be disposed of on the ground surface at each well location or contained in drums as conditions warrant.

D. Decontamination. All drilling equipment and associated tools including augers, drill rods, sampling equipment, wrenches and any other equipment or tools that have come in contact with contaminated materials will be decontaminated before any drilling on site begins, between each well, and prior to removing any equipment from the site. The preferred decontamination procedure will be to use a high pressure steam cleaner to remove soils and volatile organics from the equipment. The water used for this procedure will be contained and shall come from a controlled source, preferably a municipal drinking supply. Representative samples of the contained decontamination water and well development water will be screened in the field to determine the proper method of disposal. Every effort will be made to minimize the generation of contaminated water.

E. Groundwater Sampling Program.

1. **Well Evacuation.** Prior to sampling a monitoring well, the static water level will be recorded and the wells evacuated to assure that the water in the well is truly representative of the groundwater. All well data will be recorded on a field sampling record. For shallow wells or deep wells with a relatively low static water level, evacuation will be accomplished by using a stainless steel or teflon bailer with a ball check valve at its lower end. A bladder may be used to evacuate the deeper wells at a rate of approximately 1 gpm. Water samples to be analyzed for volatile and/or semi-volatile organics must be sampled by bailer.

2. **Sampling Procedure.** Groundwater samples will be collected using either stainless steel, teflon, or disposable polyethylene bailers with a ball check valve at the lower end. Incorporation of a check valve onto the bailers assures that a sample is representative of the depth to which the bailer is lowered. All samples will be removed from a depth just above the

well screen to further assure a representative groundwater sample. Before and after sampling, the sampling device will be cleaned inside and out with soapy water, methanol, and then rinsed with distilled deionized water. Sampling procedures are summarized on Table 4.2.

In addition to water samples collected from the monitoring wells, two types of "blanks" will be collected and submitted to the chemical laboratory for analyses. The blanks will consist of 40 ml VOA vials, as follows:

a. **Trip Blank**. A trip blank will be prepared before the sample bottles are sent by the laboratory. It consists of a sample of distilled, deionized water which accompanies the other sample bottles into the field and back to the laboratory. A trip blank will be included with each shipment of samples where sampling and analysis for TCL volatiles is planned (water matrix only). The trip blank will be analyzed for TCL volatile organic compounds as a measure of the internal laboratory procedures and their effect on the results.

b. **Field (Wash) Blanks.** Field wash blanks are analyzed to check the effectiveness of decontamination. Each sample consists of distilled deionized water (prepared by the laboratory) poured through a decontaminated bailer or other sampling apparatus. It is usually collected as a last step in the decontamination procedure prior to sampling of a monitoring well. The wash blank can be analyzed for all or some of the compounds which the subsequent monitoring well sample is scheduled for.

F. Surface Soil Sampling Program. Surface soil samples will be collected from the upper two inches of soil, excluding ground cover (asphalt, gravel, concrete) or vegetation. Accordingly, prior to sample collection all ground cover and/or vegetation will be scraped away from the surface, or otherwise removed.

Surface soil samples will be collected using stainless steel hand tools, which may include hand trowels, shovels, hand augers, or soil probe. If dedicated sampling equipment is not to be used, the sampling tools will be decontaminated between use. Decontamination may be achieved by applying an Alconox-distilled water wash by scrub brush, followed by a distilled water rinse.

G. Landfill Gas Sampling Program. Gas samples will be collected in the vadose zone from shallow (3 to 5 feet) 1-inch diameter PVC well points. Each well point will be installed in a shallow boring drilled by either a small drill rig or by hand-operated equipment, such as hand auger or

percussion hammer drill. Drilling equipment used shall be based on soil conditions, and the method that provides the most practical approach.

Each well point will have a minimum of 1 feet of screen. After each well point is installed a sand filter pack will be placed in the annulus across the screened interval, and a bentonite seal (min 1 foot) will be placed on top of the sand pack. Native soil will be packed around the remaining annulus and protective stick-up casings will be cemented in place.

Each designated gas well will be sampled for explosive gas using a portable meter capable of recording total percent methane and percent lower explosive limit (LEL) methane.

SAMPLE PRESERVATION AND SHIPMENT

Since all bottles will contain the necessary preservatives as shown in Table 4.1, they need only be filled. The 40 ml VOA vials must be filled brim full with no air bubbles. The other bottles should be filled to within about 1 inch from the top.

The bottles will be sent from the laboratory in coolers which will be organized on a per site basis. Following sample collection, the bottles should be placed on ice in the shipping cooler. The samples will be cooled to 4°C, but not frozen.

Final packing and shipment of coolers will be performed in accordance with guidelines outlined in the "User's Guide to the CLP".

TABLE 4.1

SAMPLE CONTAINERIZATION

ANALYSIS	BOTTLE TYPE	PRESERVATIVE[1]	HOLDING TIME[2]
Soil			
TCL organics	Wide mouth, plastic or glass	None	7 days (until extraction, 40 days extracted)
TAL Metals	Wide mouth, plastic or glass	None	6 months

(1) All samples will be preserved with ice during collection and shipment.
(2) From verified time of sample receipt by the analytical laboratory (within 24 to 48 hours of collection).

TABLE 4.2

SAMPLING PROCEDURE FOR MONITORING WELLS

1. Initial static water level recorded with an electric contact probe accurate to the nearest 0.1 foot.
2. Sampling device and electric contact probe decontaminated.
   - Sampling device and probe are rinsed with pesticide-grade methanol and distilled water.
   - Methanol is collected into a large funnel which empties into a five- gallon container.
3. Sampling device lowered into well.
   - Bailer lowered by dedicated PVC or polypropylene line.
4. Sample taken.
   - Sample is poured slowly from the open end of the bailer and the sample bottle tilted so that aeration and turbulence are minimized.
   - Duplicate sample is collected when appropriate.
5. Samples are capped, labeled and placed in laboratory coolers with ice packs or bagged ice.
6. All equipment is cleaned with successive rinses of pesticide-grade methanol and distilled water.
   - Dedicated line is disposed of or left at well site.
7. Equipment/wash blanks are collected when non-dedicated sampling equipment is used.
8. Chain-of-custody forms are completed in triplicate.
   - The original and one carbon copy are put into a zip-lock bag and placed into the cooler. The original will be returned following sample analysis.
   - A second carbon copy is kept on file.
9. Cooler is sealed with strapping tape and chain-of-custody seals to assure integrity and to prevent tampering of sample.

SECTION 5

SAMPLE CUSTODY

The program for sample custody and sample transfer is in compliance with the NYSDEC-ASP, June 2000. If samples may be needed for legal purposes, chain-of-custody procedures, as defined by NEIC Policies and Procedures (USEPA-330/9-78-001-R, Revised June 1988) will be used. Sample chain-of-custody is initiated by the laboratory with selection and preparation of the sample containers. To reduce the chance for error, the number of personnel handling the samples should be minimized.

FIELD SAMPLE CUSTODY

A chain-of-custody record accompanies the sample from initial sample container selection and preparation at the laboratory, shipment to the field for sample containment and preservation, and return to the laboratory. Two copies of this record follow the samples to the laboratory. The laboratory maintains one file copy and the completed original is returned to the site inspection team. Individual sample containers provided by the laboratory are used for shipping samples. The shipping containers are insulated and chemical or ice water is used to maintain samples at approximately 4°C until samples are returned and in the custody of the laboratory. All sample bottles within each shipping container are individually labeled and controlled. Samples are to be shipped to the laboratory within 24-48 hours of the day of collection.

Each sample shipping container is assigned a unique identification number by the laboratory. This number is recorded on the chain-of-custody record and is marked with indelible ink on the outside of the shipping container. The field sampler will indicate the sample designation/location number in the space provided on the appropriate chain-of-custody form for each sample collected. The shipping container is closed and a seal provided by the laboratory is affixed to the latch. This seal must be broken to open the container, and this indicates possible tampering if the seal is broken before receipt at the laboratory. The laboratory will contact the site investigation team leader and the sample will not be analyzed if tampering is apparent.

LABORATORY SAMPLE CUSTODY

The site investigation team leader or Project Quality Assurance Officer notifies the laboratory of upcoming field sampling activities and the subsequent transfer of samples to the laboratory. This notification will include information concerning the number and type of samples to be shipped as well as the anticipated date of arrival.

The laboratory sample program meets the following criteria:

1. The laboratory has designated a sample custodian who is responsible for maintaining custody of the samples and for maintaining all associated records documenting that custody.

2. Upon receipt of the samples, the custodian will check the original chain-of-custody documents and compare them with the labeled contents of each sample container for correctness and traceability. The sample custodian signs the chain-of-custody record and records the date and time received.

3. Care is exercised to annotate any labeling or descriptive errors. In the event of discrepant documentation, the laboratory will immediately contact the site investigation team leader as part of the corrective action process. A qualitative assessment of each sample container is performed to note any anomalies, such as broken or leaking bottles. This assessment is recorded as part of the incoming chain-of-custody procedure.

4. The samples are stored in a secured area at a temperature of approximately 4°C until analyses are to commence.

5. A laboratory chain-of-custody record accompanies the sample or sample fraction through final analysis for control.

6. A copy of the chain-of-custody form will accompany the laboratory report and will become a permanent part of the project records.

FINAL EVIDENCE FILES

Final evidence files include all originals of laboratory reports and are maintained under documented control in a secure area.

A sample or an evidence file is under custody if:

- It is in your possession; it is in your view, after being in your possession.
- It was in your possession and you placed it in a secure area.
- It is in a designated secure area.

SECTION 6

CALIBRATION PROCEDURES

Instruments and equipment used to gather, generate or measure environmental data will be calibrated with sufficient frequency and in such a manner that accuracy and reproducibility of results are consistent with the appropriate manufacturer's specifications or project specific requirements. The procedures for instrument calibration, calibration verification, and the frequency of calibrations are described in the NYSDEC-CLP. The calibration of instruments used for the determination of metals will be as described in the appropriate CLP standard operating procedures.

Calibration of other instruments required for measurements associated with these analyses will be in accordance with the manufacturer's recommendations and the standard operating procedures of the laboratory.

SECTION 7

ANALYTICAL PROCEDURES

Analytical procedures shall conform to the most recent revision of the NYSDEC-ASP and are summarized on Table 7.1. In the absence of USEPA or NYSDEC guidelines, appropriate procedures shall be submitted for approval by NYSDEC prior to use.

The procedures for the sample preparation and analysis for organic compounds are as specified in the NYSDEC-ASP. Analytical cleanups are mandatory where matrix interferences are noted. No sample shall be diluted any more than 1 to 5. The sample shall be either re-extracted, re-sonicated, re-stream distilled, etc. or be subjected to any one analytical cleanup noted in SW846 or a combination thereof. The analytical laboratory shall expend such effort and discretion to demonstrate good laboratory practice and demonstrate an attempt to best achieve the method detection limit.

VOLATILE ORGANICS (VOA)

For the analysis of water samples for Target Compound List (TCL), volatile organic compounds (VOCs), no sample preparation is required. The analytical procedure for volatiles is detailed in NYSDEC-ASP (Volume I, Section D-I). A measured portion of the sample is placed in the purge and trap apparatus and the sample analysis is performed by gas chromatography/mass spectrometry for the first round. USEPA Methods 8010 or 8020 (gas chromatography with different detectors) will be used if subsequent rounds with lower limits of detection are warranted.

SEMI-VOLATILE ORGANIC COMPOUNDS

The extraction and analytical procedures used for preparation of water, soil and sediment samples for the analysis of the TCL semi-volatile organic compounds are described in NYSDEC-ASP Volume I, Section D-III.

Instrument calibration, compound identification, and quantitation are performed as described in Section 6 of this document and in the NYSDEC-ASP.

METALS

Water, soil and waste samples will be analyzed for the metals listed in Table 7.2. The detection limits for these metals are as specified in the NYSDEC-ASP, Section D-V. The instrument detection limits will be determined using calibration standards and procedures specified in the NYSDEC-ASP. The detection limits for individual samples may be higher due to the sample matrix. The procedures for these analyses will be as described in the NYSDEC-ASP.

The digestion procedures for water samples are not recommended for samples requiring analysis for mercury, arsenic or selenium. The aliquot of sample analyzed for As and Se will be prepared using the modifications described in USEPA Methods 206.2 CLP-M and 270.2 CLP-M, respectively. Analysis for mercury requires a separate digestion procedure (245.1 CLP-M, or 245.2 CLP-M).

The analyses for metals will be performed by atomic absorption spectroscopy (AAS) or inductively-coupled plasma emission spectroscopy (ICPES), as specified in the ASP with regard to AAS flame analysis.

SITE SPECIFICITY OF ANALYSES

Work plans prepared for remedial investigation waste sites contain recommendations for the chemical parameters to be determined for each site. Thus, some or all of the referenced methods will apply to the analysis of samples collected at the individual waste sites. Analyses of Target Compound List (TCL) analytes will be performed on all samples.

TABLE 7-1

PROPOSED METHOD DETECTION LIMITS AND
ANALYTICAL METHODS
ASP INORGANICS, ASP VOLATILES, ASP SEMI-VOLATILES.

Superfund Target Compound List (TCL) and Contract-Required Quantitation Limit

SECTION 1 - ASP INORGANICS
Method: NYSDEC-ASP, June 2000

PARAMETER		CONTRACT-REQUIRED DETECTION LEVEL* (µg/l)
1.	Aluminum	200
2.	Antimony	60
3.	Arsenic	10
4.	Barium	200
5.	Beryllium	5
6.	Cadmium	5
7.	Calcium	5000
8.	Chromium	10
9.	Cobalt	50
10.	Copper	25
11.	Iron	100
12.	Lead	3
13.	Magnesium	5000
14.	Manganese	15
15.	Mercury	0.2
16.	Nickel	40
17.	Potassium	5000
18.	Selenium	5
19.	Silver	10
20.	Sodium	5000
21.	Thallium	10
22.	Vanadium	50
23.	Zinc	20
24.	Cyanide	10

*Matrix: groundwater. For soil matrix, multiply CRDL by 100.

TABLE 7-1 (continued)

SECTION I - ASP ORGANICS
Method: NYSDEC-ASP, June 2000

	VOLATILE	PROPOSED METHOD DETECTION LIMITS (µg/l)*
1.	Chloromethane	1
2.	Bromomethane	1
3.	Vinyl chloride	1
4.	Chloroethane	1
5.	Methylene chloride	1
6.	Acetone	1
7.	Carbon disulfide	1
8.	1,1-Dichloroethylene	1
9.	1,1-Dichloroethane	1
10.	1,2-Dichloroethylene (total)	1
11.	Chloroform	1
12.	1,2-Dichloroethane	1
13.	2-Butanone	1
14.	1,1,1-Trichloroethane	1
15.	Carbon tetrachloride	1
16.	Bromodichloromethane	1
17.	1,1,2,2-Tetrachloroethane	1
18.	1,2-Dichloropropane	1
19.	cis-1,3-Dichloropropene	1
20.	Trichloroethene	1
21.	Dibromochloromethane	1
22.	1,1,2-Trichloroethane	1
23.	Benzene	1
24.	Trans-1,3-Dichloropropene	1
25.	Bromoform	1
26.	2-Hexanone	1
27.	4-Methyl-2-pentanone	1
28.	Tetrachloroethylene	1
29.	Toluene	1
30.	Chlorobenzene	1
31.	Ethylbenzene	1
32.	Styrene	1
33.	Total xylenes	1

*Quantitation limit for medium-level soil is 1200 µg/kg (wet weight basis).

TABLE 7-1 (continued)

SECTION I - ASP ORGANICS
Method: NYSDEC-ASP, June 2000

	SEMI-VOLATILES	CONTRACT-REQUIRED QUANTITATION LIMIT (µg/l)
34.	Phenol	10
35.	Bis(2-chloroethyl) ether	10
36.	2-Chlorophenol	10
37.	1,3-Dichlorobenzene	10
38.	1,4-Dichlorobenzene	10
39.	1,2-Dichlorobenzene	10
40.	2-Methylphenol	10
41.	2,2' oxybis(1-Chloropropane)	10
42.	4-Methylphenol	10
43.	N-Nitroso-dipropylamine	10
44.	Hexachloroethane	10
45.	Nitrobenzene	10
46.	Isophorone	10
47.	2-Nitrophenol	10
48.	2,4-Dimethylphenol	10
49.	bis(2-Chloroethoxy) methane	10
50.	2,4-Dichlorophenol	10
51.	1,2,4-Trichlorobenzene	10
52.	Naphthalene	10
53.	4-Chloroaniline	10
54.	Hexachlorobutadiene	10
55.	4-Chloro-3-methylphenol	10
56.	2-Methylnaphthalene	10
57.	Hexachlorocyclopentadiene	10
58.	2,4,6-Trichlorophenol	10
59.	2,4,5-Trichlorophenol	25
60.	2-Chloronaphthalene	10
61.	2-Nitroaniline	25
62.	Dimethyl phthalate	10
63.	Acenaphthylene	10
64.	2,6-Dinitrotoluene	10
65.	3-Nitroaniline	25
66.	Acenaphthene	10
67.	2,4-Dinitrophenol	25

TABLE 7-1 (continued)

SECTION I - ASP ORGANICS
Method: NYSDEC-ASP, June 2000

	SEMI-VOLATILES	CONTRACT-REQUIRED QUANTITATION LIMIT (µg/l)
68.	4-Nitrophenol	25
69.	Dibenzofuran	10
70.	Dinitrotoluene	10
71.	Diethylphthalate	10
72.	4-Chlorophenyl phenyl ether	10
73.	Fluorene	10
74.	4-Nitroanile	25
75.	4,6-Dinitro-2-methylphenol	25
76.	N-nitrosodiphenylamine	10
77.	4-Bromophenyl phenyl ether	10
78.	Hexachlorobenzene	10
79.	Pentachlorophenol	25
80.	Phenanthrene	10
81.	Anthracene	10
82.	Carbazole	10
83.	Di-n-butyl phthalate	10
84.	Fluoranthene	10
85.	Pyrene	10
86.	Butyl benzyl phthalate	10
87.	3,3'-Dichlorobenzidine	10
88.	Benz(a) anthracene	10
89.	Chrysene	10
90.	bis(2-ethylhexyl)phthalate	10
91.	Di-n-octyl phthalate	10
92.	Benzo(b)fluoranthene	10
93.	Benzo(k)fluoranthene	10
94.	Benzo(a)pyrene	10
95.	Indeno(1,2,3-cd)pyrene	10
96.	Dibenz(a,h)anthracene	10
97.	Benzo(g,h,i)perylene	10

Appendix B
Health and Safety Plan

SITE HEALTH AND SAFETY PLAN

A. SITE DESCRIPTION

Date ..... Date: January 2006 Revised: _____
Location ..... Austin Avenue Landfill, Austin Avenue & Corporate Drive, Yonkers, NY
Hazards ..... Metals, volatile and semi-volatile organics, in soil and groundwater
Area Affected ..... Subsurface, surface soils, groundwater
Surrounding Population ..... Mixed commercial
Topography ..... Approximate 5% to 10% slope
Weather Conditions ..... Usually partly sunny to overcast, southeast winds

B. ENTRY OBJECTIVES: The objective of site entry is to investigate potential contaminant source areas at the former Austin Ave Landfill, for metals, volatile and semi-volatile organic compounds.

C. ON-SITE ORGANIZATION AND COORDINATION. The following personnel are designated to carry out the stated job functions on site. (Note: One person may carry out more than one job function.)

Project Team Leader:	Daniel Ours or designee	(315) 422-4949
Site Safety Officer:	Donald Sorbello or designee	(315) 422-4949
Field Team Leader:	Jeffrey Kiggins or designee	(315) 422-4949
Field Team Members:	Allison Menges/Jeffrey Kiggins	(315) 422-4949

D. ON-SITE CONTROL. The Yonkers Industrial Development Agency (YIDA) will coordinate access control and security on site. A safe perimeter has been established at the site boundaries. No unauthorized personnel should be within this area.

E. HAZARD EVALUATION. The principal suspected hazard for the former landfill is believed to be associated with metals present in disposed ash. The primary hazards of potential metals are identified.

SUBSTANCE	PRIMARY HAZARDS
Metals	
Beryllium	Dermatitis, skin irrit., respiratory irrit., weight loss
Chromium	Histologic fibrosis of lungs
Copper	Irrit eys, nose, metallic taste
Nickel	Headache, nausea, vomiting, stomach pain
Arsenic	Stomach disturb., nose bleeds, respiratory problems
Lead	Eye irrit., stomach pain, weakness, insomnia, kidney dis

Detailed public health profiles for each of these metals are attached to this Plan.

A secondary hazard may exist relative to organic compounds, however previous analysis of fill (ash) material at the landfill suggests that exposure to organics is less likely than to metals. Potential hazards associated with typical landfill organics are presented below.

SUBSTANCE	PRIMARY HAZARDS
Volatile Organics	
Trichlorethene	Eye & skin irritation, nausea, vomiting, headache
Benzene	Eyes, nose, throat irritation, nausea, dizziness, headache

SUBSTANCE	PRIMARY HAZARDS
Semi-Volatile Organics*	
Acenaphthene	Skin irritation, mucous membrane irritation, vomiting
Benzo(a)pyrene	Skin tumors, carcinogen
Chrysene	Carcinogen
Fluoranthene	Possible carcinogen
Naphthalene	Headache, nausea, sweating

F. PERSONAL PROTECTIVE EQUIPMENT. Based on evaluation of potential hazards, the following levels of personal protection have been designated for the applicable work areas or tasks:

LOCATION	JOB FUNCTION	LEVEL OF PROTECTION
Work zone	Site investigation	A B C (D) Other

Specific protective equipment for each level of protection is as follows:

Level A	Fully-encapsulating suit SCBA (disposable coveralls)
Level B	Splash gear (saranax-coated Tyvek suit) SCBA or airline respirators
Level C	Splash gear (Tyvek suit) Full-face canister respirator Boots Gloves Hard hat
Level D	Overalls Safety glasses Boots Gloves Hard hat

Action Levels. The following criteria shall be used to determine appropriate action:

VOLATILE ORGANICS IN BREATHING ZONE	LEVEL OF RESPIRATORY PROTECTION
0-5 ppm	Level D
5-200 ppm	Level C
200-1000 ppm	Level B - air line
1000+ ppm	Level B - SCBA

% LOWER EXPLOSIVE LIMIT (LEL)	ACTION
Above 10	Discontinue work and take remedial action

The following protective clothing materials are required for the involved substances:

SUBSTANCE	MATERIAL (MATERIAL NAME, E.G., VITON)
Volatile Organics	
Trichloroethene	Level D, Respirator
Benzene	Level D, Respirator

Semi-Volatile Organics*	
Acenaphthene	Level D, Respirator
Benzo(a)pyrene	Level D, Respirator
Chrysene	Level D, Respirator
Fluoranthene	Level D, Respirator
Naphthalene	Level D, Respirator

Metals	
Chromium	Level D, Respirator
Copper	Level D, Respirator
Nickel	Level D, Respirator
Arsenic	Level D, Respirator
Mercury	Level D, Respirator

NO CHANGE TO THE SPECIFIED LEVELS OF PROTECTION SHALL BE MADE WITHOUT THE APPROVAL OF THE SITE SAFETY OFFICER AND THE PROJECT TEAM LEADER.

G. ON-SITE WORK PLANS. The following personnel or designated alternate(s) will perform the field investigation.

Project Team Leader:.....Daniel Ours
Work Party .....Allison Menges Jeffrey Kiggins

The work party was briefed on the contents of this plan prior to commencement of work.

II. COMMUNICATION PROCEDURES. The Project Team Leader should remain in communication with the Field Team Leader. A cellular phone will be used in the field.

Continuous horn blast is the emergency signal to indicate that all personnel should leave the Work Zone.

In the event that radio communications are used, the following standard hand signals will be used in case of failure of radio communications:

Hand gripping throat	Out of air; can't breathe
Grip partner's wrist or both hands around waist	Leave area immediately
Hands on top of head	Need assistance
Thumbs up	OK; I am all right; I understand
Thumbs down	No; negative

I. SITE HEALTH AND SAFETY PLAN.

1. Donal Sorbello or a designated alternate is the Site Safety Officer and is directly responsible to the Project Team Leader for safety recommendations on site. The Field Team Leader will be responsible for executing and enforcing the Site Health and Safety Plan.

2. **Emergency Medical Care.** St Joseph's Medical Center is located approximately 5 miles southwest of the site. A map to this facility will be available at the field vehicle. Directions are provided below:

   - Take NYS Thruway from site, and go SOUTH (I-87S)
   - Get off at EXIT 6W towards Yonkers (TUCKAHOE ROAD WEST)
   - Turn slight RIGHT on TUCKAHOE RD
   - TUCKAHOE RD becomes SAW MILL RIVER RD (NY 9A)
   - Turn RIGHT on ASHBURTON AVE (NY 9A)
   - Turn LEFT on NEPPERHAN AVE (NY 9A)
   - Turn LEFT on US-9/ S BROADWAY/ NY-9A
   - Go to 127 S BROADWAY

   First aid equipment is available on site at the following locations:

   First aid kit Field vehicle

   List of emergency phone numbers:

AGENCY/FACILITY	PHONE NUMBER
Police (Yonkers Police Department)	911 or (914) 377-7900
Fire	911
Ambulance	911
Saint Joseph's Medical Center	(914) 378-7000

3. **Environmental Monitoring.** The following environmental monitoring instruments shall be used on site at the specified intervals:

   - MiniRAE photoionization detector (PID). Continuous during installation of soil gas monitoring probes.
   - Dust monitor.

4. **Emergency Procedures.** The following standard procedures will be used by on-site personnel. The Site Safety Officer shall be notified of any on-site emergencies and be responsible for ensuring that the appropriate procedures are followed:

   a. **Personnel Injury in the Work Zone.** Upon notification of an injury in the Work Zone, the designated emergency signal, a continuous horn blast, shall be sounded. A rescue team will enter the Work Zone (if required) to remove the injured person to safety. Appropriate first aid shall be initiated and contact should be made for an ambulance and with the designated medical facility (if required). No persons shall re-enter the Work Zone until the cause of the injury or symptoms is determined.

   b. **Fire/Explosion.** Upon notification of a fire or explosion on site, the designated emergency signal, a continuous horn blast, shall be sounded and all site personnel assembled at the decontamination line. The fire department shall be alerted and all personnel moved to a safe distance from the involved area.

   c. **Personal Protective Equipment Failure.** If any site worker experiences a failure or alteration of protective equipment that affects the protection factor, that person and his/her buddy shall immediately leave the Work Zone. Re-entry shall not be permitted until the equipment has been repaired or replaced.

   d. **Other Equipment Failure.** If any other equipment on site fails to operate properly, the Project Team Leader and Site Safety Officer shall be notified and then determine the effect of this failure on continuing operations on site. If the failure affects the safety of personnel or prevents completion of the Work Plan tasks, all personnel shall leave the Work Zone until the situation is evaluated and appropriate actions taken.

   In all situations, when an on-site emergency results in evacuation of the Work Zone, personnel shall not re-enter until:

   a. The conditions resulting in the emergency have been corrected.
   b. The hazards have been reassessed.
   c. The Site Health and Safety Plan has been reviewed.
   d. Site personnel have been briefed on any changes in the Site Health and Safety Plan.

5. **Personal Monitoring.** The following personal monitoring will be in effect on site:

   Personal exposure sampling: MiniRAE PID screening, sampling pumps/tubes , or organic vapor monitors.

   Medical monitoring: The expected air temperature will be less than 70EF. If it is determined that heat stress monitoring is required (mandatory if over 70EF), the following procedures shall be followed: Monitoring body temperature, body weight, pulse weight.

All site personnel have read the above plan and are familiar with its provisions.

	Name	Signature
Site Safety Officer		
Project Team Leader		
Other Site Personnel		

Hazard Profile - Arsenic

2. RELEVANCE TO PUBLIC HEALTH

2.1 BACKGROUND AND ENVIRONMENTAL EXPOSURES TO ARSENIC IN THE UNITED STATES

Arsenic is widely distributed in the Earth's crust, which contains about 3.4 ppm arsenic. In nature, arsenic is mostly found in minerals and only to a small extent in its elemental form. Arsenic is mainly obtained as a byproduct of the smelting of copper, lead, cobalt, and gold ores. Arsenic trioxide is the primary form in which arsenic is marketed and consumed. There has been no domestic production of arsenic since 1985. In 2003, the world's largest producer of arsenic compounds was China, followed by Chile and Peru.

In 2003, the U.S. was the world's largest consumer of arsenic. Production of wood preservatives, primarily copper chromated arsenic (CCA), $CrO_3 \cdot CuO \cdot As_2O_5$, accounted for more than 90% of domestic consumption of arsenic trioxide. In response to consumer concerns, U.S. manufacturers of arsenical wood preservative began a voluntary transition from CCA to other wood preservatives for certain residential wood products. This phase-out was completed on December 31, 2003; wood treated prior to this date could still be used and CCA-treated wood products continue to be used in industrial applications.

Other uses for arsenic compounds include the production of agricultural chemicals, as an alloying element in ammunition and solders, as an anti-friction additive to metals used for bearings, and to strengthen lead-acid storage battery grids. High-purity arsenic (99.9999%) is used by the electronics industry for gallium-arsenide semiconductors for telecommunications, solar cells, and space research. Various organic arsenicals are still used in the United States as herbicides and as antimicrobial additives for animal and poultry feed. However, the use of inorganic arsenic compounds in agriculture has virtually disappeared beginning around the 1960s. Arsenic trioxide and arsenic acid were used as a decolorizer and fining agent in the production of bottle glass and other glassware. Arsenic compounds also have a long history of use in medicine, and have shown a re-emergence of late with the recent introduction of arsenic trioxide treatment for acute promyelocytic leukemia.

The principal route of exposure to arsenic for the general population is likely to be the oral route, primarily in the food and in the drinking water. Dietary exposures to total arsenic were highly variable, with a mean of 50.6 µg/day (range of 1.01–1,081 µg/day) for females and 58.5 µg/day (range of 0.21–

1,276 µg/day) for males. The mean estimated average daily consumption of inorganic arsenic was 10.22 µg/day (range of 0.93–104.89 µg/day). Drinking water generally contains an average of 2 µg/L of arsenic, although 12% of water supplies from surface water sources in the North Central region of the country and 12% of supplies from groundwater sources in the Western region have levels exceeding 20 µg/L. Arsenic is also widely distributed in surface water, groundwater, and finished drinking water in the United States. Surveys of arsenic concentrations in rivers and lakes indicate that most values are below 10 µg/L, although individual samples may range up to 3,400 µg/L. Arsenic released to the land at hazardous waste sites is likely to be relatively immobile due to a high capacity for soil binding, particularly to iron and manganese oxides. Exposure to arsenic from other pathways is generally small, but may be significant for areas with high levels of arsenic contamination or in occupational settings. For a more complete discussion of possible exposures to arsenic, see Chapter 6 of the profile.

2.2 SUMMARY OF HEALTH EFFECTS

Arsenic is a potent toxicant that may exist in several valence states and in a number of inorganic and organic forms. Most cases of arsenic-induced toxicity in humans are due to exposure to inorganic arsenic, and there is an extensive database on the human health effects of the common arsenic oxides and oxyacids. Although there may be some differences in the potency of different chemical forms (e.g., arsenites tend to be somewhat more toxic than arsenates), these differences are usually minor. Humans may be exposed to a variety of organic arsenicals (mainly methyl and phenyl derivatives of arsenic acid) since these are widely used in agriculture. Although human health effects data are sparse, it is generally considered that organic arsenicals are substantially less toxic than the inorganic forms. However, available data (mainly from animal studies) make clear that adequate doses of the methyl and phenyl arsenates can produce adverse health effects that resemble those of the inorganic arsenicals; thus, the possibility of health risks from the organic arsenicals should not be disregarded.

Exposures of humans near hazardous waste sites could involve inhalation of arsenic dusts in air, ingestion of arsenic in water, food, or soil, or dermal contact with contaminated soil or water. By the inhalation route, the most sensitive effect of inorganic arsenic is an increased risk of lung cancer, although respiratory irritation, nausea, and skin effects may also occur. There are only a few quantitative data on noncancer effects in humans exposed to inorganic arsenic by the inhalation route. However, it appears that such effects are unlikely below a concentration of about 0.1–1.0 mg As/m^3. Animal data similarly identify effects on the respiratory system as the primary noncancer effect of inhaled inorganic arsenic compounds, although only a few studies are available. Only limited data on the effects of inhaled organic

arsenic compounds in humans or animals are available; these studies are generally limited to high-dose, short-term exposures, which result in frank effects.

Relatively little information is available on effects due to direct dermal contact with inorganic arsenicals, but several studies indicate the chief effect is local irritation and dermatitis, with little risk of other adverse effects.

The database for the oral toxicity of inorganic arsenic is extensive, containing a large number of studies of orally-exposed human populations. These studies have identified effects on virtually every organ or tissue evaluated, although some end points appear to be more sensitive than others. The available data from humans identify the skin as the most sensitive noncancer end point of long-term oral arsenic exposure. Typical dermal effects include hyperkeratinization of the skin (especially on the palms and soles), formation of multiple hyperkeratinized corns or warts, and hyperpigmentation of the skin with interspersed spots of hypopigmentation. Oral exposure data from studies in humans indicate that these lesions typically begin to manifest at exposure levels of about 0.002–0.02 mg As/kg/day. At these exposure levels, peripheral vascular effects are also commonly noted, including cyanosis, gangrene, and, in Taiwanese populations, the condition known as "Blackfoot Disease." Other reported cardiovascular effects of oral exposure to inorganic arsenic include increased incidences of high blood pressure and circulatory problems. Recently, the use of intravenous arsenic trioxide as therapy for acute promyelocytic leukemia has raised further concerns about the cardiovascular effects of arsenic, including alterations in cardiac QT interval and the development of torsades de pointes.

In addition to dermal and cardiovascular effects, oral exposure to inorganic arsenic may result in effects on other organ systems. Nausea, vomiting, and diarrhea are very common symptoms in humans following oral exposure to inorganic arsenicals, both after acute high-dose exposure and after repeated exposure to lower doses; these effects are likely due to a direct irritation of the gastrointestinal mucosa. Acute, high-dose exposure can lead to encephalopathy, with clinical signs such as confusion, hallucinations, impaired memory, and emotional lability, while long-term exposure to lower levels can lead to the development of peripheral neuropathy characterized by a numbness in the hands and feet that may progress to a painful "pins and needles" sensation. A recent study also reported decreases in intelligence scores of arsenic-exposed children.

Data on the effects of oral exposure to inorganic arsenic on reproductive end points in humans are not available. Animal data suggest that arsenic may cause changes to reproductive organs of both sexes,

including decreased organ weight and increased inflammation of reproductive tissues, although these changes may be secondary effects. However, these changes do not result in a significant impact on reproductive ability. Chronic exposure of humans to inorganic arsenic in the drinking water has been associated with excess incidence of miscarriages, stillbirths, preterm births, and infants with low birth weights, although dose-response data are not presently available for these effects. Animal studies of oral inorganic arsenic exposure have reported developmental effects, but generally only at concentrations that also resulted in maternal toxicity.

Arsenic is a known human carcinogen by both the inhalation and oral exposure routes. By the inhalation route, the primary tumor types are respiratory system cancers, although a few reports have noted increased incidence of tumors at other sites, including the liver, skin, and digestive tract. In humans exposed chronically by the oral route, skin tumors are the most common type of cancer. In addition to skin cancer, there are a number of case reports and epidemiological studies that indicate that ingestion of arsenic also increases the risk of internal tumors (mainly of bladder and lung, and to a lesser extent, liver, kidney, and prostate).

The Department of Health and Human Services (DHHS) has concluded that inorganic arsenic is known to be a human carcinogen. The International Agency for Research on Cancer (IARC) cites sufficient evidence of a relationship between exposure to arsenic and human cancer. The IARC classification of arsenic is Group 1. The EPA has determined that inorganic arsenic is a human carcinogen by the inhalation and oral routes, and has assigned it the cancer classification, Group A. EPA has calculated an oral cancer slope factor of 1.5 $(mg/kg/day)^{-1}$ and a drinking water unit risk of $5x10^{-5}$ $(\mu g/L)^{-1}$ for inorganic arsenic based on human dose-response data. The inhalation unit risk for cancer is 0.0043 $(\mu g/m^3)^{-1}$. EPA is currently revising the assessment for inorganic arsenic.

The following sections discuss significant effects resulting from exposure to inorganic arsenic in greater detail: dermal, cardiovascular, respiratory, gastrointestinal, neurological, and cancer. Additional information on these effects and on other effects is discussed in Section 3.2.

Dermal Effects. The most characteristic effect of long-term oral exposure to inorganic arsenic compounds is the development of skin lesions; these lesions are often used as diagnostic criteria for arsenicosis. The three lesions most often associated with chronic arsenicosis are hyperkeratinization of the skin (especially on the palms and soles), formation of multiple hyperkeratinized corns or warts, and hyperpigmentation of the skin with interspersed spots of hypopigmentation. Numerous studies of long-

term, low-level exposure to inorganic arsenic in humans have reported the presence of these lesions. In general, they begin to manifest at chronic exposure levels ranging from 0.002 to 0.02 mg As/kg/day. Chronic oral studies of lower exposure levels, ranging from 0.0004 to 0.01 mg As/kg/day, have generally not reported dermal effects. The mechanism(s) by which inorganic arsenic causes dermal effects is not well-understood. Elucidating the mechanism of dermal effects has been particularly difficult because the dermal effects common in humans have not been seen in studies in animals.

Dermal effects have also been reported following inhalation exposures to inorganic arsenic, although they are not as diagnostic as for oral exposure. Several studies of arsenic-exposed workers have reported the development of dermatitis; exposure levels required to produce this condition are not well-established. Altered dermal pigmentation and hyperkeratosis have also been reported in studies of humans exposed to inorganic arsenic by inhalation, although exposure levels have varied considerably. Direct dermal contact with inorganic arsenicals may cause irritation and contact dermatitis. Usually, the effects are mild (erythema and swelling), but may progress to papules, vesicles, or necrotic lesions in extreme cases; these conditions tend to heal without treatment if exposure ceases.

Following inhalation exposure to organic arsenic compounds, observed dermal effects are generally limited to irritation at high exposure levels. No studies of dermal effects of organic arsenic compounds were available.

Cardiovascular Effects. A large number of studies in humans have reported cardiovascular effects following oral exposure to inorganic arsenic compounds. The cardiac effects of arsenic exposure are numerous, and include altered myocardial depolarization (prolonged QT interval, nonspecific ST segment changes), cardiac arrhythmias, and ischemic heart disease. These effects have been seen after acute and long-term exposure to inorganic arsenic in the environment, as well as side effects from intravenous therapy with arsenic trioxide for acute promyelocytic leukemia. Exposure levels for environmental exposures have not been well characterized, but intravenous doses for arsenic trioxide therapy are generally on the order of 0.15 mg As/kg/day.

Chronic exposure to inorganic arsenic has also been shown to lead to effects on the vascular system. The most dramatic of these effects is "Blackfoot Disease," a disease characterized by a progressive loss of circulation in the hands and feet, leading ultimately to necrosis and gangrene. Blackfoot Disease is endemic in an area of Taiwan where average drinking water levels of arsenic range from 0.17 to 0.80 ppm, corresponding to doses of about 0.014–0.065 mg As/kg/day. Arsenic exposure in Taiwan has

also been associated with an increased incidence of cerebrovascular and microvascular diseases and ischemic heart disease. While Blackfoot Disease itself has not been reported outside of Taiwan, other vascular effects are common in areas with high arsenic exposures, and include such severe effects as increases in the incidences of Raynaud's disease and of cyanosis of fingers and toes as well as hypertension, thickening and vascular occlusion of blood vessels, and other unspecified cardiovascular conditions. However, while the majority of human studies have reported cardiovascular effects following exposure to inorganic arsenic, some have found no such effects.

Changes in cardiac rhythm and in some vascular end points have also been reported in animal studies of inorganic arsenicals, but generally only at higher exposure levels and not to the degree of severity seen in humans.

No studies of cardiovascular effects of organic arsenic compounds in humans were located. A few studies have reported cardiovascular effects in animals following exposure to organic arsenic compounds, but these effects have occurred only at very high exposure levels.

Respiratory Effects. While case reports and small cohort studies have routinely reported an increase in respiratory symptoms of humans exposed occupationally to inorganic arsenic, dose-response data for these symptoms are generally lacking. The only study that evaluated respiratory effects (changes in chest X-ray or respiratory performance) and reported an exposure estimate did not report significant changes at an exposure level of 0.613 mg As/m^3. Exposed workers often report irritation of the mucous membranes of the nose and throat, which may lead to laryngitis, bronchitis, or rhinitis. Increased mortality due to respiratory disease has been reported in some cohort mortality studies of arsenic-exposed workers, but no conclusive evidence of an association of these diseases with arsenic exposure has been presented. It is not known whether respiratory effects following inhaled inorganic arsenic compounds are due to a direct effect of arsenic on respiratory tissues, general effects of foreign material in the lungs, or an effect of arsenic on the pulmonary vasculature. Similar responses, including rales, labored breathing, and respiratory hyperplasia, have been noted in animal studies of inhaled or instilled inorganic arsenic compounds.

Respiratory effects have also been reported following oral exposure of humans to inorganic arsenic. Acute oral exposure to ≥8 mg As/kg may result in serious respiratory effects, including respiratory distress, hemorrhagic bronchitis, and pulmonary edema; however, it is not clear whether these are primary effects or are the result of damage to the pulmonary vascular system. In general, respiratory effects have

not been widely associated with repeated oral ingestion of low arsenic doses. However, some studies have reported minor respiratory symptoms, such as cough, sputum, rhinorrhea, and sore throat, in people with repeated oral exposure to 0.03–0.05 mg As/kg/day. More serious respiratory effects, such as bronchitis and sequelae (bronchiectasis, bronchopneumonia) have been observed in patients chronically exposed to arsenic and at autopsy in some chronic poisoning cases. There are few animal data reporting respiratory effects of oral exposure to inorganic arsenic, and those studies generally found effects only at very high dose levels.

Respiratory effects are not a sensitive end point following exposure to organic arsenicals by either the inhalation or oral exposure route.

Gastrointestinal Effects. Both short-term and chronic oral exposures to inorganic arsenicals have been reported to result in irritant effects on gastrointestinal tissues. Numerous studies of acute, high-dose exposure to inorganic arsenicals have reported nausea, vomiting, diarrhea, and abdominal pain, although specific dose levels associated with the onset of these symptoms have not been identified. Chronic oral exposure to 0.01 mg As/kg/day generally results in similar reported symptoms. For both acute and chronic exposures, the gastrointestinal effects generally diminish or resolve with cessation of exposure. Similar gastrointestinal effects have been reported after occupational exposures to inorganic arsenicals, although it is not known if these effects were due to absorption of arsenic from the respiratory tract or from mucociliary clearance resulting in eventual oral exposure.

The effects of organic arsenicals on the gastrointestinal tract have not been as thoroughly investigated. No reports were located of gastrointestinal complaints in humans exposed to organic arsenicals. Inhalation exposure of rats to high doses of dimethyl arsenic acid (DMA) can cause diarrhea, while oral exposure can result in diarrhea and histological damage to the stomach, small intestine, and large intestine. Oral exposure of rabbits to monomethylarsenic acid (MMA) has been shown to cause intestinal irritation and weakening of the intestinal wall. These data suggest that the organic arsenicals are capable of producing gastrointestinal effects similar to the inorganic arsenicals, but the data are too sparse to make quantitative comparisons.

Neurological Effects. A common effect following both oral and inhalation exposure to inorganic is the development of peripheral neuropathy. Following occupational exposure to inorganic arsenic in pesticide plants or smelters, exposed workers have shown increased incidence of neurological changes, including altered nerve conduction velocities. One study reported that these effects were seen after

28 years of exposure to 0.31 mg As/m^3; most other studies of the neurological effects of inhaled inorganic arsenicals in humans have not characterized the exposure concentration.

Following high-dose (>2 mg As/kg/day) acute oral exposures to inorganic arsenicals in humans, reported effects include headache, lethargy, mental confusion, hallucination, seizures, and coma. Following longer-term exposure to 0.03–0.1 mg As/kg/day, peripheral neuropathy, characterized initially by numbness of the hands and feet and a "pins and needles" sensation and progressing to muscle weakness, wrist-drop and/or ankle-drop, diminished sensitivity, and altered reflex action. Histological features of the neuropathy include a dying-back axonopathy and demylenation. Following removal from exposure, the neuropathy is only partially reversible and what recovery does occur is generally slow. Reports of neurological effects at lower arsenic levels (0.004–0.006 mg As/kg/day) have been inconsistent, with some human studies reporting fatigue, headache, depression, dizziness, insomnia, nightmare, and numbness while others reported no neurological effects. Neurological effects have also been reported in oral studies of arsenic toxicity in animals, although these were generally performed at higher doses (0.4–26.6 mg As/kg/day) than has been reported in exposed human populations. The mechanism(s) of arsenic-induced neurological changes has not been determined.

Information on the neurological effects of organic arsenicals is sparse, but the available studies suggest that high oral doses may result in neurological symptoms. A report of a 52-year-old woman who ingested high levels of organic arsenic in bird's nest soup reported numbness and tingling of the fingertips, toes, and circumoral region that resolved upon cessation of exposure. Oral animal studies with roxarsone and MMA have revealed treatment-related effects on neurological end points at doses ranging from 0.87 to 63 mg As/kg/day. By contrast, the limited data on inhalation exposure of humans to organic arsenicals have not reported significant neurological alterations; no animal studies of the neurotoxicity of inhaled organic arsenicals were located.

Cancer. There is clear evidence from studies in humans that exposure to inorganic arsenic by either the inhalation or oral routes increases the risk of cancer. Numerous studies of copper smelters or miners exposed to arsenic trioxide have reported an increased risk of lung cancer. Increased incidence of lung cancer has also been observed at chemical plants where exposure was primarily to arsenate. Other studies suggest that residents living near smelters or arsenical chemical plants may have increased risk of lung cancer, although the reported increases are small and are not clearly detectable in all cases. In general, studies reporting long-term exposure to 0.07 mg As/m^3 or greater have shown an increased incidence of lung cancer, while at lower exposure levels, the association has been less clear or not present.

There is convincing evidence from a large number of epidemiological studies and case reports that ingestion of inorganic arsenic increases the risk of developing skin cancer. The most common tumors seen are squamous cell carcinomas, which may develop from the hyperkeratotic warts or corns commonly seen as a dermal effect of oral inorganic arsenic exposure. Early studies of populations within the United States did not suggest an increased risk of cancer from oral inorganic arsenic exposure, but more recent studies have suggested that while the risk to U.S. populations is less than for some other countries, the possibility of arsenic-induced skin cancers cannot be discounted. In most cases, exposure levels associated with the development of skin cancer have not been reported.

Recent studies have also identified other suspected targets of inorganic arsenic-induced carcinogenesis. There is increasing evidence that long-term exposure to arsenic can result in the development of bladder cancer, with transitional cell cancers being the most prevalent. While studies have noted statistical dose-response trends in arsenic-induced bladder cancers, reliable quantitative assessments of dose-response relationships have not been presented. Recent studies have also suggested that chronic oral exposure to arsenic may result in the development of respiratory tumors. Exposure levels in studies evaluating respiratory and bladder cancers have been comparable to those in studies evaluating skin tumors. Studies of U.S. populations have not consistently identified an increased risk of bladder or respiratory tumors following oral exposure to inorganic arsenic.

Animal studies of both inhalation and oral exposure to inorganic arsenicals have not resulted in increased incidence of cancer formation in adult animals. However, a recent study in mice reported that arsenic could function as a complete transplacental carcinogen, resulting in tumors in the offspring of exposed animals.

No studies on the carcinogenicity of organic arsenicals following inhalation exposure in humans or animals were located. No studies of the carcinogenic effects of organic arsenicals in humans exposed by the oral route were located. No increase in tumor formation was seen in dogs given 1.5 mg As/kg/day, rats given 2.9 mg As/kg/day, or mice given 3.8 mg As/kg/day as roxarsone for 2 years or in a lifetime carcinogenicity study in rats and mice exposed to up to 1.4 mg As/kg/day as roxarsone. Studies of mice and rats exposed orally to up to 47 mg As/kg/day for 104 weeks also showed no evidence of increased tumor formation. In contrast, dietary exposure of rats to DMA at levels of 0.14 mg As/kg/day or greater resulted in a significant increase in tumors of the urinary bladder. A recent study suggested that DMA primarily exerts its carcinogenic effects on spontaneous tumor development.

2.3 MINIMAL RISK LEVELS

Estimates of exposure levels posing minimal risk to humans (MRLs) have been made for arsenic. An MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. MRLs are derived when reliable and sufficient data exist to identify the target organ(s) of effect or the most sensitive health effect(s) for a specific duration within a given route of exposure. MRLs are based on noncancerous health effects only and do not consider carcinogenic effects. MRLs can be derived for acute, intermediate, and chronic duration exposures for inhalation and oral routes. Appropriate methodology does not exist to develop MRLs for dermal exposure.

Although methods have been established to derive these levels (Barnes and Dourson 1988; EPA 1990i), uncertainties are associated with these techniques. Furthermore, ATSDR acknowledges additional uncertainties inherent in the application of the procedures to derive less than lifetime MRLs. As an example, acute inhalation MRLs may not be protective for health effects that are delayed in development or are acquired following repeated acute insults, such as hypersensitivity reactions, asthma, or chronic bronchitis. As these kinds of health effects data become available and methods to assess levels of significant human exposure improve, these MRLs will be revised.

Inhalation MRLs

No inhalation MRLs were derived for inorganic or organic arsenic. Adequate human studies evaluating dose-response relationships for noncancer end points were not located for inorganic arsenic, and animal data on the health effects of inorganic arsenic following inhalation exposure are limited to studies that did not evaluate a suitable range of health effects. In general, respiratory or immunological effects appeared to be the most common following inhalation exposure to inorganic arsenic in animals (Aranyi et al. 1985; Holson et al. 1999), while human data suggested that dermal or respiratory effects may be the most prevalent (Lagerkvist et al. 1986; Mohamed 1998; Perry et al. 1948). Lacking suitable studies upon which to base the MRLs, no inhalation MRLs were derived for inorganic arsenic. Few studies were located that examined the effects of organic arsenic compounds following inhalation exposure, none of which was suitable for use in derivation of inhalation MRLs for organic arsenic compounds due to the presence of serious effects or a lack of exposure characterization (Stevens et al. 1979; Watrous and McCaughey 1945).

Oral MRLs

- A provisional MRL of 0.005 mg/kg/day has been derived for acute-duration (14 days or less) oral exposure to inorganic arsenic.

Mizuta et al. (1956) summarized findings from 220 poisoning cases associated with an episode of arsenic contamination of soy sauce in Japan. The soy sauce was contaminated with approximately 0.1 mg As/mL, probably as calcium arsenate. Arsenic intake in the cases was estimated by the researchers to be 3 mg/day (0.05 mg/kg/day, assuming 55 kg average body weight for this Asian population). The duration of exposure was 2–3 weeks in most cases. The primary symptoms were edema of the face, and gastrointestinal and upper respiratory symptoms initially, followed by skin lesions and neuropathy in some patients. Other effects included mild anemia and leukopenia, mild degenerative liver lesions and hepatic dysfunction, abnormal electrocardiogram, and ocular lesions. For derivation of the provisional acute oral MRL, facial edema and gastrointestinal symptoms (nausea, vomiting, diarrhea), which were characteristic of the initial poisoning and then subsided, were considered to be the critical effects. The provisional MRL of 0.005 mg As/kg/day was calculated by applying an uncertainty factor of 10 (10 for use of a lowest-observed-adverse-effect level (LOAEL) and 1 for intrahuman variability) to the LOAEL of 0.05 mg As/kg/day (see Appendix A for MRL worksheets). The MRL is considered provisional because the gastrointestinal effects (nausea, vomiting, diarrhea, and occult blood in feces and gastric and duodenal juice) are serious and because serious neurological (hypesthesia in legs, abnormal patellar reflex) and cardiovascular (abnormal electrocardiogram) effects also occurred at the same dose. Although it is not customary to base an MRL on a serious LOAEL, public health concerns regarding arsenic suggested that a provisional value derived from these data would be useful for the general public.

- An MRL of 0.0003 mg/kg/day has been derived for chronic-duration (365 days or more) oral exposure to inorganic arsenic.

Tseng et al. (1968) and Tseng (1977) investigated the incidence of Blackfoot Disease and dermal lesions (hyperkeratosis and hyperpigmentation) in a large number of poor farmers (both male and female) exposed to high levels of arsenic in well water in Taiwan. A control group consisting of 17,000 people, including one group in which arsenic exposure was "undetermined" and which included those villages where arsenic-contaminated wells were no longer used or the level could not be classified, and a control population of 7,500 people who consumed water from wells almost free of arsenic (0.001–0.017 ppm) was also examined. The authors stated that the incidence of dermal lesions increased with dose, but individual doses were not provided. However, incidence data were provided based on stratification of the

exposed population into low (<300 µg/L), medium (300–600 µg/L), or high (>600 µg/L) exposure levels. Doses were calculated from group mean arsenic concentrations in well water, assuming the intake parameters described by Abernathy et al. (1989). Accordingly, the control, low-, medium-, and high-exposure levels correspond to doses of 0.0008, 0.014, 0.038, and 0.065 mg As/kg/day, respectively. The no-observed-adverse-effect level (NOAEL) identified by Tseng (1977) (0.0008 mg As/kg/day) was limited by the fact that the majority of the population was less than 20 years of age and the incidence of skin lesions increased as a function of age, and because the estimates of water intake and dietary arsenic intake are highly uncertain. Schoof et al. (1998) estimated that dietary intakes of arsenic from rice and yams may have been 15–211 µg/day (mean=61 µg/day), based on arsenic analyses of foods collected in Taiwan in 1993–1995. Use of the 50 µg/day estimate would result in an approximate doubling of the NOAEL (0.0016 mg/kg/day) (see Appendix A for MRL worksheets). The MRL was derived by applying an uncertainty factor of 3 (for intrahuman variability) to the NOAEL of 0.0008 mg/kg/day.

The MRL is supported by a large number of well-conducted epidemiological studies that identify reliable NOAELs and LOAELs for dermal effects. Southwick et al. (1981) identified a NOAEL of 0.006–0.007 mg As/kg/day for dermal lesions in several small populations in Utah. Harrington et al. (1978) identified a NOAEL of 0.003 mg As/kg/day for dermal effects in a small population in Alaska. Mazumder et al. (1988) identified a NOAEL of 0.009 mg As/kg/day and a LOAEL of 0.006 mg As/kg/day for pigmentation changes and hyperkeratosis in a small population in India. Haque et al. (2003) identified a LOAEL of 0.002 mg As/kg/day for hyperpigmentation and hyperkeratosis in a case-control study in India. Cebrián et al. (1983) identified a NOAEL of 0.0004 mg As/kg/day and a LOAEL of 0.022 mg As/kg/day in two regions in Mexico. Borgono and Greiber (1972) and Zaldívar (1974) identified a LOAEL of 0.02 mg As/kg/day for abnormal skin pigmentation in patients in Chile, and Borgono et al. (1980) identified a LOAEL of 0.01 mg As/kg/day for the same effect in school children in Chile. Valentine et al. (1985) reported a NOAEL of 0.02 mg As/kg/day for dermal effects in several small populations in California. Collectively, these studies indicate that the threshold dose for hyper-pigmentation and hyperkeratosis is approximately 0.002 mg As/kg/day. While many of these studies also identified effects on other end points at these exposure levels, including effects on gastrointestinal (Borgono and Greiber 1972; Cebrián et al. 1983; Guha Mazumder et al. 1988; Zaldívar 1974), cardiovascular (Tseng et al. 1995, 1996), hepatic (Hernandez-Zavala et al. 1998), and neurological end points (Guha Mazumder et al. 1988; Lianfang and Jianzhong 1994; Tsai et al. 2003), the overall database for dermal effects is considerably stronger than for effects on other end points.

A number of acute-duration studies of organic arsenic compounds are available, but these have focused primarily on serious or frank effects (Kaise et al. 1989; Kerr et al. 1963; Murai et al. 1993; NTP 1989b; Rogers et al. 1981) and have not consistently identified sensitive targets of organic arsenicals or exposure levels at which effects begin to occur. No intermediate- or chronic-duration oral studies of organic arsenicals in humans were located. Intermediate- and chronic-duration oral studies of roxarsone and DMA in rodents have been reported (Arnold et al. 1999; Cohen et al. 2001; NTP 1989b), but concerns regarding the high exposure levels used and possible species-related differences in sensitivity prevent the use of these studies for MRLs derivation. No oral MRLs were derived for organic arsenic compounds.

Hazard Profile - Beryllium

2. RELEVANCE TO PUBLIC HEALTH

2.1 BACKGROUND AND ENVIRONMENTAL EXPOSURES TO BERYLLIUM IN THE UNITED STATES

Beryllium is an extremely lightweight metal that occurs naturally in rocks, coal, soil, and volcanic dust. Commercially, bertrandite and beryl ore are mined for the recovery of beryllium. Because beryllium is one of the lightest metal and is very rigid, it has many uses in the electronics, aerospace, and defense industries. Beryllium is released into the atmosphere by windblown dust, volcanic particles, and the combustion of coal and fuel oil. Beryllium particulates in the atmosphere will settle out or be removed by precipitation. The annual average concentration of beryllium in ambient air in the United States is typically below the detection limit of 0.03 ng/m^3. Beryllium concentration in urban air is usually higher due primarily to burning of coal and fuel oil; for example, the annual average concentrations in 1982–1992 ranged from 0.02 to 0.2 ng/m^3 in Detroit, Michigan. Beryllium can be released into waterways by the weathering of soil and rocks. Beryllium entering surface water bodies and soil will be retained in the sediment and soil and will be generally immobile. The average concentration of beryllium in drinking water samples that were found to contain it was 190 ng/L. The mean concentration of beryllium in soil in the United States is 0.6 mg/kg.

Human exposure to beryllium and its compounds occurs primarily in the workplace. People who work in beryllium manufacturing, fabricating, and reclaiming industries have a greater probability of inhalation exposure than non-occupational groups. The general population can be exposed to trace amounts of beryllium through inhalation of air, consumption of food and water, and skin contact with air, water, or soil that contains beryllium. Individuals living near sources of beryllium emissions are likely to be exposed to higher levels of beryllium than the general population. Beryllium has been identified in at least 535 of the 1,613 hazardous waste sites that have been proposed for inclusion on the EPA NPL.

2.2 SUMMARY OF HEALTH EFFECTS

The general population can be exposed to beryllium via inhalation, oral, and dermal routes of exposure. The inhalation route is of greatest concern for systemic effects because beryllium and its compounds are poorly absorbed after oral and dermal exposure. The respiratory tract in humans and animals is the primary target of beryllium toxicity following inhalation exposure. Occupational exposure to high concentrations of soluble beryllium compounds can result in acute beryllium disease, while exposure to

relatively low concentrations (• 0.5 µg/m^3) of soluble or insoluble beryllium compounds can result in chronic beryllium disease. Acute beryllium disease is characterized by inflammation of the respiratory tract tissues and is usually resolved within several months of exposure termination. In contrast, chronic beryllium disease is an immune response to beryllium and is only observed in individuals who are sensitized to beryllium (usually <15% of an exposed population). Other systemic effects that have been observed in individuals with severe cases of chronic beryllium disease include damage to the right heart ventricle, hepatic necrosis, kidney stones, and weight loss; these effects are probably secondary to chronic beryllium disease rather than a direct effect on the tissues.

As with inhalation exposure, dermal contact with beryllium can result in an allergic response, typically skin granulomas, in certain individuals. Dermatitis, which may be due to direct irritation rather than an immune response, has also been observed in workers exposed to high concentrations of airborne beryllium.

Unlike inhalation and dermal exposure routes, the primary effects observed after oral exposure is not an immune response to beryllium. The most sensitive effects appear to be ulcerative gastrointestinal lesions in dogs and beryllium rickets in rats exposed to beryllium carbonate; no reliable human oral exposure data were identified. The beryllium rickets are not due to a direct effect on bone; they are secondary to phosphorus deficiency. Beryllium in the gut binds to soluble phosphorus compounds to form insoluble beryllium phosphate, thus decreasing the amount of soluble phosphorus compounds available for absorption.

The available data on the potential of beryllium to induce reproductive and/or developmental effects are inconclusive. The data come from several animal studies; no reliable human data were located. No histological alterations have been observed in reproductive tissues of animals orally exposed to beryllium sulfate and no alterations in fertility were observed in dogs exposed to beryllium sulfate in the diet. Similarly, no reproductive effects were observed in rats exposed to beryllium oxide via intratracheal injection. Some developmental effects (fetal mortality, decreased fetal body weight, increased prevalence of internal abnormalities) were observed in the offspring of rats receiving a single intratracheal injection of beryllium oxide or beryllium chloride. No developmental effects were observed in the offspring of dogs orally exposed to beryllium sulfate, although the study is limited because cannibalized and stillborn animals were not examined. Human and animal data provide evidence that inhaled beryllium is a human lung carcinogen; oral data are inadequate for the assessment of carcinogenic potential.

Thus, the primary adverse health of effects of beryllium are respiratory effects and lung cancer following inhalation exposure, gastrointestinal effects following oral exposure, and skin effects following dermal exposure; these effects are discussed in greater detail below. The reader is referred to Section 3.2, Discussion of Health Effects by Route of Exposure, for additional information on other health effects.

Respiratory Effects. The toxicity of beryllium to the respiratory tract is usually manifested in one of two syndromes: acute beryllium disease and chronic beryllium disease. Acute beryllium disease is usually observed at relatively high beryllium exposure levels, has a short period of induction, and is usually resolved within a couple of months of exposure termination. It is believed to be an inflammatory response to beryllium and most regions of the respiratory tract are affected; some reported symptoms include nasopharyngitis, shortness of breath, labored breathing, and chemical pneumonitis.

Chronic beryllium disease is a systemic granulomatous disorder that predominantly affects the lungs. In general, the occurrence of this disease has been confined to workers exposed to beryllium metal and to less soluble beryllium compounds, such as beryllium oxide. However, there have been cases among residents living near beryllium manufacturing facilities and in families of workers who wore contaminated clothing at home. Chronic beryllium disease is caused by an immune reaction to the inhaled beryllium that is deposited in lung airspaces and retained for a prolonged period. In certain individuals who become sensitized to beryllium, the beryllium in the lungs acts as a hapten, binds to protein/peptides in the lungs, and elicits a proliferation of T lymphocytes, a release of inflammatory mediators, and an accumulation of inflammatory cells in the lungs. This results in the formation of noncaseating granuloma, the accumulation of mononuclear cell infiltrates, and the development of fibrosis. Susceptibility to chronic beryllium disease is believed to have a genetic component. The human leukocyte antigen (HLA) class II marker, HLA-DPB1 Glu^{69}, has been found in a large number of individuals with chronic beryllium disease.

When chronic beryllium disease was first recognized, affected individuals had a number of signs and symptoms including weight loss, dyspnea, cough, chest pain, fatigue, and cor pulmonale (hypertrophy of the right heart ventricle). Impaired lung function was detected in most of the affected individuals. The typical lung function abnormalities were decreased vital capacity and total lung capacity and/or reduction in diffusing capacity for carbon monoxide (DL_{CO}). It is likely that these cases of chronic beryllium disease were diagnosed at a late stage. Technological advances in the development of methods to detect chronic beryllium disease, in particular the beryllium lymphocyte proliferation test (BeLPT) and fiber optic bronchoscopy and transbronchial biopsy methods, now allows for the early detection of the disease.

Chronic beryllium disease can be classified into three stages: beryllium sensitization, subclinical chronic beryllium disease, and clinical chronic beryllium disease. Beryllium sensitization, usually diagnosed as consistently abnormal BeLPT results, can progress to chronic beryllium disease, but not all sensitized individuals develop chronic beryllium disease. Individuals with subclinical chronic beryllium disease are sensitized to beryllium and have histological evidence of lung granulomas, but no clinical signs. Although no clinical signs are observed, there is evidence to suggest that there may be some impairment of lung function. Slight alterations in lung function during exercise were observed in approximately 60% of individuals with subclinical chronic beryllium disease, no other consistent alterations in lung function were found. Individuals with clinical chronic beryllium disease are beryllium sensitized, and have histological evidence of lung granulomas and respiratory symptoms, changes on chest radiographs, and/or altered lung function.

A number of large-scale screening studies have examined beryllium workers and found beryllium sensitization rates of 1–15% in workers involved in the production of beryllia ceramics and nuclear weapons. More than half of the beryllium sensitized workers were diagnosed with chronic beryllium disease. Several studies attempted to establish associations between beryllium sensitization and/or chronic beryllium disease and mean, cumulative, and peak exposure levels and duration of employment. In general, no consistent associations were found. Although the data are insufficient for establishment of concentration-response relationships, the available occupation exposure studies do provide exposure levels that may result in beryllium sensitization. Beryllium sensitization and/or chronic beryllium disease have been detected at exposure levels of • 0.5 $\mu g/m^3$. Respiratory disease is not likely to occur from exposure to beryllium levels in the general environment because ambient air levels of beryllium (0.03–0.2 ng beryllium/m^3) are very low.

Gastrointestinal Effects. No human data were located regarding gastrointestinal effects following exposure to beryllium. In dogs exposed to beryllium sulfate in the diet for 143–172 weeks, extensive ulcerative and inflammatory lesions were observed in the small intestine, stomach, and large intestine; the small intestine was the most severely affected. No gastrointestinal tract lesions were observed in rats exposed to similar concentrations of beryllium sulfate in the diet for 2 years. One possible explanation for the apparent species difference is the manner in which rats and dogs consumed the beryllium-containing diet. The dogs only had access to the diet for 1 hour/day, in contrast to the rats with unlimited access to the diet. Thus, immediately after eating, the dogs had a higher concentration of beryllium in the gut than the rats that ate small amounts of food throughout the day.

Dermal Effects. Two types of dermal effects have been observed in beryllium exposed workers: an inflammatory reaction and an immune reaction. Edematous papulovesicular dermatitis was observed in workers exposed to airborne beryllium sulfate, beryllium fluoride, or beryllium oxyfluoride; this is likely an inflammatory response to beryllium. Beryllium exposure may also cause a delayed, hypersensitive reaction in the skin. Biopsied skin granulomas from beryllium workers had the same mononuclear infiltrates as detected in the lungs. Sensitized guinea pigs also developed granulomatous lesions and other delayed hypersensitive reactions following dermal exposure to beryllium sulfate, beryllium fluoride, beryllium oxide, or beryllium chloride.

Cancer. A number of epidemiology studies have been conducted to assess the carcinogenic potential of beryllium. Increased incidences of lung cancer deaths were reported in retrospective cohort mortality studies of workers at beryllium extraction, processing, and fabrication facilities. Increased lung cancer mortality was also seen in entrants to the Beryllium Case Registry. No correlation between the incidence of lung cancer deaths and exposure has been established because historical exposure levels were not reported. A positive association between length of latency and lung cancer deaths was found, with the highest cancer risks among workers with a latency of • 25 years. Significant increases in the occurrence of lung cancer has also been observed in rats and monkeys exposed to beryllium.

The National Toxicology Program lists beryllium and certain beryllium compounds (beryllium-aluminum alloy, beryllium chloride, beryllium fluoride, beryllium hydroxide, beryllium oxide, beryllium phosphate, beryllium sulfate, beryllium zinc silicate, and beryl ore) as human carcinogens. Based on sufficient evidence for carcinogenicity in humans and animals, the International Agency for Research on Cancer has classified beryllium and beryllium compounds in Group 1, carcinogenic to humans. In contrast, the EPA concluded that the human data only provided limited evidence and classified inhaled beryllium in Group B1, a probable human carcinogen.

No human studies investigating the carcinogenicity of ingested beryllium were located. Animal studies have not found significant associations between ingestion of beryllium in the diet and drinking water and increased incidence of neoplasms in rats, mice, or dogs. It should be noted that no toxic effects were observed in rat and mouse chronic-duration studies tested at low doses, and the duration of the dog study was too short to be predictive of late-term cancer. The EPA concluded that the human carcinogenic potential of ingested beryllium cannot be determined.

2.3 MINIMAL RISK LEVELS

Inhalation MRLs

The available human and animal data clearly identify the respiratory tract as the critical target of beryllium toxicity following inhalation exposure. In humans, symptoms of acute beryllium disease (e.g., nasopharyngitis, pneumonia) have been reported in workers exposed to high concentrations of soluble beryllium compounds (Eisenbud et al. 1948a; VanOrdstrand et al. 1945). Longer-term exposure to relatively low concentrations of beryllium can result in chronic beryllium disease (Cotes et al. 1983; Cullen et al. 1987; Eisenbud et al. 1949). More recent studies are able to detect subclinical chronic beryllium disease and beryllium sensitization (Deubner et al. 2001; Henneberger et al. 2001; Kelleher et al. 2001; Kreiss et al. 1993a, 1996, 1997; Newman et al. 2001; Stange et al. 1996b, 2001; Viet et al. 2000). There is evidence to suggest that the occurrence of chronic beryllium disease is not related to duration of exposure, and can have a long latency period. Very few studies assessing the occurrence of chronic beryllium disease also measured airborne beryllium levels. Eisenbud et al. (1949) found no cases of chronic beryllium disease in residents living at least 0.75 miles away from a beryllium manufacturing facility. The airborne beryllium concentration at this distance was estimated to range from 0.01 to 0.1 μg beryllium/m^3. Studies by Cullen et al. (1987), Kreiss et al. (1996), and Stange et al. (1996b) reported chronic beryllium disease (and/or beryllium sensitization) in workers exposed to average beryllium concentrations of 0.52, 0.55, or 1.04 μg beryllium/m^3, respectively.

Respiratory tract effects have also been observed in animals exposed to airborne beryllium. Emphysema, pneumonitis, and lung granulomas are the most commonly reported effects following acute-, intermediate-, and chronic-duration exposure (Haley et al. 1989; Hall et al. 1950; Robinson et al. 1968; Schepers et al. 1957; Sendelbach et al. 1986; Stokinger et al. 1950; Wagner et al. 1969). In general, the animal studies have not identified a reliable no-observed-adverse-effect level (NOAEL) for respiratory effects, and the lowest-observed-adverse-effect levels (LOAELs) are several orders of magnitude higher than the LOAEL identified in the Kreiss et al. (1996) occupational exposure study.

Although the critical target of beryllium toxicity has been identified, the available database does not support derivation of acute-, intermediate-, or chronic-duration inhalation MRLs. As discussed in Section 3.4.3, an animal model that mimics all aspects of chronic beryllium disease has not been identified; thus, it is inappropriate to derive inhalation MRLs from the animal data. No human acute- or intermediate-duration studies that identify a NOAEL or LOAEL for respiratory effects were located. The

Eisenbud et al. (1949) study, found no cases of chronic beryllium disease among community residents chronically exposed to 0.01–0.1 μg beryllium/m^3. This study was not selected as the basis of a chronic-duration MRL because it utilized relatively insensitive methods to detect chronic beryllium disease; in particular, it is not known if residents exposed to 0.01 μg beryllium/m^3 would test positive for beryllium sensitization or subclinical chronic beryllium disease. The LOAELs identified in the Cullen et al. (1987), Kreiss et al. (1996), and Stange et al. (1996b) studies cannot be used to derive a chronic MRL because the observed effects were classified as serious health effects.

Oral MRLs

The only available data on the acute-duration toxicity of ingested beryllium are from lethality studies in rats and mice. Thus, an acute-duration oral MRL cannot be derived. The available data from intermediate-duration studies have identified rickets (Guyatt et al. 1933; Jacobson 1933; Kay and Skill 1934) as a critical target of beryllium toxicity. The rickets do not appear to be due to a direct effect of beryllium on the bone. Rather, the rickets are due to a phosphorus deficiency, which results from the binding of beryllium to dietary phosphorus in the gut. Additionally, these effects have only been observed following exposure to beryllium carbonate. Thus, the available data are inadequate for derivation of an intermediate-duration oral MRL.

- An MRL of 0.002 mg beryllium/kg/day has been derived for chronic-duration oral exposure (>365 days) to beryllium.

A chronic-duration oral MRL of 0.002 mg beryllium/kg/day was derived for beryllium. The MRL is based on a chronic dog feeding study in which groups of five male and five female dogs were exposed to beryllium sulfate in the diet for 143–172 weeks (Morgareidge et al. 1976). Ulcerative lesions of the small intestine were observed in 9 of 10 dogs exposed to the highest dose (500 ppm; 12 and 17 mg beryllium/kg/day for the males and females, respectively); similar lesions were also observed in 1 of 10 dogs exposed to 50 ppm (1 mg beryllium/kg/day). No gastrointestinal effects were observed at the lower dose levels. Other effects observed in the 500 ppm group included erythroid hyperplasia of the bone marrow, slight anemia, bile stasis and vasculitis in the liver, and acute inflammation of the lymph nodes; these effects were considered secondary to the gastrointestinal hemorrhages and a likely systemic bacterial invasion through the damaged intestinal mucosa. The 500 ppm test dose was discontinued after 33 weeks due to high mortality and morbidity. The MRL was derived using a benchmark dose method, which involves fitting mathematical models to the dose-response data for the ulcerative lesions of the small intestine. For this analysis, the incidence data for the male and female dogs were combined and the

calculated doses for the males and females were averaged. A benchmark dose (defined as the 95% lower confidence limit of the dose corresponding to a 10% increase in the incidence of small intestine lesions compared to controls) of 0.56 mg beryllium/kg/day was estimated using a probit model. The benchmark dose was divided by an uncertainty factor of 100 (10 for extrapolation from animals to humans and 10 for human variability) and a modifying factor of 3 (to account for the lack of a study that supports the gastrointestinal effects found in the Morgareidge et al. [1976] dog study and the uncertainty as to whether the benchmark dose level is the NOAEL).

Hazard Profile - Chromium

1. PUBLIC HEALTH STATEMENT

This public health statement tells you about chromium and the effects of exposure.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites make up the National Priorities List (NPL) and are the sites targeted for long-term federal cleanup activities. Total Chromium has been found in at least 1,036 of the 1,591 current or former NPL sites. Chromium(VI) has been found in at least 120 of the 1,591 current or former NPL sites. However, the total number of NPL sites evaluated for this substance is not known. As more sites are evaluated, the sites at which chromium is found may increase. This information is important because exposure to this substance may harm you and because these sites may be sources of exposure.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This release does not always lead to exposure. You are exposed to a substance only when you come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to chromium, many factors determine whether you'll be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with it/them. You must also consider the other chemicals you're exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT IS CHROMIUM?

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium is present in the environment in several different forms. The most common forms are chromium(0), trivalent (or chromium(III)), and hexavalent (or chromium(VI)). Chromium(III) occurs naturally in the environment and is an essential nutrient required by the human body to promote the action of insulin in body tissues so that sugar, protein, and fat can be used by the body. Chromium(VI) and chromium(0) are generally

produced by industrial processes. No known taste or odor is associated with chromium compounds. The metal chromium, which is the chromium(0) form, is a steel-gray solid with a high melting point. It is used mainly for making steel and other alloys. The naturally occurring mineral chromite in the chromium(III) form is used as brick lining for high-temperature industrial furnaces, for making metals and alloys (mixtures of metals), and chemical compounds. Chromium compounds, mostly in chromium(III) or chromium(VI) forms, produced by the chemical industry are used for chrome plating, the manufacture of dyes and pigments, leather tanning, and wood preserving. Smaller amounts are used in drilling muds, rust and corrosion inhibitors, textiles, and toner for copying machines. For more information on the physical and chemical properties and on the production and use of chromium, see Chapters 3 and 4.

1.2 WHAT HAPPENS TO CHROMIUM WHEN IT ENTERS THE ENVIRONMENT?

Chromium enters the air, water, and soil mostly in the chromium(III) and chromium(VI) forms as a result of natural processes and human activities. Emissions from burning coal and oil, and steel production can increase chromium(III) levels in air. Stainless steel welding, chemical manufacturing, and use of compounds containing chromium(VI) can increase chromium(VI) levels in air. Waste streams from electroplating can discharge chromium(VI). Leather tanning and textile industries as well as those that make dyes and pigments can discharge both chromium(III) and chromium(VI) into waterways. The levels of both chromium(III) and chromium(VI) in soil increase mainly from disposal of commercial products containing chromium, chromium waste from industry, and coal ash from electric utilities.

In air, chromium compounds are present mostly as fine dust particles. This dust eventually settles over land and water. Rain and snow help remove chromium from air. Chromium compounds will usually remain in the air for fewer than 10 days. Although most of the chromium in water binds to dirt and other materials and settles to the bottom, a small amount may dissolve in the water. Fish do not accumulate much chromium in their bodies from water. Most of the chromium in soil does not dissolve easily in water and can attach strongly to the soil. A very small amount of the chromium in soil, however, will dissolve in water and can move deeper in the soil to underground water. The movement of chromium in soil depends on the type

and condition of the soil and other environmental factors. For more information about the fate and movement of chromium compounds in the environment, see Chapters 4 and 5.

1.3 HOW MIGHT I BE EXPOSED TO CHROMIUM?

You can be exposed to chromium by breathing air, drinking water, or eating food containing chromium or through skin contact with chromium or chromium compounds. The level of chromium in air and water is generally low. The concentration of total chromium in air (both chromium(III) and chromium(VI)) generally ranges between 0.01 and 0.03 microgram (µg) (1 µg equals 1/1,000,000 of a gram) per cubic meter of air (µg/m^3). Chromium concentrations in drinking water (mostly as chromium(III)) are generally very low, less than 2 parts of chromium in a billion parts of water (2 ppb). Contaminated well water may contain chromium(VI). For the general population, eating foods that contain chromium is the most likely route of chromium(III) exposure. Chromium(III) occurs naturally in many fresh vegetables, fruits, meat, yeast, and grain. Various methods of processing, storage, and preparation can alter the chromium content of food. Acidic foods in contact with stainless steel cans or cooking utensils might contain higher levels of chromium because of leaching from stainless steel. Refining processes used to make white bread or sugar can decrease chromium levels. Chromium(III) is an essential nutrient for humans. On the average, adults in the United States take in an estimated 60 µg of chromium daily from food. You may also be exposed to chromium from using consumer products such as household utensils, wood preservatives, cement, cleaning products, textiles, and tanned leather.

People who work in industries that process or use chromium or chromium compounds can be exposed to higher-than-normal levels of chromium. An estimated 305,000 workers in the United States are potentially exposed to chromium and chromium-containing compounds in the workplace.

Occupational sources of chromium exposure (with chemical forms of interest shown in brackets) may occur in the following industries:

- Stainless steel welding (chromium(VI))

- Chromate production (chromium(VI))
- Chrome plating (chromium(VI))
- Ferrochrome industry (chromium(III) and chromium(VI))
- Chrome pigments (chromium(III) and chromium(VI))
- Leather tanning (mostly chromium(III))

Examples of other occupations that may involve chromium exposure include these:

- Painters (chromium(III) and chromium(VI))
- Workers involved in the maintenance and servicing of copying machines, and the disposal of some toner powders from copying machines (chromium(VI))
- Battery makers (chromium(VI))
- Candle makers (chromium(III) and chromium(VI))
- Dye makers (chromium(III))
- Printers (chromium(III) and chromium(VI))
- Rubber makers (chromium(III) and chromium(VI))
- Cement workers (chromium(III) and chromium(VI))

A list of other industries that may be sources of occupational exposure is given in Section 5.5.

You may be exposed to higher-than-normal levels of chromium if you live near the following:

- Landfill sites with chromium-containing wastes
- Industrial facilities that manufacture or use chromium and chromium-containing compounds
- Cement-producing plants, because cement contains chromium
- Industrial cooling towers that previously used chromium as a rust inhibitor
- Waterways that receive industrial discharges from electroplating, leather tanning, and textile industries
- Busy roadways, because emissions from automobile brake lining and catalytic converters contain chromium

In addition, you may be exposed to higher levels of chromium if you use tobacco products, since tobacco contains chromium. For additional information about chromium exposure, see Chapter 5.

1.4 HOW CAN CHROMIUM ENTER AND LEAVE MY BODY?

Chromium can enter your body when you breathe air, eat food, or drink water containing chromium. In general, chromium(VI) is absorbed by the body more easily than chromium(III), but once inside the body, chromium(VI) is changed to chromium(III). When you breathe air containing chromium, chromium particles can be deposited in the lungs. Particles that are deposited in the upper part of the lungs are likely to be coughed up and swallowed. Particles deposited deep in the lungs are likely to remain long enough for some of the chromium to pass through the lining of the lungs and enter your bloodstream. Once in the bloodstream, chromium is distributed to all parts of the body. Chromium will then pass through the kidneys and be eliminated in the urine in a few days. Everyone normally eats or drinks a small amount of chromium daily. Most of the chromium that you swallow leaves your body within a few days through the feces and never enters your blood. A small amount (about 0.4–2.1%) will pass through the lining of the intestines and enter the bloodstream. Chromium(III) present in food can attach to other compounds that make it easier for chromium to enter your bloodstream from your stomach and intestines. This form of chromium is used by your body to carry out essential body functions. If your skin comes into contact with chromium, very little will enter your body unless your skin is damaged. For more information, please read Chapter 2.

1.5 HOW CAN CHROMIUM AFFECT MY HEALTH?

To protect the public from the harmful effects of toxic chemicals and to find ways to treat people who have been harmed, scientists use many tests.

One way to see if a chemical will hurt people is to learn how the chemical is absorbed, used, and released by the body; for some chemicals, animal testing may be necessary. Animal testing may also be used to identify health effects such as cancer or birth defects. Without laboratory

animals, scientists would lose a basic method to get information needed to make wise decisions to protect public health. Scientists have the responsibility to treat research animals with care and compassion. Laws today protect the welfare of research animals, and scientists must comply with strict animal care guidelines.

Chromium(III) is an essential nutrient that helps the body use sugar, protein, and fat. An intake of 50–200 μg of chromium(III) per day is recommended for adults. On the average, adults in the United States take in an estimated 60–80 μg of chromium per day in food. Therefore, many people's diets may not provide enough chromium(III). Without chromium(III) in the diet, the body loses its ability to use sugars, proteins, and fat properly, which may result in weight loss or decreased growth, improper function of the nervous system, and a diabetic-like condition. Therefore, chromium(III) compounds have been used as dietary supplements and are beneficial if taken in recommended dosages.

The health effects resulting from exposure to chromium(III) and chromium(VI) are fairly well described in the literature. In general, chromium(VI) is more toxic than chromium(III). Breathing in high levels (greater than 2 $\mu g/m^3$) chromium(VI), such as in a compound known as chromic acid or chromium(VI) trioxide, can cause irritation to the nose, such as runny nose, sneezing, itching, nosebleeds, ulcers, and holes in the nasal septum. These effects have primarily occurred in factory workers who make or use chromium(VI) for several months to many years. Long-term exposure to chromium has been associated with lung cancer in workers exposed to levels in air that were 100 to 1,000 times higher than those found in the natural environment. Lung cancer may occur long after exposure to chromium has ended. Chromium(VI) is believed to be primarily responsible for the increased lung cancer rates observed in workers who were exposed to high levels of chromium in workroom air. Breathing in small amounts of chromium(VI) for short or long periods does not cause a problem in most people. However, high levels of chromium in the workplace have caused asthma attacks in people who are allergic to chromium. Breathing in chromium(III) does not cause irritation to the nose or mouth in most people. In the same way, small amounts of chromium(VI) that you swallow will not hurt you; however, accidental or intentional swallowing of larger amounts has caused stomach upsets and ulcers, convulsions, kidney and liver damage, and even death. The

levels of chromium(VI) that caused these effects were far greater than those that you might be exposed to in food or water. Although chromium(III) in small amounts is a nutrient needed by the body, swallowing large amounts of chromium(III) may cause health problems. Workers handling liquids or solids that have chromium(VI) in them have developed skin ulcers. Some people have been found to be extremely sensitive to chromium(VI) or chromium(III). Allergic reactions consisting of severe redness and swelling of the skin have been noted. Exposure to chromium(III) is less likely than exposure to chromium(VI) to cause skin rashes in chromium-sensitive people. The metal, chromium(0), is less common and does not occur naturally. We do not know much about how it affects your health, but chromium(0) is not currently believed to cause a serious health risk. We have no reliable information that any form of chromium has harmful effects on reproduction or causes birth defects in humans, though it does not seem likely that the amount of chromium that most people are exposed to will result in reproductive or developmental effects.

In animals that breathed high levels of chromium, harmful effects on the respiratory system and a lower ability to fight disease were noted. However, we do not know if chromium can lower a person's ability to fight disease. Some of the female mice that were given chromium(VI) by mouth had fewer offspring and had offspring with birth defects. Some male mice that were given chromium(VI) or chromium(III) by mouth had decreased numbers of sperm in the testes. The birth defects or the decrease in sperm occurred in mice at levels about several thousand times higher than the normal daily intake by humans. Some chromium(VI) compounds produced lung cancer in animals that breathed in the particles or had the particles placed directly in their lungs. In animals that were injected with some chromium(VI) compounds, tumors formed at the site of injection.

Because some chromium(VI) compounds have been associated with lung cancer in workers and caused cancer in animals, the Department of Health and Human Services has determined that certain chromium(VI) compounds (calcium chromate, chromium trioxide, lead chromate, strontium chromate, and zinc chromate) are known human carcinogens. The International Agency for Research on Cancer (IARC) has determined that chromium(VI) is carcinogenic to humans, based on sufficient evidence in humans for the carcinogenicity of chromium(VI)

compounds as found in chromate production, chromate pigment production, and chromium plating industries. IARC's determination is also based on sufficient evidence in experimental animals for the carcinogenicity of calcium chromate, zinc chromate, strontium chromate, and lead chromate; and limited evidence in experimental animals for the carcinogenicity of chromium trioxide (chromic acid) and sodium dichromate. IARC has also determined that chromium(0) and chromium(III) compounds are not classifiable as to their carcinogenicity to humans. The EPA has determined that chromium(VI) in air is a human carcinogen. The EPA has also determined that there is insufficient information to determine whether chromium(VI) in water or food and chromium(III) are human carcinogens.

For more information on the health effects of chromium, please see Chapter 2.

1.6 HOW CAN CHROMIUM AFFECT CHILDREN?

This section discusses potential health effects from exposures during the period from conception to maturity at 18 years of age in humans.

Children who live near wastes sites where chromium is found are likely to be exposed to higher environmental levels of chromium through breathing, touching soil, and eating contaminated soil. Children at age five years or younger have higher levels of chromium in their urine than do adults and children living outside of contaminated areas. Very few studies have looked at how chromium can affect the health of children. Children need small amounts of chromium(III) for normal growth and development. It is likely that the health effects seen in children exposed to high amounts of chromium will be similar to the effects seen in adults. We do not know whether children differ from adults in their susceptibility to chromium.

We do not know if exposure to chromium will result in birth defects or other developmental effects in people. Birth defects have been observed in animals exposed to chromium(VI). Death, skeletal deformities, and impaired development of the reproductive system have been observed in the newborn babies of animals that swallowed chromium(VI). Additional animal studies are needed to determine whether exposure to chromium(III) will result in birth defects.

One animal study showed that more chromium(III) will enter the body of a newborn than an adult. We do not know if this is also true for chromium(VI). We have no information to suggest that there are any differences between children and adults in terms of where chromium can be found in the body, and how fast chromium will leave the body. Studies with mice have shown that chromium crosses the placenta and concentrates in fetal tissue. Therefore, pregnant women who were exposed to chromium in the workplace or by living near chromium waste sites may transfer chromium from their blood into the baby where it may build up at levels greater than in the mother. There is some evidence in humans that chromium can be transferred from mother to infant through breast milk.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO CHROMIUM?

If your doctor finds that you have been exposed to significant amounts of chromium, ask whether your children might also be exposed. Your doctor might need to ask your state health department to investigate.

Children living near chromium waste sites are likely to be exposed to higher environmental levels of chromium through breathing, touching soil, and eating contaminated soil. Some children eat a lot of dirt. You should discourage your children from eating dirt. Make sure they wash their hands frequently and before eating. Discourage your children from putting their hands in their mouths or hand-to-mouth activity. Although chromium(III) is an essential nutrient that helps the body use sugar, protein, and fat, you should avoid excessive use of dietary supplements containing chromium such as chromium picolinate. You should only use the recommended amount if you choose to use these products and store these products out of children's reach in order to avoid accidental poisonings.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO CHROMIUM?

Chromium can be measured in the hair, urine, serum, red blood cells, and whole blood. However, since chromium(III) is an essential nutrient, low levels of chromium are normally found in body tissues and urine. Tests for chromium exposure are most useful for people exposed to high levels. These tests cannot determine the exact levels of chromium you may have been exposed to or predict whether or not health effects will occur. High chromium levels in the urine and red blood cells indicate exposure to chromium(VI) or chromium(III) compounds. Since the body changes chromium(VI) to chromium(III), the form of chromium that you were exposed to cannot be determined from levels in the urine. Much more chromium(VI) can enter red blood cells than chromium(III), but chromium(VI) can be changed to chromium(III) within these cells. Therefore, chromium levels in the red blood cells indicate exposure to chromium(VI). Because red blood cells last about 120 days before they are replaced by newly made red blood cells, the presence of chromium in red blood cells can show whether a person was exposed to chromium 120 days prior to testing but not if exposure occurred longer than 120 days before testing. Skin patch tests may indicate whether a person is allergic to some chromium salts. For more information, please see Chapters 2 and 6.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations can be enforced by law. Federal agencies that develop regulations for toxic substances include the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA). Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).

Regulations and recommendations can be expressed in not-to-exceed levels in air, water, soil, or food that are usually based on levels that affect animals; then they are adjusted to help protect people. Sometimes these not-to-exceed levels differ among federal organizations because of different exposure times (an 8-hour workday or a 24-hour day), the use of different animal studies, or other factors.

Recommendations and regulations are also periodically updated as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for chromium include the following:

EPA has set the maximum level of chromium(III) and chromium(VI) allowed in drinking water at 100 µg chromium/L. According to EPA, the following levels of chromium(III) and chromium(VI) in drinking water are not expected to cause effects that are harmful to health: 1,400 µg chromium/L for 10 days of exposure for children, 240 µg chromium/L for longer term exposure for children, 840 µg chromium/L for longer term exposure for adults, and 120 µg chromium/L for lifetime exposure of adults.

OSHA regulates chromium levels in the workplace air. The occupational exposure limits for an 8-hour workday, 40-hour workweek are 500 µg chromium/m^3 for water-soluble chromic (chromium(III)) or chromous [chromium(II)] salts and 1,000 µg chromium/m^3 for metallic chromium (chromium(0)), and insoluble salts. The level of chromium trioxide (chromic acid) and other chromium(VI) compounds in the workplace air should not be higher than 52 µg chromium(VI)/m^3 for any period of time.

For chromium(0), chromium(II), and chromium(III), NIOSH recommends an exposure limit of 500 µg chromium/m^3 for a 10-hour workday, 40-hour workweek. NIOSH considers all chromium(VI) compounds (including chromic acid) to be potential occupational carcinogens and recommends an exposure limit of 1 µg chromium(VI)/m^3 for a 10-hour workday, 40-hour workweek.

For more information, please see Chapter 7.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department or

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, Mailstop E-29
Atlanta, GA 30333

* Information line and technical assistance

Phone: 1-888-42-ATSDR (1-888-422-8737)
Fax: (404) 639-6359

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

* To order toxicological profiles, contact

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Phone: (800) 553-6847 or (703) 605-6000

Hazard Profile - Copper

2. RELEVANCE TO PUBLIC HEALTH

2.1 BACKGROUND AND ENVIRONMENTAL EXPOSURES TO COPPER IN THE UNITED STATES

Copper is a metallic element that occurs naturally as the free metal, or associated with other elements in compounds that comprise various minerals. Most copper compounds occur in +1 Cu(I) and +2 Cu(II) valence states. Copper is primarily used as a metal or an alloy (e.g., brass, bronze, gun metal). Copper sulfate is used as a fungicide, algicide, and nutritional supplement. Copper particulates are released into the atmosphere by windblown dust; volcanic eruptions; and anthropogenic sources, primarily copper smelters and ore processing facilities. Copper particles in the atmosphere will settle out or be removed by precipitation, but can be resuspended into the atmosphere in the form of dust. The mean concentration of copper in ambient air in the United States ranges from 5 to 200 ng/m^3. Copper is released into waterways by natural weathering of soil and rocks, disturbances of soil, or anthropogenic sources (e.g., effluent from sewage treatment plants). Copper concentrations in drinking water vary widely as a result of variations in pH and hardness of the water supply; the levels range from a few ppbs to 10 ppm. The mean concentration of copper in soil in the United States ranges from 5 to 70 mg/kg. The estimated daily intake of copper from food is 1.0–1.3 mg/day for adults (0.014–0.019 mg/kg/day).

The general population is exposed to copper through inhalation, consumption of food and water, and dermal contact with air, water, and soil that contains copper. The primary source of copper intake is the diet; however, the amount of copper in the diet usually does not exceed the average dietary requirements (RDAs) for copper. Drinking water is the primary source of excess copper. Populations living near sources of copper emissions, such as copper smelters and refineries and workers in these and other industries may also be exposed to high levels of copper in dust by inhalation. Copper concentrations in soils near copper emission sources could be sufficiently high to result in significantly high intakes of copper in young children who ingest soil. For example, copper concentrations of 2,480–6,912 ppm have been measured near copper smelters. These levels of copper in soils would result in the intake of 0.74–2.1 mg copper per day in a child ingesting 300 mg of soil. Copper has been identified in at least 906 of the 1,647 hazardous waste sites that have been proposed for inclusion on the EPA NPL.

2.2 SUMMARY OF HEALTH EFFECTS

Copper is an essential nutrient that is incorporated into a number of metalloenzymes involved in hemoglobin formation, drug/xenobiotic metabolism, carbohydrate metabolism, catecholamine biosynthesis, the cross-linking of collagen, elastin, and hair keratin, and the antioxidant defense mechanism. Copper-dependent enzymes, such as cytochrome c oxidase, superoxide dismutase, ferroxidases, monoamine oxidase, and dopamine β-monooxygenase, function to reduce activated oxygen species or molecular oxygen. Symptoms associated with copper deficiency in humans include normocytic, hypochromic anemia, leukopenia, and osteoporosis; copper deficiency is rarely observed in the U.S. general population. In the United States, the median intake of copper from food is 0.93–1.3 mg/day for adults (0.013–0.019 mg Cu/kg body weight/day using a 70-kg reference body weight). A recommended dietary allowance (RDA) of 0.9 mg/day (0.013 mg/kg/day) has recently been established.

Copper is readily absorbed from the stomach and small intestine. After nutritional requirements are met, there are several mechanisms that prevent copper overload. Excess copper absorbed into gastrointestinal mucosal cells induces the synthesis of and binds to the metal binding protein metallothionein. This bound copper is excreted when the cell is sloughed off. Copper that eludes binding to intestinal metallothionen is transported to the liver. It is stored in the liver bound to liver metallothionen, from which it is ultimately released into bile and excreted in the feces. Although copper homeostasis plays an important role in the prevention of copper toxicity, exposure to excessive levels of copper can result in a number of adverse health effects including liver and kidney damage, anemia, immunotoxicity, and developmental toxicity. Many of these effects are consistent with oxidative damage to membranes or macromolecules. Copper can bind to the sulfhydryl groups of several enzymes, such as glucose-6-phosphatase and glutathione reductase, thus interfering with their protection of cells from free radical damage.

One of the most commonly reported adverse health effect of copper is gastrointestinal distress. Nausea, vomiting, and/or abdominal pain have been reported, usually occurring shortly after drinking a copper sulfate solution, beverages that were stored in a copper or untinned brass container, or first draw water (water that sat in the pipe overnight). The observed effects are not usually persistent and gastrointestinal effects have not been linked with other health effects. Animal studies have also reported gastrointestinal effects (hyperplasia of forestomach mucosa) following ingestion of copper sulfate in the diet. Copper is also irritating to the respiratory tract. Coughing, sneezing, runny nose, pulmonary fibrosis, and increased vascularity of the nasal mucosa have been reported in workers exposed to copper dust.

The liver is also a sensitive target of toxicity. Liver damage (necrosis, fibrosis, abnormal biomarkers of liver damage) have been reported in individuals ingesting lethal doses of copper sulfate. Liver effects have also been observed in individuals diagnosed with Wilson's disease, Indian childhood cirrhosis, or idiopathic copper toxicosis (which includes Tyrollean infantile cirrhosis). These syndromes are genetic disorders that result in an accumulation of copper in the liver; the latter two syndromes are associated with excessive copper exposure. Inflammation, necrosis, and altered serum markers of liver damage have been observed in rats fed diets with copper sulfate levels that are at least 100 times higher than the nutritional requirement. Damage to the proximal convoluted tubules of the kidney has also been observed in rats. The liver and kidney effects usually occur at similar dose levels; however, the latency period for the kidney effects is longer than for the liver effects.

There is some evidence from animal studies to suggest that exposure to airborne copper or high levels of copper in drinking water can damage the immune system. Impaired cell-mediated and humoral-mediated immune function have been observed in mice. Studies in rats, mice, and mink suggest that exposure to high levels of copper in the diet can result in decreased embryo and fetal growth.

The carcinogenicity of copper has not been adequately studied. An increase in cancer risk has been found among copper smelters; however, the increased risk has been attributed to concomitant exposure to arsenic. Increased lung and stomach cancer risks have also been found in copper miners. However, a high occurrence of smoking and exposure to radioactivity, silica, iron, and arsenic obscure the association of copper exposure with carcinogenesis. Animal studies have not found increased cancer risks in orally exposed rats or mice. The IARC has classified the pesticide, copper 8-hydroxyquinoline, in Group 3, unclassifiable as to carcinogenicity in humans and EPA has classified copper in Group D, not classifiable as to human carcinogenicity

A more detailed discussion of the critical targets of copper toxicity, the gastrointestinal tract and the liver, follows.

Gastrointestinal Effects. The available human and animal data suggest that the gastrointestinal tract is a sensitive target of toxicity. There are numerous reports of nausea, vomiting, and/or abdominal pain in humans ingesting beverages contaminated with copper or water containing copper sulfate. These symptoms typically occur shortly after ingestion and are not persistent. The results of three single exposure studies suggest that the threshold for gastrointestinal symptoms is between 4 and 6 ppm, which is equivalent to doses of 0.11 mg/kg and 0.017–0.018 mg Cu/kg. Nausea, vomiting, and/or abdominal

pain also appear to be the most sensitive end point following repeated exposure to copper in drinking water. These symptoms were reported by adults drinking water containing ≥3 ppm copper as copper sulfate (0.0731 mg Cu/kg/day) for 1–2 weeks or 4 ppm copper as copper sulfate (0.091 mg Cu/kg/day) for 2 months. Similar gastrointestinal effects were observed in adults ingesting copper oxide in drinking water. Although gastrointestinal irritation may play a role in the observed gastrointestinal effects, data from ferrets and monkeys suggest that vagal afferent fibers and 5-HT_3 and 5-HT_4 receptors are involved in copper-induced emesis.

Hepatic Effects. In humans, copper-induced hepatic damage is dependent on several factors including genetics, age, and copper intake. Liver damage is rarely reported in adults; the few reported cases of liver damage (centrilobular necrosis, jaundice, and increased aspartate aminotransferase activity) have been associated with intentional ingestion of a lethal dose of copper sulfate. In infants and children, reported liver effects are usually manifested in one of three syndromes: Wilson's disease, Indian childhood cirrhosis, and idiopathic copper toxicosis. Wilson's disease is an autosomal recessive genetic disorder associated with impaired copper metabolism. Dietary exposure to higher than normal levels of copper does not appear to be necessary for the manifestation of liver damage. Some heterozygous carriers of Wilson's disease also have elevated hepatic levels of copper and increased urinary excretion, although adverse health effects have not been reported in these individuals. There is evidence that Indian childhood cirrhosis and idiopathic copper toxicosis are also caused by a genetic defect that is transmitted in an autosomal recessive mode. However, unlike Wilson's disease, manifestation of the disease is associated with exposure to unusually high levels of dietary copper from milk stored in copper or brass containers or from drinking water. The clinical age of onset is usually between 6 months and 5 years, and the observed liver effects include pericellular fibrosis, abnormal biochemical markers of liver damage (e.g., increased serum aspartate aminotransferase and alkaline phosphatase activities and serum bilirubin levels), and very high levels of copper in the liver. In general, the potential hepatotoxicity of copper has not been extensively investigated in healthy humans. No effect levels of 0.14–0.17 and 0.315 mg Cu/kg/day for liver effects in adults and infants (3–12 months of age), respectively, had been reported in intermediate-duration studies (2–9 months); these studies used serum chemistry biomarkers (e.g., alanine aminotransferase, aspartate aminotransferase) to assess liver damage. Two community survey studies also found no evidence of liver damage in infants living in households with 0.8 ppm copper in drinking water. The results of the three studies involving infants should be interpreted cautiously due to the high drop out rate, small number of subjects examined for possible liver damage, and the dismissal of anomalous findings as secondary to infection rather than possibly indicative of copper toxicity.

Adverse liver effects have been observed in rats exposed to dietary copper levels that were more than 100 times higher than the nutritional requirement. The liver effects included inflammation, necrosis, and abnormal serum chemistry markers of liver damage. Rats appear to develop a tolerance to copper doses of 180–<550 mg Cu/kg/day. Tolerance is defined as "the ability to endure the continued or increasing administration of a toxicant and the capacity to exhibit less response to a test dose than previous." As the levels of hepatic copper increase, so does the severity of the damage until peak copper levels are reached. After about 3–5 weeks of exposure, the copper levels begin to decline and are maintained at a steady level for the remainder of the exposure period. When the hepatic levels decline, regeneration of hepatic tissue is observed, and continued exposure or exposure to higher doses does not result in more tissue damage. The decline in hepatic copper levels and regeneration of damaged tissue occurs early at higher doses. At doses >550 mg Cu/kg/day, the liver becomes permanently overloaded and chronic hepatitis develops.

2.3 MINIMAL RISK LEVELS (MRLs)

Estimates of exposure levels posing minimal risk to humans (Minimal Risk Levels or MRLs) have been made for copper. An MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. MRLs are derived when reliable and sufficient data exist to identify the target organ(s) of effect or the most sensitive health effect(s) for a specific duration within a given route of exposure. MRLs are based on noncancerous health effects only and do not consider carcinogenic effects. MRLs can be derived for acute, intermediate, and chronic duration exposures for inhalation and oral routes. Appropriate methodology does not exist to develop MRLs for dermal exposure.

Although methods have been established to derive these levels (Barnes and Dourson 1988; EPA 1990), uncertainties are associated with these techniques. Furthermore, ATSDR acknowledges additional uncertainties inherent in the application of the procedures to derive less than lifetime MRLs. As an example, acute inhalation MRLs may not be protective for health effects that are delayed in development or are acquired following repeated acute insults, such as hypersensitivity reactions, asthma, or chronic bronchitis. As these kinds of health effects data become available and methods to assess levels of significant human exposure improve, these MRLs will be revised.

A User's Guide has been provided at the end of this profile (see Appendix B). This guide should aid in the interpretation of the tables and figures for Levels of Significant Exposure and the MRLs.

Inhalation MRLs

The available data on the toxicity of inhaled copper were considered inadequate for derivation of acute-, intermediate-, or chronic-duration inhalation MRLs. Data on the inhaled toxicity of copper in humans following acute-duration exposure are limited to a report of workers developing metal fume fever while cutting brass pipe with an electric cutting tool in a poorly ventilated area (Armstrong et al. 1983); exposure levels were not reported. Respiratory effects and impaired immune function have been observed in mice following a single 3-hour exposure to 3.3 mg Cu/m^3 as copper sulfate or repeated exposure (3 hours/day, 5 days/week for 1–2 weeks) to 0.12–0.13 mg Cu/m^3 as copper sulfate (Drummond et al. 1986). The Drummond et al. (1986) study was not selected as the basis of an acute-duration inhalation MRL because a small number of animals was tested (four per group) and a limited number of end points (respiratory tract and immune function) were examined. Intermediate-duration data are limited to studies by Johansson et al. (1983, 1984), which did not find any histological alterations in the lungs or functional or morphological alterations in alveolar macrophages of rabbits exposed to copper chloride. As with the acute-duration data, the limited number of end points examined precludes deriving an intermediate-duration inhalation MRL. The chronic-duration database for copper consists of two occupational exposure studies reporting respiratory (Askergren and Mellgren 1975; Suciu et al. 1981) and gastrointestinal (Suciu et al. 1981) irritation, hepatic effects (Suciu et al. 1981), and possible neurological and reproductive effects (Suciu et al. 1981). Chronic-duration inhalation MRLs cannot be derived from these studies due to poor exposure characterization and/or lack of controls.

Oral MRLs

- An MRL of 0.01 mg/kg/day has been derived for acute-duration oral exposure (1–14 days) to copper.

The available human and animal acute-duration studies strongly suggest that the gastrointestinal tract is the most sensitive target of copper toxicity. Numerous studies and case reports have reported nausea, vomiting, and/or abdominal pain in humans immediately following ingestion of copper-contaminated water or other beverages (Araya et al. 2001, 2003a, 2003b, 2003c; Chuttani et al. 1965; Gotteland et al. 2001; Knobeloch et al. 1994; Nicholas and Brist 1968; Olivares et al. 2001; Pizarro et al. 1999, 2001; Spitalny et al. 1984). In human studies involving a single exposure to copper following an overnight fast, adverse gastrointestinal effects (nausea, vomiting, abdominal pain, and/or diarrhea) have been observed at doses of 0.011–0.03 mg Cu/kg (Araya et al. 2001, 2003a, 2003c; Gotteland et al. 2001; Olivares et al. 2001). Under these experimental conditions, the apparent threshold appears to fall between 0.011 and

0.017 mg Cu/kg (Araya et al. 2001, 2003a; Olivares et al. 2001). Slightly higher thresholds for gastrointestinal symptoms were observed in two acute-duration repeated exposure studies in which subjects used a copper-containing water as their primary source of drinking water for 1 or 2 weeks (Pizarro et al. 1999, 2001). In the 2-week study, 60 women were given copper sulfate containing water to be used for drinking and cooking purposes. No significant alterations in serum biomarkers of liver damage (alanine aminotransferase, aspartate aminotransferase, γ-glutamyl transferase) were observed in the subjects at the end of the study. An increased occurrence of nausea, vomiting, and/or abdominal pain was observed when the women were exposed to 3 ppm copper as copper sulfate (0.0731 mg Cu/kg/day) (Pizarro et al. 1999); no significant increases in the incidence of gastrointestinal symptoms were noted at 1 ppm (0.0272 mg Cu/kg/day). Nausea, vomiting, and/or abdominal pain were also reported by women ingesting water containing 5 ppm (0.096 mg Cu/kg/day) as copper sulfate or copper oxide for 1 week (Pizarro et al. 2001). Animal studies support the identification of the gastrointestinal tract as a sensitive target of toxicity. Hyperplasia of the forestomach mucosa was observed in rats exposed to 44 mg Cu/kg/day as copper sulfate in the diet (NTP 1993) and in mice exposed to 197 mg Cu/kg/day as copper sulfate in the diet (NTP 1993). At higher doses, liver and kidney damage have been observed (Haywood 1980; Haywood and Comerford 1980; Haywood et al. 1985b; NTP 1993).

The Pizarro et al. (1999) 2-week study was selected as the basis of the acute-duration oral MRL for copper. This study identified no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect level (LOAEL) values of 0.0272 and 0.0731 mg Cu/kg/day for increases in the incidence of nausea, vomiting, and/or abdominal pain. Although the LOAEL values identified in the single exposure studies (Araya et al. 2001, 2003; Olivares et al. 2001) are slightly lower than the than the NOAEL identified in the Pizarro et al. (1999) study, the Pizarro et al. (1999) study was selected as the critical study because it is a longer-duration study and it more closely mimics an exposure scenario of a population drinking copper-contaminated drinking water. The NOAEL was divided by an uncertainty factor of 3 (to account for human variability) to yield an acute-duration oral MRL of 0.01 mg Cu/kg/day. The observed gastrointestinal effects were probably due to direct contact; thus, only a partial uncertainty factor of 3 was used to account for human variability because toxicokinetic differences among individuals should not affect sensitivity. The acute-duration MRL is intended to protect against the health effects associated with exposure to copper-contaminated drinking water; it assumes that the affected population will have a normal intake of copper from the diet.

- An MRL of 0.01 mg/kg/day has been derived for intermediate-duration oral exposure (15–365 days) to copper.

There are limited data on the intermediate-duration toxicity of copper in humans. Araya et al. (2003b) exposed groups of 327–355 adults to <0.01 (control group), 2, 4, or 6 ppm copper sulfate in water for 2 months. The subjects prepared the copper sulfate solution to be used at home by mixing a stock copper sulfate solution with tap water; this solution was used for drinking water and preparing beverages and soups. Exposure to copper sulfate resulted in increases in the occurrence of gastrointestinal symptoms; the incidence was significantly higher than controls at 6 ppm when the data were analyzed using the chi-square test with Bonferroni correction and at 4 ppm when the Bonferroni correction was not used. Only one test was used to assess whether exposure to copper results in adverse gastrointestinal effects (reported symptoms); thus, the Bonferroni correction is not needed for this end point. Therefore, the 4 ppm concentration is identified as the LOAEL and the 2 ppm concentration as the NOAEL. The study authors reported copper intakes for 48–49 subjects per group who provided blood samples; no information on selection criteria were provided. The copper intakes were 0, 0.042, 0.091, and 0.17 mg Cu/kg/day for the control, 2, 4, and 6 ppm groups, respectively. The dietary intake of copper was not measured in this study; however, Araya et al. (2003b) noted that copper intake found in a survey of other community residents was 0.9 mg Cu/day. No significant alterations in copper status or liver function (as assessed by serum alanine aminotransferase, asparatate aminotransferase, and γ-glutamyl transferase activities) were observed in a subset of subjects from each group. In a study by Pratt et al. (1985), a group of seven adults were administered 10 mg Cu/day (0.14 mg Cu/kg/day) as copper gluconate in a capsule for 12 weeks. No significant alterations in serum markers of liver damage (cholesterol and triglyceride levels and serum aspartate aminotransferase, alkaline phosphatase, γ-glutamyl transferase, and lactate dehydrogenase activities) were found. Similarly, no alterations in total bilirubin or serum alanine aminotransferase, aspartate aminotransferase, or γ-glutamyl transferase activities were observed in infants exposed to 0.315 mg Cu/kg/day for 9 months (Olivares et al. 1998). Zietz et al. (2003a, 2003b) also did not find evidence of liver damage in infants living in households with water concentrations of 0.8 ppm and higher. The Pratt et al. (1985), Olivares et al. (1998), and Zietz et al. (2003a, 2003b) studies did not report significant alterations in the occurrence of gastrointestinal disturbances and the study design did not include symptoms questionnaires, although the high dropout rate observed in the Olivares et al. (1998) study may have been related to gastrointestinal effects. Severe liver damage (pericellular fibrosis and increased serum aminotransferase and alkaline phosphatase activities) has been observed in children with a genetic susceptibility to high levels of copper in the liver. The liver was a critical target of toxicity in rats exposed to very high levels of copper in diet (greater than 100 times the nutritional requirement), Inflammation, necrosis, and increased alanine and aspartate aminotransferases activities have been

reported in rats at exposure levels of 16 mg Cu/kg/day as copper sulfate in the diet (Haywood 1980, 1985; Haywood and Comerford 1980; Haywood and Loughran 1985; Haywood et al. 1985a; NTP 1993). No liver effects where observed at 8 mg Cu/kg/day (NTP 1993). Histological alterations in stomach, indicative of irritation (hyperplasia of the squamous mucosa on the limiting ridge separating the forestomach from the glandular stomach), have also been observed in rats and mice exposed to 33 or 267 mg Cu/kg/day, respectively, as copper sulfate in the diet for 13 weeks (NTP 1993).

An intermediate-duration oral MRL of 0.01 mg Cu/kg/day was derived for copper based on gastrointestinal effects using the data from the Araya et al. (2003b) study. This study identified NOAEL and LOAEL values of 0.042 and 0.091 mg Cu/kg/day, respectively; these copper doses were in excess of normal dietary intake. The NOAEL was divided by an uncertainty factor of 3 (to account for human variability) to yield an intermediate-duration oral MRL of 0.01 mg Cu/kg/day. As with the acute-duration MRL, the intermediate-duration MRL is intended to protect against exposure to excess copper in drinking water and assumes a normal copper dietary intake.

The database on the chronic oral toxicity of copper is inadequate for derivation of a MRL. Massie and Aiello (1984) reported a 15% decrease in the lifespan in mice exposed to 4.2 mg Cu/kg/day as copper gluconate in drinking water.

Hazard Profile - Lead

2. RELEVANCE TO PUBLIC HEALTH

2.1 BACKGROUND AND ENVIRONMENTAL EXPOSURES TO LEAD IN THE UNITED STATES

Lead is a naturally occurring metal found in the Earth's crust at about 15–20 mg/kg. In comparison to the two most abundant metals in the Earth, (aluminum and iron), lead is a relatively uncommon metal. Lead rarely occurs in its elemental state, but rather its +2 oxidation state in various ores throughout the earth. The most important lead containing ores are galena (PbS), anglesite ($PbSO_4$), and cerussite ($PbCO_3$). The world's reserves of lead are estimated at $7.1x10^7$ tons, with over one third located in North America. Levels of lead in the environment (not contained in ore deposits) have increased over the past three centuries as a result of human activity. Human exposure to lead is common and results from the many uses of this metal due to its exceptional properties. The largest industrial use of lead today is for the production of lead batteries, largely used in the automobile industry. Other uses of lead include the production of lead alloys, use in soldering materials, shielding for X-ray machines, and in the manufacture of corrosion and acid resistant materials used in the building industry (see Chapter 5 for more details regarding lead usage).

The greatest potential for human exposure to lead arises from its previous use as an additive in gasoline, which resulted in its widespread dispersal throughout the environment, and its use as a pigment in both interior and exterior paints. Although the use of lead as a gasoline additive has been gradually phased out in the United States and its use in paints was banned in 1978, human exposure to lead continues because unlike organic chemicals released to the environment, lead does not degrade to other substances. Leaded paint is still prevalent in many older homes in the United States, and peeling or flaking paint contributes to indoor and outdoor dust levels. Prior to World War II, lead-arsenic compounds were used as pesticides, especially in orchards. Because lead does not degrade and is strongly absorbed to soil, the lead released from past uses still remains in the soil. Since the ban on the use of leaded gasoline took effect, lead emissions to the atmosphere have decreased significantly. According to the EPA, atmospheric emissions of lead decreased 93% over the 21-year period of 1982–2002. The atmospheric concentration of lead varies greatly, with the highest levels observed near stationary sources such as lead smelters. Levels of lead in ambient air range from about $7.6x10^{-5}$ $\mu g/m^3$ in remote areas such as Antarctica to >10 $\mu g/m^3$ near point sources. The EPA national ambient air quality standard for lead is 1.5 $\mu g/m^3$.

The amount of lead contained in pipes and plumbing fittings have been strictly regulated since 1988; however, human exposure to lead from drinking water still occurs as a consequence of leaching of lead from corroding pipes and fixtures or lead containing solder. Based on several data sets, it is estimated that <1% of the public water systems in the United States have water entering the distribution system with lead levels above 5 µg/L. Copper pipes have replaced lead pipes in most residential plumbing. Section 1417 of the Safe Drinking Water Act, which took effect in August 1998, requires that all pipes, fixtures, and solder be lead-free. However, lead-free means that solders and flux may not contain more than 0.2% lead, while pipes, pipe fittings, and well pumps may not contain more than 8% lead. The EPA requires public water distribution systems to reduce the corrosivity of water if >10% of the samples exceed the 15 µg/L threshold level for lead.

Occupational exposure to lead occurs for workers in the lead smelting and refining industries, battery manufacturing plants, steel welding or cutting operations, construction, rubber products and plastics industries, printing industries, firing ranges, radiator repair shops, and other industries requiring flame soldering of lead solder. In these occupations, the major routes of lead exposure are inhalation and ingestion of lead-bearing dusts and fumes. In the smelting and refining of lead, mean concentrations of lead in air can reach 4,470 µg/m^3; in the manufacture of storage batteries, mean airborne concentrations of lead from 50 to 5,400 µg/m^3 have been recorded; and in the breathing zone of welders of structural steel, an average lead concentration of 1,200 µg/m^3 has been found.

Certain populations may be exposed to lead from other sources. Several non-western folk medicines can contain substantial levels of lead. Lead glazing that is applied to some pottery and ceramic ware may leach lead into foods or liquids that are stored in them (see Section 6.4.5 for more information). The FDA regulates the amount of leachable lead from food containers (see Table 8-1).

Blood lead levels (PbB) in the general population of the United States have been decreasing over the past 3 decades as regulations regarding lead paint, leaded fuels, and lead-containing plumbing materials have reduced exposure. PbBs measured as a part of the National Health and Nutrition Examination Surveys (NHANES) indicated that from 1976 to 1991, the mean PbBs of the U.S. population aged from 1 to 74 years dropped 78%, from 12.8 to 2.8 µg/dL. The prevalence of PbBs ≥10 µg/dL also decreased sharply from 77.8 to 4.3%. Data from NHANES III, phase II (1991–1994) showed that 4.4% of children aged 1–5 years had PbBs ≥10 µg/dL, and the geometric mean PbBs for children 1–5 years old was 2.7 µg/dL. From the most recent sampling data conducted for 1999–2002, 1.6% of children aged 1–5 years had PbBs ≥10 µg/dL, with a geometric mean PbBs of 1.9 µg/dL (see Section 6.5 for greater

detail). The Centers for Disease Control and Prevention (CDC) action level for children ≤7 years of age is 10 µg/dL. A tiered approach is recommended for managing lead-exposed children (see Section 3.9).

Analysis of lead in whole blood is the most common and accurate method of assessing lead exposure. Erythrocyte protoporphyrin (EP) tests can also be used, but are not as sensitive at low blood lead levels (≤20 µg/dL); the screening test of choice is blood lead levels. X-ray fluorescence techniques (XRF), although not widely available, can be used for the determination of lead concentration in bones. Lead partitions to the bone over a lifetime of exposure; therefore, bone lead measurements are a good indicator of cumulative exposure, whereas measurements of lead in blood are more indicative of recent exposure (see Sections 3.3 and 3.6.1 for greater detail).

2.2 SUMMARY OF HEALTH EFFECTS

An enormous amount of information is available on the health effects of lead on human health. In fact, the toxic effects of lead have been known for centuries, but the discovery in the past few decades that levels of exposure resulting in relatively low levels of lead in blood (e.g., <20 µg/dL) are associated with adverse effects in the developing organism is a matter of great concern. Most of the information gathered in modern times regarding lead toxicity comes from studies of workers from a variety of industries and from studies of adults and children in the general population. The most sensitive targets for lead toxicity are the developing nervous system, the hematological and cardiovascular systems, and the kidney. However, due to the multi-modes of action of lead in biological systems, lead could potentially affect any system or organs in the body.

Studies of lead workers suggest that long-term exposure to lead may be associated with increased mortality due to cerebrovascular disease. The same was found in a study of adults from the general population who were hospitalized for lead poisoning during childhood. Population studies suggest that there is a significant association between bone-lead levels and elevated blood pressure. Blood lead levels (PbB) also have been associated with small elevations in blood pressure. Between the two biomarkers, bone lead appears to be the better predictor. Lead also affects kidney functions; glomerular filtration rate appears to be the function affected at the lowest PbBs. Decreased glomerular filtration rate has been consistently observed in populations with mean PbB <20 µg/dL and two studies have reported effects at PbB <10 µg/dL. Lead may alter glomerular filtration rate by several mechanisms.

Lead has long been known to alter the hematological system by inhibiting the activities of several enzymes involved in heme biosynthesis. Particularly sensitive to lead action is δ-aminolevulinic acid dehydratase (ALAD). Inhibition of ALAD activity occurs over a wide range of PbBs beginning at <10 µg/dL. The anemia induced by lead is primarily the result of both inhibition of heme synthesis and shortening of erythrocyte lifespan, but lead also can induce inappropriate production of the hormone erythropoietin leading to inadequate maturation of red cell progenitors, which can contribute to the anemia.

A recent study in children 8–10 years of age suggested that lead accelerates skeletal maturation, which might predispose to osteoporosis in later life. Lead also has been associated with increased occurrence of dental caries in children and periodontal bone loss, which is consistent with delayed mineralization in teeth observed in studies in animals. Current mean PbBs in these cohorts were <5 µg/dL; however, the cross-sectional nature of the studies precluded assessment of the exposure history.

Changes in circulating levels of thyroid hormones, particularly serum thyroxine (T_4) and thyroid stimulating hormone (TSH), generally occurred in workers having mean PbB ≥40–60 µg/dL. Altered serum levels of reproductive hormones, particularly follicle stimulating hormone (FSH), luteinizing hormone (LH), and testosterone have been observed at PbB ≥30–40 µg/dL. Lead also has been shown to decrease circulating levels of the active form of vitamin D, 1,25-dihydroxyvitamin D, in children with moderate to high PbB (30–60 µg/dL), but not in children with low to moderate PbB (average lifetime PbB between 4.9 and 23.6 µg/dL, geometric mean, 9.8 µg/dL). Normal levels of vitamin D are important for maintaining calcium homeostasis.

Altered immune parameters have been described in lead workers with PbB in the range of 30–70 µg/dL. Reported effects included changes in some T-cell subpopulations, response to T-cell mitogens, and reduced chemotaxis of polymorphonuclear leukocytes. Two studies of children reported significant associations between PbB and increases in serum IgE levels. IgE is the primary mediator for type-I hypersensitivity and is involved in various allergic diseases such as asthma. These findings in children along with results from studies in rodents exposed *in utero* have led some to suggest that lead may be a risk factor for childhood asthma.

Exposure to high amounts of lead resulting in PbBs of 100–120 µg/dL in adults or 70–100 µg/dL in children produce encephalopathy, a general term that describes various diseases that affect brain function. Symptoms develop following prolonged exposure and include dullness, irritability, poor attention span,

epigastric pain, constipation, vomiting, convulsions, coma, and death. Lead poisoning in children can leave residual cognitive deficits that can be still detected in adulthood. Neurobehavioral effects including malaise, forgetfulness, irritability, lethargy, headache, fatigue, impotence, decreased libido, dizziness, weakness, and paresthesia have been reported in lead workers with PbBs in the range of 40–80 µg/dL. Also, PbBs between 40 and 80 µg/dL have been associated with neuropsychological effects in lead workers. Studies of older populations with current mean PbBs <10 µg/dL have reported associations between PbB and/or bone lead and poorer performance in neurobehavioral tests. Lead also has been shown to affect nerve conduction velocity and postural balance in workers with PbB in the range of 30–60 µg/dL. Alterations of somatosensory evoked potentials also have been reported in lead workers with mean PbBs in the range of 30–50 µg/dL.

As previously mentioned, one of the major concerns regarding lead toxicity is the cognitive and neurobehavioral deficits that are observed in children exposed to lead. Prospective studies have provided the greatest amount of information. Analyses of these and other studies suggest that an IQ decline of 1–5 points is associated with an increase in PbB of 10 µg/dL. Of special interest and concern are the results of recent studies that have reported neurobehavioral deficits in children associated with PbBs <10 µg/dL and an apparent lack of threshold down to even the lowest PbBs recorded in these studies. Lead also has caused neurobehavioral alterations in developing animals, and at PbBs similar to those reported in children. Studies in animals, particularly in monkeys, have provided key information for the interpretation of a cognitive basis for IQ changes. Studies of children also have shown associations between PbB and growth, delayed sexual maturation in girls, and decreased erythropoietin production.

Some studies of humans occupationally or environmentally exposed to lead have observed associations between PbB and abortion and pre-term delivery in women and alterations in sperm and decreased fertility in men. On the other hand, there are several studies that found no significant association between lead exposure and these end points. At least for the effects in males, the threshold PbB appears to be in the range of 30–40 µg/dL. Studies have shown that lead can affect the association of protamines with DNA in germ cells from exposed males. Lead does so by competing or reducing zinc in protamine P2 *in vivo*, which would leave sperm chromatin and DNA open to damage from other exposures.

In vitro mutagenicity studies in microorganisms have yielded mostly negative results for lead, but lead is a clastogenic agent, as shown by the induction of chromosomal aberrations, micronuclei and by sister chromatid exchanges in peripheral blood cells from lead workers. Studies of cancer in lead workers have been inconclusive. A meta-analysis of eight major occupational studies on cancer mortality or incidence

in workers with high lead exposure concluded that there is some limited evidence of increased risk of lung cancer and stomach cancer, although there might have been confounding with arsenic exposure in the study with highest relative risk of lung cancer. The results also showed a weak evidence for an association with kidney cancer and gliomas. In the only study of the general population available, there was suggestive evidence for an increase risk of cancer mortality in women, but not men, with a threshold PbB of 24 µg/dL. This study used data from the Second National Health and Nutrition Survey (NHANES II) Mortality Study. Lead has produced primarily renal tumors in rodents by a mechanism not yet elucidated. Some nongenotoxic mechanisms that have been proposed for lead-induced cancer include inhibition of DNA synthesis and repair, alterations in cell-to-cell communication, and oxidative damage.

The Department of Health and Human Services (DHHS) has determined that lead and lead compounds are reasonably anticipated to be human carcinogens based on limited evidence from studies in humans and sufficient evidence from animal studies. The EPA has determined that lead is a probable human carcinogen based on sufficient evidence from studies in animals and inadequate evidence in humans. The International Agency for Research on Cancer (IARC) has determined that inorganic lead is probably carcinogenic to humans based on sufficient evidence from studies in animals and limited evidence of carcinogenicity from studies in humans. IARC also determined that organic lead compounds are not classifiable as to their carcinogenicity in humans based on inadequate evidence from studies in humans and animals.

A discussion of the most sensitive end points for lead toxicity, neurodevelopmental, cardiovascular/renal, and hematological, is presented below. The reader is referred to Chapter 3, Health Effects, for information on additional effects.

Neurodevelopmental Effects. Lead can impair cognitive function in children and adults, but children are more vulnerable than adults. The increased vulnerability is due in part to the relative importance of exposure pathways (i.e., dust-to-hand-mouth) and differences in toxicokinetics (i.e., absorption of ingested lead). Although the inhalation and oral routes are the main routes of exposure for both adults and children, children are more likely to have contact with contaminated surfaces due to playing on the ground and to hand-to-mouth activities. Furthermore, children absorb a larger fraction of ingested lead than adults. However, perhaps more important is the fact that the developing nervous system is especially susceptible to lead toxicity. During brain development, lead interferes with the trimming and pruning of synapses, migration of neurons, and neuron/glia interactions. Alterations of any of these processes may result in failure to establish appropriate connections between structures and

eventually in permanently altered functions. Because different brain areas mature at different times, the final outcome of the exposure to lead during development (i.e., *in utero* vs. pediatric exposure) will vary depending on the time of exposure. This has been demonstrated in studies in animals. The time of exposure-specific response appears to have contributed to the failure to identify a "behavioral signature" of lead exposure in children. Other factors that may affect individual vulnerability are certain genetic polymorphisms, such as that for the vitamin D receptor, the lead-binding enzyme ALAD, or the APOE genotype. One important additional factor shown to influence the toxicity of lead is the characteristics of the child's rearing environment, a modifying factor. It was argued that effect modification is a property of a true association and should be distinguished from confounding. Effect modification can explain inconsistencies in findings, and if it exists, failure to address it will lead to an error in inference. For example, if social class is an effect modifier of the association between PbB and IQ, and differs between two cohorts, the strength of the association based on these two studies will necessarily be different.

Despite the many factors that can potentially work against finding agreement among studies, the preponderance of the evidence indicates that lead exposure is associated with decrements in cognitive function. Meta-analyses conducted on cross-sectional studies or a combination of cross-sectional and prospective studies suggest that an IQ decline of 1–5 points is associated with an increase in PbB of 10 μg/dL. Most importantly, no threshold for the effects of lead on IQ has been identified. This has been confirmed by a series of recent studies in children that found significant inverse associations between neuropsychological function and PbBs <10 μg/dL. It should be stressed, however, that the effects of lead on IQ and other neurobehavioral scores are very small compared with the effects of other factors such as parents' IQ, but is also important to stress that lead exposure, unlike most of those other factors, is highly preventable.

While measurements of IQ are convenient in that they allow comparison across populations of different demographic and cultural characteristics, and help define the extent of the public health issue, they only partially advance our understanding of the problem of lead-induced behavioral toxicity. It is important to elucidate the underlying basis of the deficits in IQ as well as the behavioral mechanisms that account for them. It was noted that "the answers are critical not only to further define neurobiological mechanisms associated with learning deficits, but also to determine behavioral or neurochemical therapeutic approaches to alleviate them." Studies in animals have provided answers to some of these questions. Studies in animals have great utility because the possibility of confounding is reduced with the controlled experimental design and genetic factors. In addition, they address specific domains of cognitive function and allow determination of critical periods of exposure. Results of behavioral tests performed primarily

in rats and monkeys exposed to lead have suggested that the impaired performance is the result, at least in part, of a combination of distractibility, inability to inhibit inappropriate responding, and perseveration in behaviors that are no longer appropriate. Evaluation of children exposed to lead with different subscales of IQ tests in conjunction with assessments of behavior on teacher's rating scales on young school-age children suggest that increased distractibility, impulsivity, short attention span, and inability to follow simple and complex sequences of directions are associated with increased lead body burden. The similarity between neurobehavioral effects in lead-exposed children and in animals, and the fact that the deficits are observed at similar PbBs should stimulate continued research to elucidate the biochemical and morphological substrates that underlie specific behaviors.

Although the decrement of IQ points in children associated with lead exposure is generally small, lead neurotoxicity may have major implications for public health when exposure is considered in terms of large populations and its preventable nature. One study quantified the economic benefits from projected improvements in worker productivity resulting from the reduction in children's exposure to lead in the United States since 1976. Based on data from NHANES (a study designed to provide national estimates of the health and nutritional status of the U.S. civilian noninstitutionalized population aged 2 months and older) and meta-analyses, it was estimated that mean PbBs declined 15.1 µg/dL between 1976 and 1999 and that IQ scores increased between 0.185 and 0.323 points for each 1 µg/dL blood lead concentration. It was further estimated that each IQ point raises worker's productivity by 1.76–2.38%, and that the economic benefit for each year's cohort of 3.8 million 2-year-old children ranges from $110 to $319 billion. In another study, using an environmentally attributable fraction model, it was estimated that the present value of economic losses in the United States attributable to lead exposure in amounts to $43.4 billion per year in each annual birth cohort. More recently, one study estimated that mild mental retardation and cardiovascular outcomes resulting from exposure to lead amounts to almost 1% of the global burden of disease, with the highest burden in developing regions.

A related and important issue is whether lead-lowering interventions, such as with chelators, are paralleled by improvement in health outcomes reportedly altered by lead. In one study, improvement in cognitive functions was related to decreases in blood lead but not to chelation treatment. In a multi-center study of 780 children, chelation therapy lowered blood lead by a mean of 4.5 µg/dL during the 6 months after initiation of treatment, but it did not improve scores on tests of cognition, behavior, or neuro-psychological function in children with PbB below 45 µg/dL. Re-analysis of these data showed that improvement in test scores was associated with greater falls in PbB only in the placebo group. A further evaluation of this cohort showed that chelation therapy lowered blood lead, but produced no benefits in

cognitive, behavioral, or neuromotor end points. The conclusion of this series of studies reached by the investigators was that chelation therapy is not indicated in children with moderate blood lead levels. Thus, it appears that lead abatement must remain the primary approach in the public health management of lead poisoning.

Cardiovascular/Renal Effects. Although lead has been shown to produce various cardiovascular and renal effects in animals, end points of greatest concern for humans at low exposures and low PbB are elevations in systemic blood pressure and decrements in glomerular filtration rate. These effects may be mechanistically related and, furthermore, can be confounders and covariables in epidemiological studies. Decrements in glomerular filtration rate may contribute to elevations in blood pressure, and elevated blood pressure may predispose people to glomerular disease.

Effects on Blood Pressure. Numerous covariables and confounders affect studies of associations between PbB and blood pressure, including, age, body mass, race, smoking, alcohol consumption, ongoing or family history of cardiovascular/renal disease, and various dietary factors. Varying approaches and breadth of inclusion of these may account for some of the disparity of results that have been reported. Measurement error may also be an important factor. Blood pressure estimates based on multiple measurements or, preferably, 24-hour ambulatory measurements, are more reproducible than single measurements. Few studies have employed such techniques and, when used, have not found significant associations between PbB and blood pressure.

An additional limitation of blood lead studies, in general, is that PbB may not provide the ideal biomarker for long-term exposure to target tissues that contribute a hypertensive effect of lead. Bone lead appears to be a better predictor of lead-induced elevations in blood pressure than PbB. In a recent prospective analysis of the Normative Aging Study, higher tibial lead levels, but not PbBs, were associated with higher systolic blood pressure and abnormalities in electrocardiographic conduction.

Chronic lead exposure increases blood pressure in rats through diverse mechanisms that include alterations in neurohumoral control of peripheral vascular resistance, heart rate, and cardiac output (see Section 3.4.2). Studies conducted in animal models provide strong evidence for the plausibility of lead elevating blood pressure in humans. Meta-analyses of the epidemiological findings have found a persistent trend in the data that supports a relatively weak, but significant association. Quantitatively, this association amounts to an increase in systolic blood pressure of approximately 1 mmHg with each doubling of PbB. The results of more recent epidemiology studies indicate that the lead contribution to

elevated blood pressure is more pronounced in middle age than at younger ages. A longitudinal study of males, mean age 67 years, found positive associations between systolic blood pressure and bone lead concentrations, and increased risk of hypertension in association with increased bone lead concentration. Based on this study, an increase in patella bone lead from the midpoint of the lowest quintile (12.0 μg/g) to the highest quintile (53.0 μg/g) was associated with a 1.71-fold increase in hypertension risk (rate-ratio, 95%; confidence interval [CI], 1.08–2.71). A case-control study of women, ages >55 years, found increased risk of hypertension in association with increased bone lead concentration. In this study, an increase in patella bone lead from 6 to 31 μg/g was associated with a 1.86-fold (odds ratio [OR], 95%; CI, 1.09–3.19) increase in risk of hypertension. A large-scale cross-sectional analysis of the NHANES III data on males and females, age 40–59 years, found increasing risk for hypertension in association with increasing PbB, with higher risks in postmenopausal women than in premenopausal women. Risks of diastolic hypertension for pre- and postmenopausal women, combined, who were in the highest blood lead quartile (mean, 6.4 μg/dL; range, 3.0–31.1) was predicted to be 3.4-fold higher (OR, 95%; CI, 1.3–8.7) than that of women in the lowest quartile (mean, 1 μg/dL; range, 0.5–1.6); corresponding risks for postmenopausal women were 8.1 times greater (OR, 95%; CI, 2.6–24.7) (highest vs. lowest quartile). Lead poisoning during childhood has also been associated with hypertension during adulthood in the absence of clinically significant renal disease and discernable elevations in PbB.

Effects in Renal Glomerular Filtration. Classic lead nephrotoxicity is characterized by proximal tubular nephropathy, glomerular sclerosis, and interstitial fibrosis and related functional deficits, including enzymuria, low- and high-molecular weight proteinuria, impaired transport of organic anions and glucose, and depressed glomerular filtration rate. In humans, the overall dose-effect pattern suggests an increasing severity of nephrotoxicity associated with increasing PbB, with effects on glomerular filtration evident at PbBs below 10 μg/dL, enzymuria and proteinuria becoming evident above 30 μg/dL, and severe deficits in function and pathological changes occurring in association with PbB exceeding 50 μg/dL. Thus, the renal effects of greatest concern, at low exposures (i.e., low PbB), are on glomerular filtration.

The results of epidemiological studies of general populations have shown a significant effect of age on the relationship between glomerular filtration rate (assessed from creatinine clearance of serum creatinine concentration) and PbB (see Section 3.2.2. Renal Effects). Furthermore, as noted previously, hypertension can be both a confounder in studies of associations between lead exposure and creatinine clearance as well as a covariable with lead exposure. When age and other covariables that might contribute to glomerular disease are factored into the dose-response analysis, decreased glomerular filtration rate has been consistently observed in populations that have average PbBs <20 μg/dL, with some

studies finding effects at PbBs <10 μg/dL (see Section 3.2.2, Table 3-4). Two studies provide evidence for an effect at lead concentrations below 10 μg/dL. A longitudinal study found a significant relationship between increasing serum creatinine concentration and increasing PbB below 10 μg/dL. A cross-sectional analysis of data from the NHANES III found increased risk of chronic renal disease (defined as severely depressed glomerular filtration rate) in association with PbB <6 μg/dL. The confounding and covariable effects of hypertension are also relevant to the interpretation of the regression coefficients reported in these studies. Given the evidence for an association between lead exposure and hypertension, and that decrements in glomerular filtration rate can be a contributor to hypertension, it is possible that the reported hypertension-adjusted regression coefficients may underestimate the actual slope of the PbB relationship with serum concentration of creatinine or creatinine clearance.

Hematological Effects. The adverse hematological effects of lead are mainly the result of its perturbation of the heme biosynthesis pathway. The activity of ALAD, an enzyme occurring early in the heme synthesis pathway, is negatively correlated with PbBs between 5 and 95 μg/dL. Although inhibition of ALAD occurs at very low exposure levels, there is some controversy as to the toxicological significance of a depression in ALAD activity in the absence of a detectable effect on hemoglobin levels. Nevertheless, because the impairment of heme synthesis has a far-ranging impact not limited to the hemopoietic system, there is concern that developing organisms might be particularly susceptible.

A potential consequence of the inhibition of heme synthesis is a decreased formation of mixed function oxidases in the liver resulting in impaired metabolism of endogenous compounds, as well as impaired detoxification of xenobiotics. Mitochondrial cytochrome oxidase is another heme-requiring protein that could be affected by heme synthesis inhibition. In addition, tryptophan pyrrolase, a hepatic heme-requiring enzyme system, is inhibited via the reduction in the free hepatic heme pool. This could ultimately lead to increased levels of the neurotransmitter serotonin in the brain and increased aberrant neurotransmission in serotonergic pathways. Inhibition of heme synthesis also results in increased levels of δ-aminolevulinic acid (ALA), which has a structure similar to that of the inhibitory neurotransmitter gamma-aminobutyric acid (GABA), and therefore, interferes with GABA neurotransmission. Finally, a prospective study of children with moderate PbB (25–40 μg/dL) and hemoglobin levels within normal limits found that serum erythropoietin (EPO) was positively associated with PbB at ages 4.5 and 6.5 years, but the magnitude of the association gradually declined from 4.5 to 12 years. EPO is a glycoprotein hormone produced in the kidney that regulates both steady-state and accelerated erythrocyte production. This suggested that in non-anemic children with moderate PbB, hyperproduction of EPO is necessary to maintain normal hemoglobin concentrations. The decline in slope with age suggested that

the compensatory mechanism gradually begins to fail due to direct lead-induced inhibition of EPO production or indirectly through toxic effects of lead on the kidney. Inhibition of EPO production may contribute to lead-induced anemia. Anemia occurs at PbBs of ≥20 µg/dL.

2.3 LEAD DOSE-RESPONSE RELATIONSHIPS

MRLs were not derived for lead because a clear threshold for some of the more sensitive effects in humans has not been identified. In addition, deriving an MRL would overlook the significant body of PbB literature. These data suggest that certain subtle neurobehavioral effects in children may occur at very low PbBs. In lieu of MRLs, ATSDR has developed a framework to guide decisions at lead sites. This approach utilizes site-specific exposure data to estimate internal doses as measured by PbBs (see Appendix D).

Epidemiological studies and clinical observations provide evidence for a progression of adverse health effects of lead in humans that occur in association with PbBs ranging from <10 to >60 µg/dL (Table 2-1). At the low end of the blood lead concentration range, adverse effects include delays and/or impaired development of the nervous system, delayed sexual maturation, neurobehavioral effects, increased blood pressure, depressed renal glomerular filtration rate, and inhibition of pathways in heme synthesis. Although fewer studies have examined associations between health outcomes and bone lead concentrations, recent studies provide evidence for adverse effects occurring in association with bone lead concentrations in excess of 10 µg/g (e.g., cardiovascular/renal, neurobehavioral effects).

The timing of exposure, in addition to the exposure intensity, appears to be an important variable in the exposure-response relationship for lead. Exposures that occur during pre- and postnatal development, which result in PbBs of 10 µg/dL or less, produce delays or impairments of neurological and sexual development. Cognitive deficits, hypertension, and depressed glomerular filtration rate have been observed in older adults (>60 years and/or post-menopause) in association with PbBs <10 µg/dL. This may reflect a higher vulnerability with age and/or the effects of cumulative life-time exposures that are less evident in younger populations that have lower time-integrated exposures.

The epidemiological literature provides a basis for associating specific biomarkers (e.g., PbB, bone lead concentration) with adverse health effects. Prediction of health outcomes that might result from any given environmental exposure requires an understanding of the relationships between environmental

Table 2-1. Blood and Bone Lead Concentrations Corresponding to Adverse Health Effects

Age	Effect	Blood lead[a] (µg/dL)	Bone lead[a] (µg/g)
Children	Depressed ALAD	<5	ND
Children	Neurodevelopmental effects	<10	ND
Children	Sexual maturation	<10	ND
Children	Depressed vitamin D	>15	ND
Children	Elevated EP	>15	ND
Children	Depressed NCV	>30	ND
Children	Depressed hemoglobin	>40	ND
Children	Colic	>60	ND
Adults (elderly)	Neurobehavioral effects	>4	>30
Adults	Depressed ALAD	<5	ND
Adults	Depressed GFR	<10	>10
Adults	Elevated blood pressure	<10	>10
Adults	Elevated EP (females)	>20	ND
Adults	Enzymuria/proteinuria	>30	ND
Adults	Peripheral neuropathy	>40	ND
Adults	Neurobehavioral effects	>40	ND
Adults	Altered thyroid hormone	>40	ND
Adults	Reduced fertility	>40	ND
Adults	Depressed hemoglobin	>50	ND

[a]Concentration range associated with effect.

EP = erythrocyte protoporphyrin; GFR = glomerular filtration rate; NCV = nerve conduction velocity; ND = no data

exposure (level, frequency, duration), human physiology and behaviors that result in intake of lead (e.g., ingestion of dust, drinking water, inhalation), and lead biokinetics. Models that predict PbBs corresponding to specific exposure scenarios have been used in this context for the purpose of assessing lead health risks. Two general approaches have been explored: (1) integrated exposure-biokinetics models that simulate lead exposure, intake, absorption, tissue distribution, and excretion of lead in humans; and (2) slope factor models that predict PbB based on an empirically-derived linear parameter relating exposure level, or rate of lead absorption, to PbB. Descriptions of exposure-biokinetics and slope factor models that have been used or have potential use in assessing exposure-effect relationships in human populations are described in Section 3.3.5 and in Appendix D.

Hazard Profile - Nickel

2. RELEVANCE TO PUBLIC HEALTH

2.1 BACKGROUND AND ENVIRONMENTAL EXPOSURES TO NICKEL IN THE UNITED STATES

Nickel is a very hard metal that occurs naturally in soils and volcanic dust. Nickel is used in combination with other metals to form alloys used for coins, jewelry, and stainless steel. Nickel compounds are used for electroplating, to color ceramics, and in battery production.

Nickel is released to the atmosphere by windblown dust, volcanoes, combustion of fuel oil, municipal incineration, and industries involved in nickel refining, steel production, and other nickel alloy production. The form of nickel emitted to the atmosphere is dependent upon the source. Complex nickel oxides, nickel sulfate, and metallic nickel are associated with combustion, incineration, and smelting and refining processes. Ambient air concentrations of nickel range between 7 and 12 ng/m^3, mainly in the form of aerosols and can be as high as 150 ng/m^3 near point sources. Based on 1996 air quality data, EPA has reported average U.S. ambient air levels of 2.2 ng/m^3. Ambient air levels of nickel are expected to be higher in urban air than in rural air. Concentrations of nickel in indoor air are generally 10 ng/m^3.

Background levels of nickel in soils vary widely depending on local geology and anthropogenic inputs, but concentrations typically range between 4 and 80 ppm. Some areas of the United States may contain natural levels as high as 5,000 ppm. Concentrations of nickel in household dust can be high and therefore pose an increased risk to young children who have greater contact with floors. Nickel concentrations in surface water and groundwater range between 3 and 10 µg/L. Nickel levels in drinking water in the United States generally range from 0.55 to 25 µg/L and average between 2 and 4.3 µg/L. Based on these average nickel concentrations and a reference water intake of 2 L/day, the estimated average intake of nickel from drinking water ranges from 4 to 8.6 µg/day. Elevated levels of nickel may exist as a result of the corrosion and leaching of nickel alloys used in valves and faucets. For the general population, the predominant route of exposure to nickel is through food intake. Nickel intake in the United States ranges between 69 and 162 µg/day for adults (>18 years of age). Based on these average water and food nickel levels, a daily dose of 0.001–0.0024 mg/kg/day can be estimated using a reference body weight of 70 kg. In children, mean daily nickel intakes of 9, 39, 82, and 99 µg/day have been determined for children aged 0–6 months, 7–12 months, 1–3 years, and 4–8 years, respectively. The mean daily dietary intakes of

nickel in children aged 9–18 years (128–137 µg/day in males and 101–109 µg/day for females) are similar to the mean intakes determined in adults (>18 years of age).

A 70 kg reference man contains 10 mg of nickel, giving an average body concentration of 0.1 ppm. Reference values for nickel in healthy adults is 0.2 µg/L in serum and 1–3 µg/L in urine. A National Health and Nutritional Examination Survey II of hair found mean nickel levels of 0.39 ppm, with 10% of the population having levels >1.50 ppm.

About 20–35% of the inhaled nickel that is retained in the lungs is absorbed into the blood. Absorption of nickel following oral exposure has been shown to vary (3–40%) depending on whether the nickel was in drinking water or food, with greater absorption occurring with drinking water. Fasting individuals have also been shown to absorb more nickel from the gastrointestinal tract. Most of the absorbed nickel is excreted in the urine, regardless of the route of exposure.

Nickel does not bioaccumulate to a great extent in animals. There is evidence of uptake and accumulation in certain plants.

Nickel is an essential trace element in animals, although the functional importance of nickel has not been clearly demonstrated. It is considered essential based on reports of nickel deficiency in several animal species (e.g., rats, chicks, cows, goats). Nickel deficiency is manifested primarily in the liver; effects include abnormal cellular morphology, oxidative metabolism, and increases and decreases in lipid levels. Decreases in growth and hemoglobin concentration and impaired glucose metabolism have also been observed. The essentiality of nickel in humans has not been established, and nickel dietary recommendations have not been established for humans.

2.2 SUMMARY OF HEALTH EFFECTS

The general population can be exposed to nickel via inhalation, oral, and dermal routes of exposure. Based on occupational exposure studies, reports of allergic contact dermatitis, and animal exposure studies, the primary targets of toxicity appear to be the respiratory tract following inhalation exposure, the immune system following inhalation, oral, or dermal exposure, and possibly the reproductive system and the developing organism following oral exposure.

2. RELEVANCE TO PUBLIC HEALTH

The most commonly reported adverse health effect associated with nickel exposure is contact dermatitis. Contact dermatitis is the result of an allergic reaction to nickel that has been reported in the general population and workers exposed via dermal contact with airborne nickel, liquid nickel solution, or prolonged contact with metal items such as jewelry and prosthetic devices that contain nickel. After an individual becomes sensitized to nickel, dermal contact with a small amount of nickel or oral exposure to fairly low doses of nickel can result in dermatitis. Approximately 10–20% of the general population is sensitized to nickel.

Adverse respiratory effects have been reported in humans and animals exposed to nickel compounds at concentrations much higher than typically found in the environment. The available data on noncancerous respiratory effects in humans are limited. In nickel workers, exposure to nickel did not result in increases in the risk of death from nonmalignant respiratory system disease. Studies examining potential nonlethal respiratory effects have not found consistent results. Animal data provide strong evidence that nickel is a respiratory toxicant; lung inflammation is the predominant effect. Evidence of lung inflammation has been observed following acute-, intermediate-, and chronic-duration exposure of rats to nickel sulfate, nickel subsulfide, or nickel oxide. Nickel sulfate was the most toxic of the three compounds and nickel oxide was the least toxic. For all three compounds, the threshold for lung effects decreased as the duration of exposure increased. Exposure to nickel sulfate or nickel subsulfide also produced damage to the nasal olfactory epithelium. Human and animal data provide strong evidence that inhalation exposure to some nickel compounds can induce lung cancer. As described in greater detail later in this section, carcinogenic responses have been observed following inhalation exposure to nickel subsulfide and nickel oxide; in the absence of exposure to other carcinogenic agents, nickel sulfate does not appear to be carcinogenic following inhalation exposure.

The potential for nickel compounds to induce reproductive effects has not been firmly established. Several animal studies have reported adverse effects in the male reproductive system following oral exposure to nickel sulfate, nickel chloride, or nickel nitrate. The observed effects included histological alterations in the epididymis and seminal vesicles, decreases in sperm concentration, motility, and abnormalities, and decreases in fertility following male exposure, but not female only exposure. However, the poor reporting of study results, particularly incidence data and statistical analysis, limits the interpretation of these studies. Additionally, other studies have not found histological alterations in the male reproductive system following long-term oral exposure or impaired fertility following oral exposure. A number of studies have reported decreases in survival of the offspring of animals exposed prior to mating and during the gestation and lactation periods. Interpretation of these data are complicated by

maternal toxicity, particularly decreases in body weight gain, which frequently occurred at the same dose levels.

The most consistently reported adverse effects resulting from exposure to nickel are contact dermatitis and respiratory effects, including cancer; a more detailed discussion of these effects follows. The reader is referred to Section 3.2, Discussion of Health Effects by Route of Exposure, for additional information on other health effects.

Contact Dermatits. Nickel sensitivity is a form of delayed hypersensitivity that is found in 10–20% of the general population. The prevalence of nickel sensitivity is higher among young women than any other segment of the population, which is probably the result of higher rates of ear and other types of body piercing rather than increased susceptibility to sensitization. There is some evidence of a genetic susceptibility factor that may predispose certain individuals to the development of nickel sensitivity. A significant increase in human leukocyte antigen (HLA)-DRw6 antigens were found among individuals with nickel contact dermatitis compared to individuals with no history of atopy or contact dermatitis. The relative risk of individuals with the HLA-DRw6 allele developing nickel sensitivity was estimated to be 3.3.

Nickel sensitization typically involves initial prolonged contact with nickel or exposure to a very large nickel dose. In the general population, the initial nickel contact often comes from body piercing with jewelry that releases large amount of nickel ions. The resulting dermatitis, which is an inflammatory reaction mediated by type IV hypersensitivity, typically occurs beneath the metal object. With repeated exposure, the area of sensitization can spread to other locations, particularly the hands. Shorter contact with nickel items, such as nickel-plated coins or door handles, does not result in nickel sensitization. After an individual becomes sensitized to nickel, much lower concentrations are needed to elicit a response. There is limited information on nickel levels resulting in sensitization. One study found that the sensitizing nickel level was 100–1,000 times higher than the level eliciting dermatitis in a previously sensitized individual. Among sensitized individuals, a direct relationship between nickel exposure level and severity of the dermatitis has been found. A weak reaction has been reported in individuals exposed to nickel alloys that release nickel ions at a rate of <0.5 $\mu g/cm^2$/week; a strong reaction was observed for nickel alloys that release >1 $\mu g/cm^2$/week. No reaction was seen in nickel-sensitized subjects undergoing patch testing with 0.01% nickel as nickel sulfate in petrolatum; however, exposure to 0.03% nickel resulted in dermatitis. Similarly, an oral challenge dose of 0.02 mg Ni/kg can induce dermatitis in a small percentage of nickel-sensitized individuals, whereas exposure to higher doses (0.06 mg Ni/kg) will often

result in dermatitis in most nickel-sensitized individuals. Exposure to these nickel concentrations will not result in dermatitis in nonsensitized individuals.

Respiratory Effects. Both noncancerous and cancerous respiratory effects have been observed in humans and animals exposed to airborne nickel compounds. Chronic bronchitis, emphysema, pulmonary fibrosis, and impaired lung function have been observed in nickel welders and foundry workers. These effects were not consistently seen across studies, and co-exposure to other toxic metals such as uranium, iron, lead, and chromium confounds the interpretation of the results. Studies examining the risk of death from nonmalignant respiratory disease among nickel workers have not found significant increases; however, many studies found that the number of observed deaths were significantly lower than expected, suggesting a healthy worker effect.

In animals, the predominant noncancerous effect is lung inflammation following exposure to nickel sulfate, nickel subsulfide, and nickel oxide. The toxicity of nickel in the respiratory tract appears to be related to the solubility of the individual nickel compounds, with soluble nickel sulfate being the most toxic and insoluble nickel oxide being the least toxic. The pulmonary toxicity appears to be related to exposure concentration rather than nickel lung burden. It has been postulated that the higher toxicity of soluble nickel is due to the higher concentrations of free nickel ions, which can diffuse across the cell membrane and interact with cytoplasmic proteins. In contrast, insoluble nickel compounds are phagocytized and a smaller amount of nickel ions interact with cytoplasmic proteins. Following an intermediate-duration exposure, the respective no-observed-adverse effect level (NOAEL) and lowest-observed-adverse effect level (LOAEL) values for lung inflammation were 0.06 and 0.11 mg Ni/m^3 for nickel sulfate, 0.11 and 0.22 mg Ni/m^3 for nickel subsulfide, and 2 and 3.9 mg Ni/m^3 for nickel oxide. At approximately 0.4 mg Ni/m^3 as nickel sulfate, nickel subsulfide, and nickel oxide, the lung burdens following a 13-week exposure were 6, 7, and 80 µg Ni/g lung, respectively. For all durations and nickel compounds tested, rats appear to be more sensitive to the lung effects than mice; significant increases in the incidence of lung inflammation were observed at lower concentrations in the rats than mice. However, mice were more susceptible to the lethal effects (presumably from impaired lung function) than rats. In addition to the pulmonary effects, atrophy of the nasal olfactory epithelium was observed in rats exposed to nickel sulfate or nickel subsulfide for acute, intermediate, and chronic durations; nasal effects were not observed following exposure to nickel oxide.

The carcinogenicity of nickel has been well documented in occupationally-exposed individuals. Significant increases in the risk of mortality from lung or nasal cancers were observed in several cohorts

of nickel refinery workers. Studies of workers in other nickel industries, including nickel mining and smelting, nickel alloy production, stainless steel production, or stainless steel welding, which typically involve exposure to lower concentrations of nickel, have not found significant increases in cancer risks. In most of the occupational exposure studies, the workers were exposed to several nickel species, thus making it difficult to compare carcinogenic potential across nickel species. An extensive re-evaluation of the studies published prior to 1990 found the strongest evidence of carcinogenicity for sulfidic nickel; exposure to high concentrations (>10 mg Ni/m^3) resulted in increased lung cancer risks. There is weaker evidence that high concentrations (>10 mg Ni/m^3) of oxidic nickel, particularly when there is co-exposure to soluble nickel, is also carcinogenic. Soluble nickel does not appear to be carcinogenic in the absence of exposure to other carcinogenic agents. There is no evidence that exposure to low levels of nickel is carcinogenic in humans. The conclusions drawn from the occupational exposure studies are supported by animal inhalation studies. Significant increases in the incidence of lung tumors were observed in rats chronically exposed to nickel subsulfide or nickel oxide. The carcinogenic response was stronger for nickel subsulfide compared to nickel oxide. In contrast, no increases in lung tumor incidences were observed in rats exposed to nickel sulfate; however, the highest concentration tested (0.11 mg Ni/m^3) was lower than the cancer effect levels for nickel subsulfide (0.73 mg Ni/m^3) or nickel oxide (1 mg Ni/m^3).

Although the evidence is sufficient to consider less-soluble nickel compounds as carcinogens following inhalation exposure, how environmental exposure to nickel affects cancer risk is not clear. Nickel levels in the environment are much lower than those that were associated with cancer in workers. In the environment, nickel is also more likely to be in the form of a mineral lattice rather than the more active nickel refinery dust that contains nickel subsulfide, the form of nickel most consistently associated with cancer. Although soluble nickel compounds may not be directly carcinogenic, as indicated by the negative results in the nickel sulfate bioassay, inhalation of nickel sulfate did result in an inflammatory response in the lungs of animals. Because sustained tissue damage can serve to promote carcinogenesis, epidemiology studies of humans who are exposed to many substances may not be able to distinguish between the carcinogenic activity of less-soluble nickel compounds and the promoting activity of toxic concentrations of soluble nickel compounds.

The Department of Health and Human Services has determined that metallic nickel may reasonably be anticipated to be a human carcinogen and nickel compounds are known to be human carcinogens. Similarly, IARC classified metallic nickel in group 2B (possibly carcinogenic to humans) and nickel compounds in group 1 (carcinogenic to humans). EPA has classified nickel refinery dust and nickel subsulfide in Group A (human carcinogen). Other nickel compounds have not been classified by the

EPA. Based on the occupational data, inhalation unit risk levels of $2.4x10^{-4}$ $(\mu g/m^3)^{-1}$ and $4.8x10^{-4}$ $(\mu g/m^3)^{-1}$ were derived by EPA for nickel refinery dust and nickel subsulfide, respectively.

2.3 MINIMAL RISK LEVELS

Estimates of exposure levels posing minimal risk to humans (MRLs) have been made for nickel. An MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. MRLs are derived when reliable and sufficient data exist to identify the target organ(s) of effect or the most sensitive health effect(s) for a specific duration within a given route of exposure. MRLs are based on noncancerous health effects only and do not consider carcinogenic effects. MRLs can be derived for acute, intermediate, and chronic duration exposures for inhalation and oral routes. Appropriate methodology does not exist to develop MRLs for dermal exposure.

Although methods have been established to derive these levels (Barnes and Dourson 1988; EPA 1990), uncertainties are associated with these techniques. Furthermore, ATSDR acknowledges additional uncertainties inherent in the application of the procedures to derive less than lifetime MRLs. As an example, acute inhalation MRLs may not be protective for health effects that are delayed in development or are acquired following repeated acute insults, such as hypersensitivity reactions, asthma, or chronic bronchitis. As these kinds of health effects data become available and methods to assess levels of significant human exposure improve, these MRLs may be revised.

Inhalation MRLs

The acute toxicity of nickel has been assessed in several animal studies involving exposure to nickel sulfate (Evans et al. 1995; NTP 1996c), nickel chloride (Adkins et al. 1979; Graham et al. 1978), nickel subsulfide (Benson et al. 1995b; NTP 1996b), and nickel oxide (NTP 1996a). The observed effects include inflammatory changes in the lungs (Benson et al. 1995a; NTP 1996a, 1996b, 1996c), atrophy of the nasal olfactory epithelium (Evans et al. 1995; NTP 1996b, 1996c), hyperplasia in the bronchial and mediastinal lymph nodes (NTP 1996b, 1996c), impaired immune function (Adkins et al. 1979; Graham et al. 1978), and decreases in body weight gain (NTP 1996b, 1996c), which are probably secondary to the lung damage. NOAEL values for respiratory tract effects were not established for nickel sulfate or nickel subsulfide. In studies by the National Toxicology Program (NTP 1996b, 1996c) (6 hours/day for 12 days in a 16-day period), chronic lung inflammation and atrophy of the nasal olfactory epithelium were

observed at the lowest tested nickel sulfate (0.7 mg Ni/m^3) and nickel subsulfide (0.44 mg Ni/m^3) concentrations. At 0.7 and 3.65 mg Ni/m^3 as nickel sulfate and nickel subsulfide, respectively, the inflammation was accompanied by labored breathing, suggestive of impaired lung function. Alveolitis was also observed in rats exposed to 0.22 mg Ni/m^3 as nickel subsulfide 6 hours/day for 7 days (Benson et al. 1995b). In mice, the LOAELs for chronic lung inflammation were 0.7 and 1.83 mg Ni/m^3 for nickel sulfate and nickel subsulfide, respectively. Nickel oxide was less toxic than the other two nickel compounds. The NOAEL and LOAEL values for acute lung inflammation were 3.9 and 7.9 mg Ni/m^3 in rats, respectively; in mice, the highest concentration tested (23.6 mg Ni/m^3) was a NOAEL for respiratory effects. Based on these data and data from longer-term studies (NTP 1996a, 1996b, 1996c), nickel sulfate appears to be the most toxic to the respiratory tract of the three nickel compounds tested by NTP. Although the acute-duration nickel subsulfide study used lower concentrations than the nickel sulfate study, there is some evidence to suggest that the nickel sulfate effects were more severe. At 0.7 mg Ni/m^3 as nickel sulfate, the chronic lung inflammation was given a severity score of 1.2–1.8 (minimal to mild) and was accompanied by labored breathing and a 28% decrease in body weight. The lung inflammation in rats exposed to 0.44 or 0.88 mg Ni/m^3 as nickel subsulfide was scored as minimal (1.0) and was not accompanied by altered respiration or body weight effects.

These acute-duration studies provide strong evidence that the respiratory tract is the most sensitive target following inhalation exposures. The three NTP (1996a, 1996b, 1996c) studies demonstrate that nickel sulfate is more toxic to the lungs than nickel subsulfide or nickel oxide. Because the lowest concentration tested in the nickel sulfate study (0.7 mg Ni/m^3) was a serious LOAEL for respiratory and body weight effects, this study cannot be used for MRL derivation. An immunotoxicity study by Graham et al. (1978) established a lower LOAEL (0.25 mg Ni/m^3) for a soluble nickel compound, nickel chloride; the NOAEL was 0.1 mg Ni/m^3. This study was not selected as the basis for MRL because the respiratory tract was not examined and it is not known if the NOAEL for immunotoxicity would also be a NOAEL for respiratory effects.

- An MRL of 0.0002 mg Ni/m^3 has been derived for intermediate-duration exposure to nickel.

The intermediate-duration toxicity of nickel has been assessed in several animal studies involving exposure to metallic nickel, nickel sulfate, nickel chloride, nickel subsulfide, and nickel oxide. The observed effects include inflammatory changes in the lungs (Benson et al. 1995b; Horie et al. 1985; NTP 1996a, 1996b, 1996c), alveolar macrophage hyperplasia (Benson et al. 1995b; Johansson and Camner 1986; NTP 1996a, 1996b, 1996c), atrophy of the nasal olfactory epithelium (NTP 1996b, 1996c),

hyperplasia in the bronchial and mediastinal lymph nodes (NTP 1996b, 1996c), impaired immune function (Adkins et al. 1979; Graham et al. 1978; Haley et al. 1990; Johansson et al. 1980, 1987, 1988a, 1989; Johansson and Camner 1986; Morimoto et al. 1995; Spiegelberg et al. 1984), decreases in body weight gain which are probably secondary to the lung damage (NTP 1996b, 1996c; Weischer et al. 1980), decreased sperm concentration (NTP 1996a), and developmental toxicity (Weischer et al. 1980).

As with the acute-duration studies, the most sensitive target of nickel toxicity is the lungs. Chronic lung inflammation was observed at the lowest-adverse-effect levels following 13-week (6 hours/day, 5 days/week) exposures to nickel sulfate, nickel subsulfide, or nickel oxide (NTP 1996a, 1996b, 1996c). Intermediate-duration studies clearly demonstrate that nickel sulfate is more toxic than nickel subsulfide and nickel oxide. In rats, the respective NOAEL and LOAEL values for chronic lung inflammation were 0.06 and 0.11 mg Ni/m^3 for nickel sulfate (NTP 1996c), 0.11 and 0.22 mg Ni/m^3 for nickel subsulfide (NTP 1996b), and 2.0 and 3.9 mg Ni/m^3 for nickel oxide (NTP 1996a). Atrophy of the nasal olfactory epithelium was observed at 0.22 and 0.44 mg Ni/m^3 as nickel sulfate (NTP 1996c) and nickel subsulfide (NTP 1996b), respectively. Similar effects were observed in mice. For nickel sulfate and nickel subsulfide, the LOAEL values for mice were higher than the LOAELs identified in rats; the LOAEL for chronic inflammation following exposure to nickel oxide was the same in rats and mice. The LOAEL values for immunotoxicity, reproductive toxicity, and developmental toxicity were higher than the LOAEL values for respiratory effects in rats exposed to nickel sulfate.

Derivation of an intermediate-duration MRL based on the NTP study of nickel sulfate (NTP 1996c) would be protective against the toxicity of other nickel compounds. In the nickel sulfate study, alveolar macrophage hyperplasia was observed in rats exposed at the two lowest concentrations (0.03 and 0.06 mg Ni/m^3). NTP noted that when lung effects only consisted of alveolar macrophage hyperplasia, there was only a slight increase in the number of alveolar macrophages and the differences between controls and nickel-exposed animals were subtle; the severity score for the alveolar macrophage hyperplasia was 1.0 (minimal). The minimal alveolar macrophage hyperplasia was not considered adverse because it is considered to be part of the normal physiologic response to inhaled particles and it is not believed to compromise the lung's ability to clear foreign matter. This is supported by the Benson et al. (1995a) study, which found no effect on the clearance of a nickel sulfate tracer in animals exposed to 0.03 or 0.11 mg Ni/m^3 as nickel sulfate for 6 months. Thus, the 0.06 mg Ni/m^3 concentration was identified as a NOAEL and adjusted for intermittent exposure ($NOAEL_{ADJ}$).

The intermediate-duration inhalation MRL of 0.0002 mg Ni/m^3 was derived by dividing the $NOAEL_{HEC}$ of 0.0052 mg Ni/m^3 by an uncertainty factor of 30 (3 for species to species extrapolation with dosimetric adjustments and 10 for human variability). The $NOAEL_{HEC}$ was calculated using the following equations:

$$NOAEL_{ADJ} = 0.06 \text{ mg Ni/m}^3 \times 6 \text{ hours}/24 \text{ hours} \times 5 \text{ days}/7 \text{ days} = 0.011 \text{ mg Ni/m}^3$$
$$NOAEL_{HEC} = NOAEL_{ADJ} \times RDDR = 0.011 \text{ mg Ni/m}^3 \times 0.474 = 0.0052 \text{ mg Ni/m}^3$$

The regional deposited dose ratio (RDDR) for the pulmonary region was used to extrapolate deposited doses in rats to deposited doses in humans. The RDDR was calculated using EPA software and the following parameters: particle size (mass median aerodynamic diameter, MMAD) of 2.11 µm with a geometric standard deviation (sigma g) of 2.7 (as reported in Table K1 of NTP 1996c); default human body weight (70 kg), minute volume (13 L), and pulmonary surface area (54 m^2); and default female F344 rat body weight (0.124 kg), minute volume (101.3 mL), and pulmonary surface area (0.34 m^2).

No intermediate-duration human inhalation exposure studies were identified; a number of chronic exposure studies have examined the potential of nickel and nickel compounds to induce respiratory effects in workers. Most of these studies are cohort mortality studies that did not find significant increases in the number of deaths from nonmalignant respiratory system disease (Arena et al. 1998; Cox et al. 1981; Cragle et al. 1984; Egedahl et al. 2001; Enterline and Marsh 1982; Redmond 1984; Roberts et al. 1989b; Shannon et al. 1984b, 1991). A few studies have examined workers for possible nonlethal respiratory effects. Two studies examined chest x-rays of workers: one found an increased risk of moderate pulmonary fibrosis (Berge and Skyberg 2003) and the other did not find any significant alterations (Muir et al. 1993). Although most of occupational exposure studies did not report exposure levels, workers were typically exposed to nickel levels that far exceed levels found in ambient air.

- An MRL of 9x10^{-5} mg Ni/m^3 has been derived for chronic-duration exposure to nickel.

One human study (Vyskocil et al. 1994a) and several animal studies (NTP 1996a, 1996b, 1996c; Ottolenghi et al. 1974; Takenaka et al. 1985; Tananka et al. 1988) assessed the noncarcinogenic toxicity of nickel sulfate, nickel chloride, nickel subsulfide, and nickel oxide. These studies found inflammatory changes in the lungs (NTP 1996a, 1996b, 1996c; Ottolenghi et al. 1974; Tanaka et al. 1988), atrophy of the nasal olfactory epithelium (NTP 1996b, 1996c), evidence of renal damage (Vyskocil et al. 1994a), adverse adrenal effects (NTP 1996a), decreased body weight gain, which was probably associated with

impaired lung function (NTP 1996b, 1996c; Takenaka et al. 1985), and damage to the bronchial lymph nodes (NTP 1996a, 1996b, 1996c).

As with the acute- and intermediate-duration exposures, chronic exposure to nickel sulfate, nickel subsulfide, or nickel oxide resulted in chronic active lung inflammation. A 2-year exposure (6 hours/day, 5 days/week) to nickel sulfate (NTP 1996c) resulted in chronic lung inflammation and bronchialization at 0.06 mg Ni/m^3 and atrophy of the olfactory epithelium at 0.11 mg Ni/m^3; no adverse respiratory effects were observed at 0.03 mg Ni/m^3. A similar exposure to nickel subsulfide (NTP 1996b) resulted in chronic inflammation, alveolar epithelium hyperplasia, fibrosis, and rapid and shallow breathing at 0.11 mg Ni/m^3, and atrophy of the nasal olfactory epithelium at 0.73 mg Ni/m^3. Chronic lung inflammation and alveolar epithelial hyperplasia were observed at the lowest nickel oxide concentration tested (0.5 mg Ni/m^3) (NTP 1996a). Similar effects were observed in mice exposed to nickel sulfate, nickel subsulfide, or nickel oxide for 2 years; however, the LOAEL values were higher than for rats. The NTP (1996c) study of nickel sulfate identified the lowest LOAEL for respiratory effects (0.06 mg Ni/m^3); the NOAEL of 0.03 mg Ni/m^3 associated with this LOAEL was used to derive a chronic-duration inhalation MRL for nickel.

The chronic-duration inhalation MRL of $9x10^{-5}$ mg Ni/m^3 was derived by dividing the $NOAEL_{HEC}$ of 0.0027 mg Ni/m^3 by an uncertainty factor of 30 (3 for species to species extrapolation with dosimetric adjustments and 10 for human variability). The $NOAEL_{HEC}$ was calculated using the following equations:

$$NOAEL_{ADJ} = 0.03 \text{ mg Ni/m}^3 \text{ x } 6 \text{ hours}/24 \text{ hours x } 5 \text{ days}/7 \text{ days} = 0.0054 \text{ mg Ni/m}^3$$
$$NOAEL_{HEC} = NOAEL_{ADJ} \text{ x RDDR} = 0.0054 \text{ mg Ni/m}^3 \text{ x } 0.506 = 0.0027 \text{ mg Ni/m}^3$$

The RDDR for the pulmonary region was used to extrapolate deposited doses in rats to deposited doses in humans. The following parameters were used to calculated the RDDR: mean particle size (MMAD) of 2.5 µm with a geometric standard deviation (sigma g) of 2.38 (as reported in Table K1 of NTP 1996c); default human body weight (70 kg), minute volume (13 L), and pulmonary surface area (54 m^2); and default female F344 rat body weight (0.229 kg), minute volume (167.3 mL), and pulmonary surface area (0.34 m^2).

As discussed for the intermediate-duration inhalation MRL, the potential of nickel to induce nonmalignant respiratory tract effects has been examined in a number of cohort mortality studies. In general, these studies did not find significant increases in the risk of dying from nonmalignant respiratory

system disease (Arena et al. 1998; Cox et al. 1981; Cragle et al. 1984; Egedahl et al. 2001; Enterline and Marsh 1982; Redmond 1984; Roberts et al. 1989b; Shannon et al. 1984b, 1991). Mixed results have been found in the few studies examining nonlethal respiratory tract effects. Two studies examined chest x-rays of nickel workers; one found an increased risk of moderate pulmonary fibrosis (Berge and Skyberg 2003) and the other did not find any significant alterations (Muir et al. 1993). Although most of occupational exposure studies did not report exposure levels, workers were typically exposed to nickel levels that far exceed levels found in ambient air.

Oral MRLs

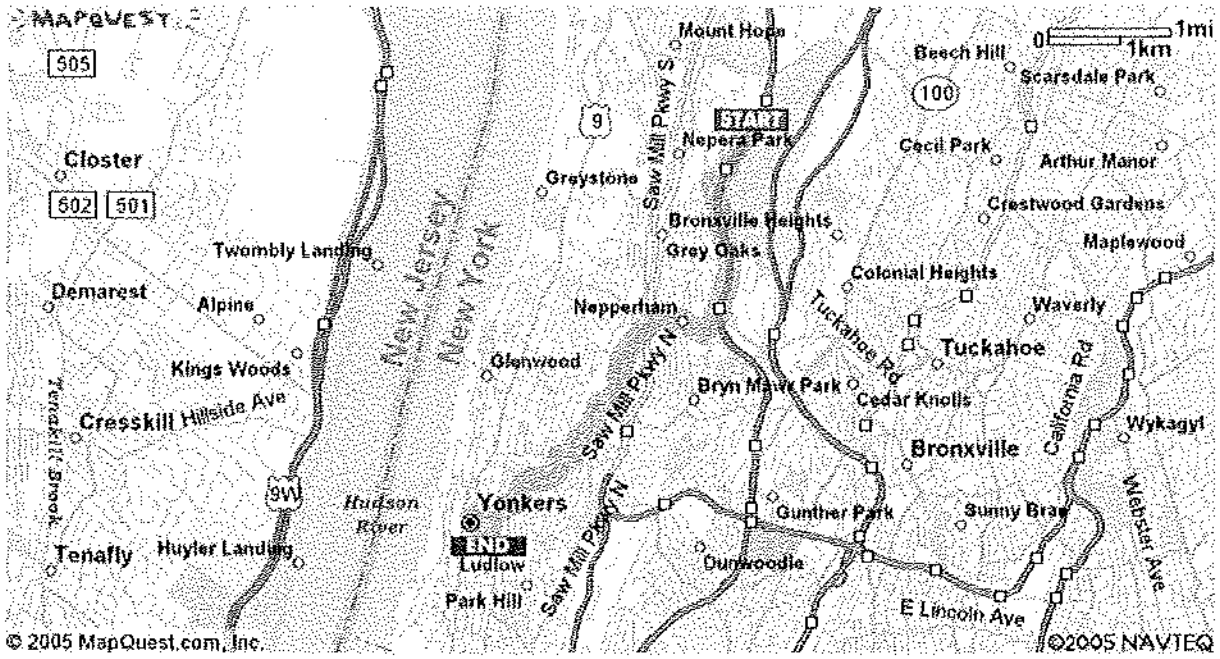
Information on the acute oral toxicity of nickel in humans comes from reports of accidental exposures and studies of nickel-sensitized individuals. Gastrointestinal upset (vomiting, cramps, diarrhea) and neurological symptoms (giddiness, headache, weariness) were observed in workers accidentally ingesting water containing approximately 7.1–35.7 mg Ni/kg as nickel sulfate and nickel chloride; boric acid was also present in the water (Sunderman et al. 1988). Allergic dermatitis was observed in previously nickel-sensitized individuals ingesting a single challenge dose of greater than 0.01 mg Ni/kg as nickel sulfate (Hindsén et al. 2001; Jensen et al. 2003; Menne and Maibach 1987). Reliable data on the acute oral toxicity of nickel in animals is limited to two studies that examined a limited number of end points. A reproductive toxicity study in mice found significant increases in sperm head abnormalities in mice exposed to a single gavage dose of 23 mg Ni/kg as nickel nitrate (Sobti and Gill 1989). No developmental effects were observed in the offspring of mice exposed via gavage to 90.6 mg Ni/kg/day as nickel chloride on gestational days 8–12 (Seidenberg et al. 1986). Intermediate-duration studies suggest that the developing organism may be a sensitive target of nickel toxicity; however, this end point has not been adequately examined following acute-duration exposure; thus, an acute-duration oral MRL for nickel has not been derived.

A number of animal studies have assessed the toxicity of nickel following intermediate-duration oral exposure. Significant decreases in body weight and organ weight (liver, kidney, pituitary) were consistently observed in rats exposed to 8.6 mg Ni/kg/day and higher as nickel chloride (American Biogenics Corporation 1988; RTI 1988a, 1988b), nickel acetate (Hanger 1973), or nickel sulfate (Dieter et al. 1988). Other systemic effects included kidney damage (minimal convoluted tubular damage) at 108 mg Ni/kg/day as nickel sulfate (Dieter et al. 1988) and adverse lung effects at 8.6 and 20 mg Ni/kg/day as nickel chloride (American Biogenic Corporation 1988; RTI 1988b). Inconsistent results have been reported for the reproductive toxicity of nickel. Decreased sperm motility and count and sperm

abnormalities were observed at 1.9 mg Ni/kg/day and higher as nickel sulfate (Pandey and Srivastava 2000; Pandey et al. 1999) and decreased fertility was observed in studies in which males and females were exposed to 3.6 mg Ni/kg/day as nickel chloride (Käkelä et al. 1999). However, impaired reproduction has not been observed in multigeneration studies of rats orally exposed to nickel sulfate or nickel chloride (RTI 1988a, 1988b; Springborn Laboratories 2000a). There is stronger evidence that prenatal exposure to nickel results in decreased survival, as measured by live litter size and neonatal mortality, in pups of rat dams exposed to nickel chloride in drinking water prior to mating and during gestation and lactation (Ambrose et al. 1976; Käkelä et al. 1999; RTI 1988a, 1988b; Smith et al. 1993; Springborn Laboratories 2000b). Interpretation and comparison of the studies is complicated by differences in study design and maternal toxicity, which often occurs at the same dose levels as the developmental effects. The available data are not sufficient to establish a threshold for developmental effects to nickel chloride in rats; the lowest LOAEL values identified in the studies range from 1.3 to 90 mg Ni/kg/day and the highest NOAEL values range from 2.2 to 45 mg Ni/kg/day. Because decreased pup survival is considered a serious LOAEL and a NOAEL for developmental effects has not been clearly identified, an intermediate-duration oral MRL was not derived for nickel.

Data on the chronic toxicity of ingested nickel are limited to one animal study that found significant decreases in body weight and liver weights in rats exposed to 75 mg Ni/kg/day as nickel sulfate in the diet and decreases in body weight, increases in liver weight, and adverse renal and lung effects in dogs 62.5 mg Ni/kg/day (Ambrose et al. 1976). The available chronic-duration database was considered inadequate for MRL derivation because intermediate-duration studies found significant decreases in survival of the offspring of rats exposed to ≥1.3 mg Ni/kg/day (Ambrose et al. 1976; Käkelä et al. 1999; RTI 1988a, 1988b; Smith et al. 1993; Springborn Laboratories 2000b).

Map to Hospital



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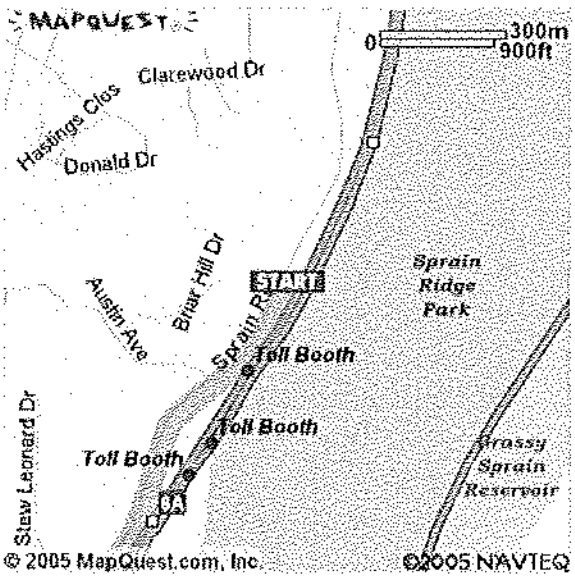
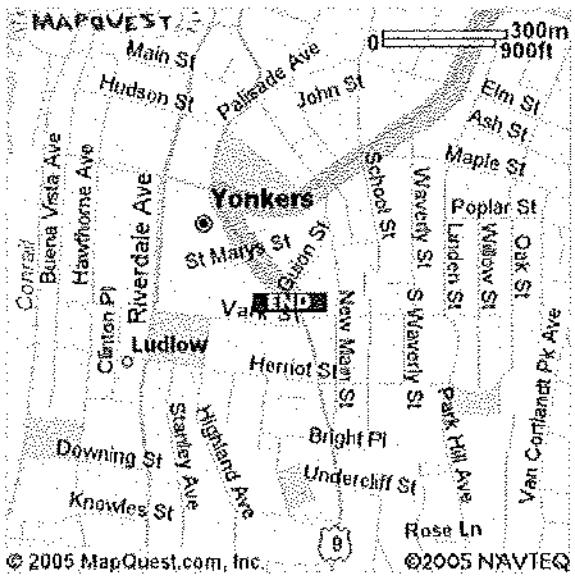
601 Sprain Rd
Yonkers, NY 10710-2211, US

End:
127 S Broadway
Yonkers, NY 10701-4006, US





MAPQUEST

Start: **601 Sprain Rd**
Yonkers, NY 10710-2211, US

End: **127 S Broadway**
Yonkers, NY 10701-4006, US

Notes:

Directions	Distance
Total Est. Time: 11 minutes **Total Est. Distance:** 4.99 miles	
1: Start out going SOUTHWEST on SPRAIN RD toward AUSTIN AVE.	0.5 miles
2: Turn LEFT onto STEW LEONARD DR.	<0.1 miles
3: Merge onto NEW YORK STATE TRWY S / I-87 S.	1.0 miles
4: Take the TUCKAHOE RD WEST exit- EXIT 6W- toward YONKERS.	0.2 miles
5: Turn SLIGHT RIGHT onto TUCKAHOE RD.	0.4 miles
6: TUCKAHOE RD becomes SAW MILL RIVER RD / NY-9A.	1.4 miles
7: Turn RIGHT onto ASHBURTON AVE / NY-9A.	0.1 miles
8: Turn LEFT onto NEPPERHAN AVE.	0.9 miles
9: Turn LEFT onto US-9 / S BROADWAY / NY-9A.	0.1 miles
10: End at **127 S Broadway** Yonkers, NY 10701-4006, US	
Total Est. Time: 11 minutes **Total Est. Distance:** 4.99 miles	

Appendix C
Community Air Monitoring Plan

COMMUNITY AIR MONITORING PLAN

1 - INTRODUCTION

The former Austin Avenue Landfill site has been accepted into the voluntary New York State Department of Environmental Conservation (NYSDEC) Brownfield Cleanup Program (BCP). Under the BCP, a Brownfield Site Investigation must be completed in accordance with NYSDEC's draft *Brownfield Cleanup Program Guidance* and *Technical Guidance for Site Investigation and Remediation* (DER-10), to provide a systematic assessment of environmental conditions on the property. Under the terms of the Brownfield Cleanup Agreement (BCA), the volunteer must define the nature and extent of site contamination in a manner that enables the selection of an appropriate remediation strategy to support the site's contemplated future use. S&W Redevelopment of North America, LLC (SWRNA) will complete the site investigation on behalf of the Yonkers Industrial Development Agency (YIDA). This Community Air Monitoring Plan (CAMP) describes the measures that will be undertaken during field work to monitor ambient air at the downwind site perimeter.

2 - OBJECTIVES

The objective of this CAMP is to provide a measure of protection for the downwind community from potential airborne contaminant releases that might arise as a result of the planned field work that penetrates the ground surface, which will include test pits and soil borings.

3 - METHODS

The CAMP will include monitoring for volatile organic compounds (VOCs) and particulate matter (e.g. airborne "dust"). Readings will be recorded and will be available for State (DEC and DOH) personnel to review, as requested.

A. VOC MONITORING

A MiniRAE photoionization detector (PID) will be used to measure VOCs in air. VOCs will be monitored at the downwind perimeter of the site, based on the prevailing wind direction as determined at the beginning of each workday. The site perimeter is defined as the existing property boundary.

Upwind concentrations of VOCs will be measured at the beginning of every workday to establish background conditions. VOC concentrations will be measured at the property boundary directly downwind of the work area. Downwind data will be checked as needed to provide a measure of assurance that contaminants are not being spread off site through the air.

- If the ambient air concentration for total organic vapors at the downwind property boundary exceeds 5 parts per million (ppm) above background for a 15-minute average, work activity will be halted and monitoring will continue until levels decline to below 5 ppm over background. At this point, work will resume and monitoring will continue.

- If total organic vapor levels at the downwind property boundary persist at levels above 5 ppm over background but less than 25 ppm, work activities will be halted, the source of the vapors will be identified, and corrective actions will be taken to abate emissions. Work will resume after organic vapor levels fall to below 5 ppm over background at the downwind property boundary.

- If organic vapor levels exceed 25 ppm at the downwind property boundary activities will be shut down. An appropriate course of action to abate emissions in order to resume work will be discussed with NYSDEC personnel.

B. PARTICULATE MONITORING

Particulate (e.g. "dust") emissions will be measured continuously at the upwind and downwind property boundaries. Real time monitoring equipment (e.g. MiniRAM or equivalent), with audible alarms and capable of measuring particulate matter less than 10 micrometers in size, will be used.

- If the downwind particulate level is 100 micrograms per cubic meter (ug/m^3) greater than background (upwind) for a 15-minute period, then dust suppression techniques will be employed. Work will continue with dust suppression provided that downwind particulate levels do not exceed 150 ug/m^3 above upwind levels and provided that no visible dust is migrating from the work area.

- If, after dust suppression techniques, downwind particulate levels are greater than 150 ug/m^3 above upwind levels, work will be stopped and a re-evalaution of activities will be initiated. Work will resume provided that dust suppression measures and other controls are successful in reducing downwind particulate concentrations to within 150 ug/m^3 of the upwind level and in preventing visible dust migration.

Appendix D
Fact Sheet

New York State Department of Environmental Conservation

FACT SHEET

Brownfield Cleanup Program

Former Austin Avenue Landfill **March 2006**
C360066
City of Yonkers, NY

Draft Remedial Investigation Work Plan Available for Public Comment

The New York State Department of Environmental Conservation (NYSDEC) requests public comments as it reviews a draft work plan to investigate the former Austin Avenue Landfill located on Austin Avenue in the City of Yonkers, New York. See map for the location of the site. The draft "Remedial Investigation Work Plan" was submitted by Austin Avenue Brownfield Redevelopment, LLC under New York's Brownfield Cleanup Program (BCP).

NYSDEC previously accepted an application submitted by Austin Avenue Brownfield Redevelopment, LLC to participate in the BCP. The application proposes that the site will be used for commercial/industrial purposes.

Public Comments About the Draft Remedial Investigation Work Plan
NYSDEC is accepting written public comments about the draft Remedial Investigation (RI) Work Plan for 30 days, from **March 16, 2006** through **April 14, 2006**. The draft RI Work Plan is available for public review at the document repositories identified in this fact sheet.

Written comments should be submitted to:
Michelle Tipple
New York State Department of Environmental Conservation
Region 3
Division of Environmental Remediation
21 South Putt Corners
New Paltz, New York 12561

Brownfield Cleanup Program: New York's Brownfield Cleanup Program (BCP) encourages the voluntary cleanup of contaminated properties known as "brownfields" so that they can be reused and redeveloped. These uses include recreation, housing and business.

A **brownfield** is any real property that is difficult to reuse or redevelop because of the presence or potential presence of contamination.

For more information about the BCP, visit:
www.dec.state.ny.us/website/der/bcp

Highlights of the Proposed Remedial Investigation
The remedial investigation has several goals:
1) define the nature and extent of contamination in soil, surface water, groundwater and any other impacted media;
2) identify the source(s) of the contamination;
3) assess the impact of the contamination on public health and/or the environment; and
4) provide information to support the development of a Remedial Work Plan to address the contamination.
The investigation will be performed by Yonkers Industrial Development Agency (YIDA) with oversight by NYSDEC and the New York State Department of Health (NYSDOH).

The findings of previous investigation indicate measurable, but subtle, groundwater contamination with respect to inorganic constituents, including iron, manganese, chloride and nitrate, and little or no evidence of methane gas. These findings are consistent with inorganic material typical of an ash landfill.

A preliminary review of the existing data also indicates that landfill impacts are isolated, since the various sampling locations at the landfill have distinct chemical "fingerprints".

The Remedial Investigation (RI) program will include the following main elements:

- Delineation/characterization of the solid waste mass
- groundwater investigation
- geotechnical borings
- explosive gas monitoring
- qualitative human health exposure assessment
- fish and wildlife resource evaluation

Approximately 15-20 test pits will be dug around the perimeter of the waste area. The objective will be to delineate the edge of the landfill waste by direct visual observation of the test pits. Additionally, up to five (5) samples will be collected from the test pits and analyzed for TCLP (toxicity characteristics leaching procedure), Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs) and target analyte list (TAL) metals.

Two (2) existing monitoring wells will be examined to determine their condition for use. These wells will be replaced if necessary and the replacement wells utilized during the groundwater sampling.

Three (3) additional monitoring wells will be installed and groundwater will be sampled and analyzed for VOCs, SVOCs and TAL metals.

Five (5) geotechnical borings will be drilled in site locations to be determined through discussions with Yonkers Industrial Development Agency (YIDA) based on the ultimate end use for the site.

Although previous methane sampling indicates very little methane is being produced by the former landfill, ten (10) methane samples will be collected (five each) along the site's northern and southern perimeters. Since gas monitoring wells are already present along the southern boundary, five (5) wells will be installed along the northern boundary.

Site data will be evaluated to determine whether human receptors, both on-site and off-site, are potentially exposed. Additionally, a Fish and Wildlife Resource Evaluation will be completed to provide and initial screening of potentially affected fish and wildlife resources in connection with the site.

Next Steps
NYSDEC will consider public comments when it completes its review, has any necessary revisions made, and approves the RI Work Plan. NYSDOH must concur in the approval of the RI Work Plan. The approved RI Work Plan will be placed in the document repository (see below). After the RI Work Plan is approved, YIDA may proceed with the remedial investigation of the site. It is estimated that the remedial investigation will take about {insert time frame}.

The applicant will develop a Remedial Investigation Report that summarizes the results of the remedial investigation.

NYSDEC will keep the public informed during the investigation and remediation of the former Austin Avenue Landfill Site.

Background
The former Austin Avenue Landfill site consists of approximately 20-acres located on the south side of Austin Avenue, just west of Sprain Brook Road and the New York State Thruway in Yonkers, New York. The former Austin Avenue landfill is situated on the site, and contains primarily incinerator ash as well as bulky waste, including trees, brush and building debris. The site is currently vacant, and since the landfill closed it has become covered by invasive vegetation, consisting of various species of grasses and shrubs. The natural topography of the site is steep, with a vertical drop of more than 100 feet from a ridge at the western site boundary to Sprain Brook, which is a distance of approximately 1,200 feet.

FOR MORE INFORMATION

Document Repositories
Document repositories have been established at the following locations to help the public to review important project documents. These documents include the draft RI Work Plan and the application to participate in the BCP accepted by NYSDEC:

Yonkers Public Library
Riverfront Branch
One Larkin Center
Yonkers, NY 10701
(914) 375-7940

NYSDEC
Region 3 Office
21 South Putt Corners Road
New Paltz, NY 12561
(845) 256-3000

Who to Contact
Comments and questions are always welcome and should be directed as follows:

Project Related Questions
Michelle Tipple
New York State Department of Environmental Conservation
Region 3
21 South Putt Corners
New Paltz, NY 12561
(845) 256-3153

Health Related Questions
Ian Ushe
New York State Department of Health
547 River Street
Troy, NY 12180
(800) 458-1158, ext. 27850

If you know someone who would like to be added to the project mailing list, have them contact the NYSDEC project manager above. We encourage you to share this fact sheet with neighbors and tenants, and/or post this fact sheet in a prominent area of your building for others to see.