REMEDIAL ACTION PLAN
FOR THE
LINDEN ROAD SITE
FLINT TOWNSHIP, MICHIGAN

Prepared for

GENERAL MOTORS CORPORATION
Environmental and Energy Staff
Remediation Group

Prepared by

ROY F. WESTON, INC.
Three Hawthorn Parkway
Vernon Hills, Illinois 60061

January 1996

Work Order No. 01138-079-001

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EXECUTIVE SUMMARY

This Remedial Action Plan (RAP) has been prepared on behalf of General Motors Corporation (GM) to address remedial actions at the Linden Road site, located in Flint Township, Michigan. The Linden Road site was a source of sand and gravel prior to 1931. It was subsequently used as an industrial landfill until 1969, where miscellaneous refuse, including construction debris, plastic, butting and grinding chips, and potentially other waste material were reportedly deposited.

A detailed site investigation and an interim remedial measures evaluation conducted in 1991 identified the environmental conditions of the site. Investigations included a geophysical survey, a soil gas survey, test pits, soil borings, monitoring well installations and groundwater sampling, and surface water sampling. The findings of this investigation were used to develop a site-specific public health evaluation and a remedial alternatives screening.

Based on the recommendations of the Interim Remedial Measures Evaluation and Site Investigation Report (WESTON, March 1992), an Interim Remedial Measures Removal Action was conducted at the site in December 1992. This removal action was conducted to minimize or prevent potential accidental exposure to surface waste material from specific areas of the site that may have posed a direct contact threat to human health and the environment.

In addition, as part of the interim remedial measures action, 18 observation wells at the site that were installed in 1979 and 1980 were decommissioned due to their limited utility.

The past investigations and data evaluations associated with the Linden Road site were based on the Michigan Environmental Response Act (MERA), 1982 PA 307, as amended.

The current RAP was prepared pursuant to Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451 and its administrative rules. The RAP provides detailed background information regarding the site, compares soil and groundwater data to

Michigan Department of Environmental Quality (MDEQ) generic cleanup criteria for various land use categories, and describes the proposed remedial action. The proposed remedial action is based on limited land/resource use and generic land use criteria consistent with Section 20120a(1)(f,g,h, and i) of Michigan Public Act 451.

An evaluation of the soil data compared to MDEQ generic cleanup criteria indicates that selected chemicals may pose potential direct contact for unrestricted potential future residential use of the site. A preliminary screening of potentially applicable remedial technologies for the site indicated that containment and institutional controls will eliminate any threat posed by direct contact by exposure, inhalation exposure, acute skin toxicity, or skin sensitization and terrestrial receptor exposure.

Past investigations indicated that the deep groundwater has not been impacted. While several VOCs in the shallow groundwater were detected at low levels, this shallow water-bearing zone is not a useable aquifer because of the low groundwater yield and the State of Michigan restrictions on installation of drinking water wells in the shallow groundwater. In addition, no known domestic wells are installed in the shallow water-bearing zone in the area surrounding the Linden Road site, and water supplies are readily available from the municipal distribution system. Therefore, any potential risk to future site users is considered to be nominal. Furthermore, the number of VOCs detected in the shallow groundwater, as well as their levels, has decreased over time, suggesting that groundwater quality at the site is improving through natural chemical and/or biological processes.

Independent of the end use chosen for the Linden Road site, the major activities of the remedial action will include site preparation and land clearing, site regrading, and placement of a soil cover system ranging in thickness from 6 inches to 4 feet. Site drainage and stormwater management will be designed based on the selected end use. Access control measures including maintenance of the security fence, and deed restrictions to limit subgrade excavations will also be implemented.

Specific end uses for the Linden Road site will be consistent with the allowed limited land/resource use designation. Any significant change in the final cover system to facilitate a specific land use will be reviewed and approved by MDEQ prior to implementation.

SECTION 1
INTRODUCTION

Roy F. Weston, Inc. (WESTON®), on behalf of General Motors Corporation (GM), has prepared this Remedial Action Plan (RAP) pursuant to Part 201 of Michigan Public Act 451 (Natural Resources and Environmental Protection Act) and its administrative rules to address the Linden Road Site in Flint Township, Michigan. This RAP has been prepared based on previous site investigations conducted by WESTON and others. WESTON conducted a Phase I Environmental Assessment of the site in February 1990 and an Interim Remedial Measures Evaluation (IRME) and Site Investigation (SI) between November 1990 and September 1991. The Phase I assessment included review of background information and results of past investigations, review of historical aerial photographs, performance of an aerial survey, preparation of a detailed topographic map, and a detailed site inspection. The findings of this assessment were documented in a report titled *Phase I Environmental Assessment of Linden Road Landfill, Flint Township, Michigan (WESTON, 1990).*

The IRME and SI included sampling and analysis of surface waste material, a geophysical survey, soil gas investigation, excavation and sampling of test pits, drilling of auger probes, soil borings, installation and sampling of shallow and deep monitoring wells, installation of piezometers, and sampling and analysis of surface waters.

Findings of the IRME and SI were documented in a report titled *Interim Remedial Measures Evaluation and Site Investigation Report, Linden Road Landfill Site, Flint Township, Michigan* (Volumes I and II)(WESTON, March 1992). The IRME and SI report was prepared prior to the implementation of amendments to Part 201 of PA 451. The findings were based on Type C cleanup criteria as described in PA 307. An evaluation of findings presented as Section 7 in the above-referenced report is included as Appendix A.

Within the IRME and SI Report, WESTON presented an assessment of the potential risks associated with impacted soils on site. This risk assessment entitled *Public Health Evaluation* is excerpted from Section 6 of the IRME and SI Report and included herein as

Appendix B. Based on this risk assessment, a remedial alternatives screening was conducted to determine the effectiveness and feasibility of implementing a wide range of potential remedial actions. This alternatives screening (also presented as part of the above-referenced IRME and SI Report) is included as Appendix C. This analysis determined that a soil cover system with limited regrading was an appropriate and effective remedial action for the specific conditions at the Linden Road site.

Based upon the findings and recommendations presented in the IRME and SI Report, a limited waste removal action was conducted at the site in November 1992. In addition, 17 observation wells constructed in 1980 were decommissioned. Reports documenting the waste removal action and the well decommissioning are presented as Appendix D and Appendix E, respectively.

In addition to the two rounds of groundwater sampling conducted during the site investigation documented in the IRME and SI Report (WESTON, March 1992), two additional rounds of groundwater sampling were performed. The most recent sampling was completed in March of 1995 and included three new monitoring wells that were installed along the western boundary of the site. The three new monitoring wells were installed in order to supplement existing groundwater data, as agreed to by GM and the Michigan Department of Environmental Quality (MDEQ). The results of the last two rounds of groundwater sampling, as well as water table contour maps generated from recent groundwater elevation data, are included in Appendix F.

Based on the investigations and the limited removal action conducted to date, as well as conferences conducted with the MDEQ, GM has determined that a remedial action based on limited land/resource use and generic land use cleanup criteria, consistent with Section 20120a.(1)(f to i) of Public Act 451. Reference to documentation supporting the proposed remedy is presented in Subsection 2.5 of this RAP.

This document is consistent with the requirements of Part 201 of PA 451, which outlines the informational requirements of a RAP. This RAP includes a site-specific evaluation of potential exposure risks based on various potential end uses for the site, and a description of the proposed remedial action (Section 4). GM proposes that a soil cover system meeting the performance objectives stated in PA 451, Part 201 applicable limited use categories is an appropriate and cost-effective remedial action alternative for the Linden Road site. An operation and maintenance (O&M) plan is provided in Section 5 to describe how the proposed action will maintain effectiveness of the remedial action over time. The remedial action implementation schedule is discussed in Section 6. The estimated costs to maintain the proposed remedial action and GM's financial assurance mechanism is provided in Section 7. Documentation and reporting, including post-remedial action documentation, are presented in Section 8. A list of references related to this RAP is presented in Section 9.

SECTION 2
BACKGROUND INFORMATION

This section presents background information for the Linden Road site (the Site) regarding location, surrounding land use, site history, previous investigations, geologic/hydrogeologic settings, findings of WESTON investigations, and details of limited remedial measures implemented. This section also presents the results of the public health evaluation conducted, a regulatory requirement analysis, and remedial alternatives screening.

2.1 SITE LOCATION AND SURROUNDING LAND USE

The Site is a 40-acre parcel in Flint Township, Genesee County, Michigan (Figure 2-1), and is located in Section 17 of Township 7 North and Range 6 East. The Site is approximately 1.5 miles west of the City of Flint. The Site is bounded by Linden Road on the east. The northern boundary of the Site is approximately ¼ mile south of Calkins Road, and the southern boundary is approximately ½ mile north of West Court Street. The west boundary of the Site is approximately ¼ mile east of Dye Road.

Land use of properties adjoining the Site includes agricultural, residential, and commercial uses. The land use is characteristic of a developing suburban community adjacent to a larger metropolitan area. According to the 1990 Census, the population of Genesee County is approximately 430,000, which is a four percent decrease from the 1980 Census figure of 450,000. Genesee County is the fourth most populous county in the State of Michigan. Single family residences are located south of the Site. The land east of the Site is presently being developed with office complexes. An office complex is located to the north. A privately owned property, currently referred to as the "Dye Road Dump," lies immediately to the west of the Site between the Site, the residences, and Dye Road. The Dye Road Dump site is currently included in the Michigan Act 307 Priority List.

Most of the area surrounding the Site has mixed zoning classifications including office complexes and R-1B, which is designated for single family dwellings. This zoning

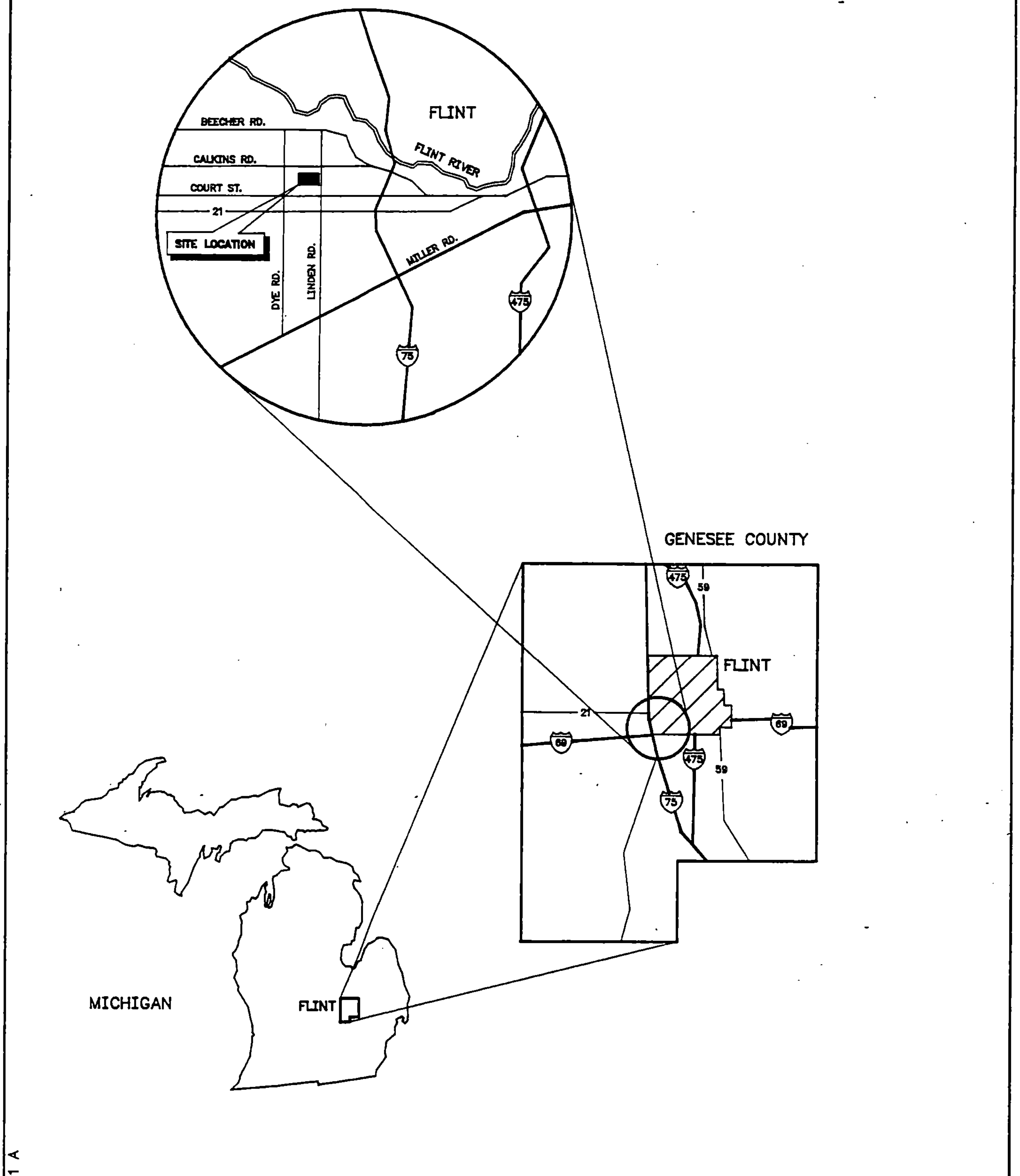

FIGURE 2-1

WESTON MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway
Vernon Hills, Illinois
60061

SITE LOCATION MAP

LINDEN ROAD LANDFILL SITE
Flint, Michigan

designation includes publicly-owned-and-operated parks, playfields, playgrounds, and other recreational facilities; public or parochial non-profit schools; and residences.

2.2 SITE HISTORY AND CURRENT SITE CONDITIONS

Based on current knowledge, the Site has had three periods of land use during this century: a source of mined gravel, a landfill, and an unused property. It was first used as a source of mined sand and gravel. The extent of the gravel excavation is uncertain. WESTON's review of an aerial photograph of the Site taken in 1941 did not indicate any evidence of large excavations or traces of a filled excavation. For an undetermined number of years preceding 1931, a rubbish incinerator reportedly occupied part of the Site. The Chevrolet Division of GM purchased the 40-acre property from several owners in 1931. GM used the Site as a general refuse landfill from 1931 until 1969. The refuse reportedly consisted of construction debris, plaster, buffing and grinding wheels, buffing and grinding refuse, metallic chips, and potentially other process wastes. Landfill operations ceased in 1969, and GM constructed a security fence around the Site in July 1980. Since landfill activities ceased in 1969, the Linden Road property has been enclosed by a fence and monitored but has not been used for any beneficial purpose. A more detailed account of the site history is presented in the *Phase I Environmental Assessment of Linden Road Landfill* (WESTON, 1990).

2.2.1 Investigations Prior to 1990

In 1969, the Genesee County Parks and Recreation Commission (GCPRC) prepared a preliminary study of the Site's suitability as a park site. Based upon the findings of this study, GCPRC recommended that the Linden Road site is a suitable site for a township or local park and should be acquired for this purpose. In 1979, Gould Engineering photographed and mapped the Site for The Nature Conservancy. Also in 1979, Keck Consulting Services, Inc., (Keck) performed a hydrogeologic investigation of the Site. WESTON identified a total of 18 observation wells presumably installed on site by Keck. In 1981, Gilbert/Commonwealth Associates completed a land reclamation study of the site, and in 1983 conducted a subsurface investigation by excavating 46 test pits. Data from the Keck and Gilbert/Commonwealth Associates studies are limited in scope, based on current standards for environmental investigations. A detailed summary of the results of previous site investigations is presented in the *Phase I Environmental Assessment of Linden Road Landfill, Flint Township, Michigan* (WESTON 1990).

2.2.2 Phase I Environmental Assessment

In February 1990, WESTON completed a Phase I Environmental Assessment of the Site for the AC Rochester Division of GM. This investigation consisted of a file review, a site inspection, a historical aerial photograph review, and an aerial survey. As part of the Phase I investigation, a detailed topographic map (1 inch = 50 feet) was prepared. The findings of this investigation are documented in the Phase I report titled *Environmental Assessment of Linden Road Landfill* (WESTON, 1990).

2.3 GEOLOGIC/HYDROGEOLOGIC SETTING

2.3.1 Regional Geology

Glacial till deposits in Genesee County are approximately 100 to 200 feet thick in the eastern section of the county and 50 to 100 feet in the western section. Well logs of the area around the Site indicate that the glacial drift ranges in thickness from 62 to 145 feet. The drift, according to the well logs, is predominantly clay/till with isolated lenses of sand and/or gravel. Some of the more extensive lenses provide limited water resources for domestic wells.

Stratigraphically, the area is part of the Michigan Basin, which is a relatively shallow, intracratonic structure that includes all of the Lower Peninsula, part of the Upper Peninsula, and parts of Wisconsin, Illinois, Indiana, Ohio, and Ontario. The topography of the bedrock surface in Genesee County ranges from 650 to 700 feet above mean sea level (MSL).

The predominant underlying bedrock in Genesee County is the Saginaw Formation. The Saginaw Formation is Lower Pennsylvanian in age and has a maximum thickness of 765 feet, as reported from well logs collected in the Michigan Basin (MDEQ, 1978). In Genesee County, the Saginaw Formation is thickest (100 to 200 feet) in the northwestern part of the county. The formation thins and finally pinches out in the east and southeastern parts of the county. The Saginaw Formation is generally composed of interbedded sandstones, shales, limestone, and coal. The sandstone beds vary considerably in thickness, and thin or pinch out within relatively short intervals. Studies of the Saginaw Formation have shown several cycles of deposition that indicate a previous, fluctuating marine environment with many changes in sea level.

Underlying the Saginaw Formation are the Michigan Formation of Upper Mississippian age and the Marshall Sandstone of Lower Mississippian age. The Michigan Formation is the underlying bedrock in eastern Genesee County in areas where the Saginaw Formation has thinned out. The Michigan Formation is composed of beds of anhydride and gypsum, gray to dark gray and greenish-gray shale, limestone, dolomite, and sandstone. A sand unit of the Michigan Formation, called the Michigan "Stray Sandstone" is reported to be a potential source for large quantities of natural gas. The Michigan Formation is approximately 50 to 200 feet thick in Genesee County. The Marshall Sandstone underlies the Michigan Formation and consists of sandstone and siltstone with some zones exhibiting red coloration. The Michigan Formation thins out south of Genesee County and is replaced by Marshall Sandstone as the uppermost bedrock formations underlying the glacial drift. The Marshall Sandstone is a major water-bearing unit (MDEQ, 1978).

2.3.2 <u>Site Geology</u>

Based upon the subsurface information gathered from soil borings, test pits, auger probes, monitoring wells, and limited data available from past investigations, a generalized site stratigraphy was formulated (Figure 2-2). The deepest boring was drilled to 48 feet below ground surface. In general, up to 2 feet of topsoil was encountered near the surface. Landfill waste material beneath the topsoil ranged in thicknesses from zero to approximately 15 feet. A water-bearing glacial sand and gravel unit ranging in thickness from 0 to 6 feet was observed below the landfilled material. This unit is underlain by a glacial till unit composed mainly of a homogeneous, silty, low permeability clay (K_h = 7.2 x 10^{-8} cm/sec) which is 8 to 13 feet thick. This unit is considered a "confining unit" based upon its stratigraphic position beneath the shallow water-bearing zone and its lateral continuity across the site. The glacial till unit is underlain by laminated glacial deposits. The glacial deposits were composed primarily of interlayered low-permeability silty clay and clayey silt and occasional thin (0.5 to 2.5 ft) layers of fine-grained sand. Borings and monitoring wells were not advanced through the glacial materials into the underlying bedrock. The deep wells were screened in the first water-bearing zone encountered beneath the confining unit. These water-bearing zones generally consist of thin isolated sand lenses. The Pennsylvanian Saginaw Formation is believed to be the underlying bedrock below the glacial materials at an estimated 55 to 140 feet from the surface. The Saginaw Formation is composed of interbedded sandstone, shale, limestone, and coal.

2.3.3 Regional Precipitation and Surface Water Drainage

Flint Township is in the temperate zone of the United States, and as such, experiences four seasons of weather. The central portion of the state, where Flint Township is located, receives approximately 35 inches of precipitation annually. The area has a precipitation surplus of approximately 5 inches, which will either infiltrate, be transported by the natural drainage system as surface water, or be absorbed and transpirated by vegetation.

The surface water in Genesee County drains to the Flint River as part of the Flint River Drainage Basin. This drainage basin encompasses most of Genesee and Lapeer counties and parts of Saginaw and Oakland counties. The Flint River flows to the northwest into the Saginaw River, which drains into Saginaw Bay of Lake Huron. The regional drainage from areas surrounding and including the Site flows eastward via a surface drain into Prince Creek, which discharges into the Flint River.

UNIT	APPROXIMATE THICKNESS, (ft)	GRAPHIC COLUMN	DESCRIPTION
TOP SOIL	0–2		DARK BROWN SOIL WITH LITTLE ORGANIC MATTER
LANDFILL WASTE	0–15		BLACK, FINE GRAINED METALLIC WASTE, MIXED WITH WOOD BLOCKS, GRINDING WHEELS, & MISC. METAL DEBRIS
GLACIAL SAND & GRAVEL DEPOSITS WITH CLAY	0–6		BROWN, MED. GRAINED SAND, TRACE TO LITTLE GRAVEL, WITH CLAY
GLACIAL TILL (CONFINING UNIT)	8–13		GRAY, SILTY CLAY, TRACE SAND & GRAVEL
GLACIAL TILL LACUSTRINE & MORAINAL DEPOSITS	55–140		GRAY, SILTY CLAY INTERLAYERED WITH CLAYEY SILT UNITS. OCCASIONAL UNITS OF FINE TO MEDIUM GRAINED SAND (UP TO 2.5' THICK)
SAGINAW FORMATION			INTERLAYERED SANDSTONES, SHALES & COALS.

FIGURE 2-2

WESTON MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway
Vernon Hills, Illinois
60061

GENERALIZED STRATIGRAPHIC COLUMN

LINDEN ROAD LANDFILL
Flint, Michigan

65391 B

2.3.4 Regional Hydrogeology

According to MDEQ records, there were a total of 13,187 water wells in Genesee County in 1980. Of these, 1,075 wells were in Flint Township. Some of the domestic wells were developed in more substantial discontinuous sand and gravel beds within the glacial drift. A larger portion of the wells was developed in bedrock formations, typically the Marshall Sandstone.

Genesee County is located on the border of usable groundwater from Mississippian formations (Marshall Sandstone) and the Pennsylvanian (Saginaw) formations. At the western edge of Genesee County, well sampling efforts have documented that the total dissolved solid (TDS) levels in these formations are as high as 100,000 mg/L. The glacial drift also has been shown to have elevated levels of TDS. The brine content of these formations diminishes to the east, away from the center of the Michigan Basin. The regional groundwater flow in the Saginaw Formation and Mississippian formations is to the northwest.

2.3.5 Site Hydrogeology

Investigations at the Site determined that a shallow water-bearing zone (water table) exists at a depth of 5 to 10 feet below the site surface. The shallow water-bearing zone, 0 to 6 feet in thickness, exists between fill and a gray silty clay, within sand and gravel deposits. Groundwater flow in the shallow water-bearing zone is to the east-northeast. Soil borings, auger probes, and test pits installed during the most recent SI indicated that the silty clay layer is continuous across the Site. Soil boring and monitoring well installation indicated that this clay layer is 8 to 13 feet thick. This silty clay confining unit is underlain by laminated glacial deposits composed of low-permeability silty clay, and thin (0.5 to 2.5 ft.), isolated lenses of saturated sand. The groundwater in these saturated zones is of limited quantity and does not appear to be usable as a resource. Groundwater flow in the uppermost water-bearing zone within the laminated glacial deposits is to the north-northeast towards the Flint River.

↑ If these are isolated water bearing zones, how was a gw flow direction calculated?

As mentioned previously, many wells in the surrounding area are developed in the bedrock aquifers underlying the glacial overburden at depths ranging from approximately 55 to 140 feet below the surface. According to the Flint Township Water and Sewer Department, Flint Township has 10,232 customers. Of those 10,232 customers, 562 are sewer customers only. These 562 households use other source of water. Flint Township does not keep records on the private residential wells. There may be other residences within Flint Township that utilize private wells and septic systems.

2.4 RECENT SITE INVESTIGATION AND EVALUATIONS

Following completion of the Phase I Environmental Assessment, GM conducted an IRME and SI to gather additional information regarding the geologic/hydrogeologic conditions of the site in order to determine the extent and nature of potential contamination, and to evaluate potential remedial alternatives for the site.

The objectives of the IRME and SI were to:

- Identify and characterize fill material and debris present at the surface of the Site and determine the potential for direct exposure and/or migration.
- Evaluate the nature and extent of potential contamination in subsurface materials, groundwater, and surface water.
- Evaluate human health risks associated with the Site.
- Screen potential alternatives for addressing any existing contamination at the Site.

2.4.1 Investigative Methods

The IRME field investigations involved the collection of 62 surface waste samples representative of the five surface waste categories at 35 locations within the Site. These samples were analyzed using the Toxicity Characteristic Leachate Procedure (TCLP) for organic and inorganic parameters, as well as for total PCB and pesticide compounds.

The SI activities included a geophysical survey, a soil gas survey, and subsurface investigations. Nineteen test pits were excavated and sampled at pre-selected locations based on the soil gas survey, historical aerial photographs review, and previous investigations. Auger probes were installed at 27 locations to visually characterize subsurface material. Three soil borings were also drilled to supplement subsurface stratigraphic information, as well as to collect samples for analysis. Test pit and soil boring samples were analyzed for total organic and inorganic compounds, pesticides, and PCBs. Four shallow and three deep groundwater wells were installed at the Site, and were sampled to determine the nature and extent of groundwater contamination, if any. In addition, the monitoring wells were used to obtain hydraulic data on the groundwater system to characterize potential contaminant transport mechanisms. Two piezometers were also installed at the Site to supplement water level data from monitoring wells. Water samples were also collected from the on-site ponds to determine the quality of surface water. As part of the SI, a total of 79 soil/waste, groundwater, and surface water samples were collected and analyzed for a series of organic and inorganic parameters.

2.4.2 Results of Investigations

The following sections provide a summary of the results of the IRME and SI. Detailed discussions of the investigations, results and conclusions drawn from the investigations can be found in the *Interim Remedial Measures Evaluation and Site Investigation Report*, (WESTON, 1992).

Interim Remedial Measures Evaluation Results

The analytical results of surface waste materials indicated the following:

- The concentrations of VOCs, semivolatiles, and metals in the TCLP extracts of all the red barren areas (RBA) soils were below their respective Resource Conservation and Recovery Act (RCRA) regulatory limits for classification as hazardous waste. Polychlorinated biphenyls (PCBs) were presented at levels significantly lower than the 50 mg/kg Toxic Substance Control Act (TSCA) limit for disposal of soils contaminated with PCBs. The RBAs are several distinct areas within the site whose primary characteristic in the presence of surface soils exhibiting a red/rusty color.

- All the wood block samples analyzed indicated that VOC, semivolatile, and metal concentrations in their respective TCLP extracts were below hazardous waste regulatory limits. PCB concentrations were well below the TSCA limit as for the RBAs.

- None of the samples from surface drums, except a single sample, contained material that exceeded the RCRA criteria for classification as hazardous waste. PCB concentrations higher than the TSCA limit of 50 mg/kg were detected in only two drum samples.

- None of the samples from the 13 Surface Sludge Areas sampled contained VOC or semivolatile contamination. Metal concentrations in the TCLP extract exceeded RCRA criteria at a single sample location. PCB levels higher than the TSCA limit were detected in only one sample.

- Samples collected from the Oil Disposal Area indicated levels of trichloroethene exceeding the RCRA regulatory limit for classification as hazardous waste. PCB levels were just above the TSCA limit of 50 mg/kg in one of the samples collected from this location.

Site Investigation

The field investigation determined the following:

- Landfilled material beneath the topsoil ranged in thickness from zero to 15 feet.

- The landfilled material is underlain by a thin (0 to 6 ft) water-bearing zone of glacial sand and gravel. This water-bearing zone is directly underlain by a 8- to 13-foot thick low-permeability silty clay continuous confining unit.

- The silty clay confining unit is underlain by laminated glacial deposits composed of low-permeability silty clay, and thin (0.5 to 2.5 ft) isolated lenses of saturated sand.

- The groundwater flow in the shallow water-bearing zone is to the east-northeast, and the flow in the deeper water-bearing zone is to the north-northeast.

- The groundwater flow rate in the shallow water-bearing zone is an estimated 27 ft/year.

Analytical results of samples collected during the SI indicated the following regarding the extent of subsurface contamination:

- Test pit waste samples analyses indicated the presence of widely ranging levels of organic and inorganic constituents in the landfill wastes. Elevated levels of chemical constituents are confined to limited quantities of waste occurring randomly within the fill.
- Natural soils beneath the waste material are not affected by the overlying wastes.
- Groundwater in the shallow water-bearing zone is not significantly impacted by waste material present on site.
- Elevated levels of trichloroethene detected in the upgradient shallow monitoring well are likely due to an off-site source(s).
- Groundwater in the deep water-bearing zone has not been impacted by the waste material present at the Site.
- Trace levels of organic and inorganic constituents were detected in the surface water samples.

Based upon the findings of the field investigations, an interim remedial measures removal action was performed and a public health evaluation reflecting site conditions was developed.

2.4.3 Interim Remedial Measures Removal Action

Based on the findings of the IRME, WESTON conducted an Interim Remedial Measures Removal Action at the Linden Road Landfill site in December 1992. This action was performed in accordance with the Work Plan titled *Work Plan for Interim Remedial Measures Removal Action, Linden Road Landfill Site, Flint Township, Michigan* (WESTON, August 1992). Approximately 60 cubic yards of waste material were removed from an oil disposal area, a specific surface waste area with elevated PCBs, and two areas with miscellaneous waste material associated with drums. This material was shipped off site for appropriate disposal. A detailed description of this removal action is documented in a letter report presented in Appendix D.

2.4.4 Public Health Evaluation

The public health evaluation was presented in the form of a baseline risk assessment that evaluated the potential threats to public health from the Site. Potential effects on the environment were also evaluated. The following sections present the results of the public health evaluation. The detailed evaluation of findings from the assessment and the complete risk assessment are provided in Appendix A and Appendix B, respectively.

This risk assessment excluded data of samples collected from material that was removed during the IRM. Furthermore, the risk assessment also assumed that no other remedial actions other than those described in Subsection 2.4.3 have occurred at the site.

Exposure scenarios were developed to describe potential human exposure under current site conditions and potential future site uses. Two exposure scenarios were selected for quantitative evaluation: current exposures were evaluated with a potential site trespasser scenario and future exposures were evaluated with a potential short-term worker exposure involving considerable contact with surface and subsurface materials. This future exposure scenario was selected to represent the type of activities that would precede development of the property.

The results of the risk assessment are summarized in Tables 6-20 and 6-21 included in Appendix B. The carcinogenic risk associated with the potential current site trespasser exposure ranged from 1.5×10^{-7} to 2.2×10^{-5}. The carcinogenic risk associated with the potential future site worker exposure ranged from 1.4×10^{-6} to 4.6×10^{-5}. The majority of the carcinogenic risk was contributed by benzo(a)pyrene, dibenzo(a,h)anthracene, and Aroclor-1254. The noncarcinogenic risks associated with potential current trespasser exposure to site contaminants were found to be insignificant. The noncarcinogenic risks associated with potential future site workers exposure were found to be insignificant for all pathways evaluated, with the exception of inhalation of airborne particulates. The vast majority of the non-cancer risk associated with this pathway is due to the inhalation of chromium.

Based on the qualitative analysis of ecological risk that was performed, the risks associated with exposure of aquatic receptors is expected to be acceptable. There is a potential for adverse effects to terrestrial species, particularly burrowing mammals with small home ranges that might spend a considerable amount of time on the Site.

Applicable remedial alternatives for the site were identified and screened based on the results of the investigations and the public health evaluation.

2.4.5 Additional Groundwater Investigations

In addition to the groundwater sampling performed at the site in June 1991 and September 1991 (WESTON, March 1992), a third round of groundwater sampling was conducted in December 1992 concurrent with the interim removal actions implemented at the site. Samples were collected from all the wells present at that time including four shallow and three deep monitoring wells and two piezometers. Results of this sampling were submitted to the MDEQ in a report dated 26 February 1993, a copy of which is included in Appendix F.

Pursuant to a meeting between the MDEQ and GM in January 1995, three additional shallow monitoring wells were installed at the Linden Road site to supplement existing information on groundwater quality, particularly along the western boundary of the site. In March 1995, groundwater samples were collected and analyzed from the three newly installed wells and from the four existing shallow wells. Results of this sampling effort were submitted to the MDEQ in a letter report dated 21 April 1995. A copy of this letter report is also included in Appendix F. The newly installed wells were surveyed in August 1995 and a water table contour map from all the wells on site was prepared and is included in Appendix F.

2.5 SUPPORTING DOCUMENTATION FOR PROPOSED REMEDIAL ACTION BASED ON MDEQ GENERIC CLEANUP CRITERIA

As indicated in Section 1, based on the findings of previous investigations and the removal action conducted at the site, a remedial action based on generic industrial/commercial and residential land use criteria is presented for this site. Required documentation supporting the remedial action for the Linden Road site is presented within this RAP, as well as associated investigation reports. Table 2-1 provides an outline of the site-specific information as required by *Environmental Response Division Operational Memorandum #14, Revision 2*, and references where information supporting the proposed remedial action can be found.

Table 2-1

Reference for Site-Specific Information
Linden Road Site
Remedial Action Plan
Flint Township, Michigan

Site-Specific Information	Applicable Citation	Location of Information
1. Physical Setting of the Site	(R299.5717(3)(c)(i to v)(q))	RAP Section 2
2. Background Media Quality at the Site	(R299.5717(3)(d))	IRME and SI Sections 4, 5.3
3. Climate	(R299.5717(3)(k))	RAP Section 2
4. Characteristics of Hazardous Substances Detected at the Site	(R299.5717(3)(g)(i to viii))	IRME and SI Sections 3, 5.2
5. Environmental Media Affected by Contamination	(R299.5717(3)(a)(b))	IRME and SI Section 4
6. Source Identification and Characterization	(R299.5717(3)(h))	IRME and SI Section 7
7. Potential Pathways and Impacts of Hazardous Substance Migration	(R299.5717(3)(f)(h)(i)(j))	IRME and SI Sections 6.2 and 8.2
8. Potential Exposure of Human and Natural Resource Targets	(R299.5717(3)(a))	IRME and SI Section 6.2
9. Current and Reasonably Foreseeable Natural Resource Use	(R299.5717(2)(b) and (3)(e))	RAP Section 3.5
10. Uncertainties in the Evaluation of Human Health Risks	(R299.5717(3)(n))	IRME and SI Section 6.4.3
11. Ability to Monitor Remedial Performance	(R299.5717(3)(o))	RAP Section 5
12. Consistency with Great Lakes Water Quality Agreement of 1978	(R299.5717(3)(p))	N/A
13. Evaluation of Remedial Action Alternatives	(R299.5717(3)(l)(m))	IRME and SI Section 8

Notes:

RAP - Remedial Action Plan.
IRME and SI - Interim Remedial Measures Evaluation and Site Investigation Report (WESTON, March 1992).

SECTION 3

COMPARISON OF SITE DATA TO GENERIC SOIL CLEANUP CRITERIA

Generic soil cleanup criteria have been developed by MDEQ for residential, industrial, and commercial land uses. These values are contained in the 1995 amendments to Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451, and have been distributed in two MDEQ operational memoranda [*Interim Environmental Response Division Operational Memorandum #8, Revision 4: Generic Residential Cleanup Criteria (5 June 1995)*, and *Environmental Response Division Operational Memorandum #14, Revision 2: Remedial Action Plans Using Generic Industrial or Generic Commercial Cleanup Criteria and Other Requirements (6 June 1995)*]. On-site soil data are compared to these various soil cleanup criteria in this section.

Generic groundwater criteria have also been developed by MDEQ and presented in the above-referenced operational memoranda. On-site groundwater data are also compared to residential and industrial/commercial groundwater cleanup criteria in this section.

The potential exposure pathways pertinent to the Linden Road site include direct contact with soils and ingestion of groundwater. However, the shallow water-bearing zone is not a usable aquifer as defined by Part 201 of PA 451, and groundwater in the deeper water-bearing zone has not been inspected as evidenced from past investigations.

3.1 <u>SOILS</u>

3.1.1 <u>Average On-Site Soil Concentrations</u>

On-site soil concentrations previously reported in the *Interim Remedial Measures Evaluation and Site Investigation Report* (WESTON, 1992) were used in this evaluation. Data from the near-surface soils (0 to 10 feet) were used since potential future residential, industrial, or commercial land use at the site requires site development activities that are expected to include soil excavation. These data are the best representation of soils that might reasonably be expected to be brought to the surface during such site development. This analysis also assumes no remedial actions or exposure controls would be implemented at the site during or after its development.

All data used in this evaluation were included based on guidance presented in *Risk Assessment Guidance for Superfund* (U.S. EPA, 1989). The following guidelines were followed:

- Contract Laboratory Program (CLP) laboratory data qualifiers were provided by the laboratory with the raw data and also by WESTON's Sample Management Coordinator after data validation. The qualified data were used based on established criteria (U.S. EPA, 1989). All data values qualified as "J" (estimated) or "D" (diluted) were used as presented.

- If a sample was duplicated (i.e., in the field), the data from the two duplicates were averaged if both duplicates had positive detections. If only one duplicate had a positive detection, that value was used in the data set and the nondetect was ignored. If both duplicates were nondetect, the lower sample quantitation limit was used in the data set.

- If a substance was not found in any sample in a medium at a detectable concentration, that substance was eliminated from further quantitative consideration for the medium.

- If a substance was not detected in a particular sample, then one-half of the sample quantitation limit (SQL) was used as a proxy concentration in subsequent calculations where applicable.

- Acetone, 2-butanone (methyl ethyl ketone), methylene chloride, toluene, and the phthalate esters are considered by U.S. EPA to be common laboratory contaminants. If a trip, field, or laboratory blank sample contained a detectable level of a common laboratory contaminant, then detections of that contaminant in corresponding site samples were considered positive only if they exceeded 10 times the maximum amount detected in the blank.

Both an average soil concentration and 95th percent upper confidence limit on the arithmetic mean (95% UCL) concentration were calculated for site soil. In developing these concentrations, the data were log-transformed since in most cases soil data are log-normally distributed. The lower of either the log-transformed arithmetic mean or the maximum detected concentration was used to represent the average; the lower of either the maximum detected concentration or the 95% UCL of the log-transformed arithmetic mean concentration was used to represent the 95% UCL. The on-site soil concentrations used in this document differ slightly from the concentrations presented in the risk assessment (WESTON, 1992), but follow MDEQ's current protocol (i.e., to assume by default a log-normal distribution of environmental data unless statistical evidence for another type of distribution is presented). The 95% UCL was calculated according to the following standard equation (U.S. EPA, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, OSWER Publication No. 9285.7-018, May, 1992):

$$95\%\,UCL = \exp\left[\bar{Y} + 0.5s_y^2 + \frac{s_y H_{0.95}}{\sqrt{n-1}}\right]$$

where:

95% UCL	= Upper confidence limit.
exp(x)	= Inverse of the natural logarithm (base = e = 2.718) of x.
Y	= Mean of log-transformed data.
$H_{0.95}$	= H-statistic (e.g., from table published in Gilbert, 1987).
s_y	= Standard deviation of the transformed data.
n	= Number of samples.

3.1.2 Comparison to Generic MDEQ Cleanup Criteria

The MDEQ soil cleanup criteria are based on direct human contact with the soils, and on the potential for chemicals in soil to leach to groundwater. This evaluation addresses only soil cleanup criteria based upon direct contact. Groundwater impacts are being directly monitored at the site and are discussed in Subsection 3.2. In addition, it is contemplated that any remedy will include groundwater use restrictions for the shallow groundwater zone.

The following subsections discuss the on-site soil concentrations versus generic soil cleanup criteria based upon direct contact for the following land uses: residential, industrial, and commercial (subcategories I, II, III, and IV).

3.1.2.1 Residential Land Use

MDEQ's generic cleanup criteria for residential land use are designed to protect residents, including both adults and children, at their homes. A comparison of MDEQ's generic cleanup criteria for residential land use to average and 95% UCL concentrations is presented in Table 3-1. The frequency of detection (i.e., the ratio of the number of samples in which the substance was positively detected to the number of samples available) is also presented in this table. Exceedences are observed for the following substances:

- Arsenic (95% UCL; average)
- Chromium (95% UCL)
- Lead (95% UCL; average)
- Manganese (95% UCL)
- Benz(a)anthracene (95% UCL)
- Benzo(b)fluoranthene (95% UCL)
- Benzo(a)pyrene (95% UCL; average)
- Indeno(1,2,3-cd)pyrene (95% UCL)
- Dibenz(a,h)anthracene (95% UCL; average)
- Methylene chloride (95% UCL)
- PCBs - Aroclors 1248, 1254, and 1260 (95% UCL; average)

The exceedences for chromium, manganese, and methylene chloride are relatively minor (less than two times its respective direct contact criterion) and likely to represent minimal potential risks. Levels of lead, various carcinogenic PAHs, and PCBs are somewhat higher relative to the direct contact with generic residential cleanup criteria.

The generic residential soil cleanup criteria for lead is 400 mg/kg. This value was determined by MDEQ using U.S. EPA's Integrated Exposure Uptake Biokinetic Model (IEUBK) for lead, which is designed to quantitatively estimate risks to children exposed to lead in a residential setting. Children are considered the most sensitive subgroup with respect to exposure to lead; therefore, soil values protective for children will also be protective for older individuals.

The IEUBK model estimates blood lead levels in children exposed to lead in air, water, soil, dust, and food. U.S. EPA guidance indicates that the best single-number prediction of blood lead levels resulting from soil exposure is the geometric mean soil lead concentration. The average concentration for lead listed in Table 3-1 (420 mg/kg) is equivalent to the geometric mean since it is the arithmetic mean of log-transformed data. Thus, there is only a very modest exceedence (420 mg/kg versus 400 mg/kg) of the site-wide soil lead level that is considered to be of concern to pre-school age children in a residential setting.

Moreover, the soil lead cleanup criterion of 400 mg/kg has some uncertainty or flexibility associated with it. The IEUBK model makes default assumptions regarding lead intake from various sources such as water and food. Since the IEUBK model sums lead intake from these sources, adjustments of the various non-soil intakes would result in adjustments to the acceptable soil lead level from 400 mg/kg. This is consistent with the approach approved by MDEQ in Memo #8.

Commercial land use subcategory I identifies facilities intended to house, educate, or provide care for sensitive subpopulations such as children, the infirm, or the elderly (e.g., day care centers, elder care facilities). MDEQ has stated that generic residential cleanup criteria are applicable to this commercial subcategory. Therefore, the exceedences listed above are also applicable to commercial subcategory I.

3.1.2.2 Industrial Land Use

MDEQ's generic cleanup criteria for industrial land use are designed to protect workers at a facility where public access is restricted and the primary activity at the site is industrial in nature. A comparison of MDEQ's generic cleanup criteria for industrial land use to average and 95% UCL concentrations is presented in Table 3-1. Exceedences are observed for the following substances:

- Lead (95% UCL; average)
- Benzo(a)pyrene (95% UCL)
- Dibenz(a,h)anthracene (95% UCL)
- PCBs - only Aroclor 1254 (95% UCL)

Lead is the only constituent where the average concentration exceeds the generic direct contact criterion for industrial land use. It is noted that the generic industrial soil cleanup criterion for lead (400 mg/kg) is based upon the protection of small children in a residential setting. Therefore, while the 400 mg/kg soil lead criterion may not be directly applicable to industrial exposures, potential risks could be managed through exposure controls.

Commercial land use subcategory II identifies facilities where public access is restricted and the primary duties of its workers are performed outdoors (e.g., wholesale lumber yard, commercial warehouse). MDEQ has stated that generic industrial cleanup criteria are applicable to this commercial subcategory. Therefore, the exceedences listed above are also applicable to commercial subcategory II.

3.1.2.3 Commercial Land Use - Subcategory III

MDEQ's generic cleanup criteria for subcategory III commercial land use are designed to protect workers at a facility where public access is unrestricted and a significant portion of business activities are conducted outdoors (e.g., retail gas station, retail warehouse). A comparison of MDEQ's generic cleanup criteria for commercial subcategory III to average and 95% UCL concentrations is presented in Table 3-1. Exceedences are observed for the following substances:

- Lead (95% UCL; average)
- Benzo(a)pyrene (95% UCL)
- Dibenz(a,h)anthracene (95% UCL)
- PCBs - only Aroclor 1254 (95% UCL)

Lead is the only constituent where the average concentration exceeds the generic direct contact criterion for commercial land use (subcategory III). It is noted that the generic commercial (subcategory III) soil cleanup level for lead (400 mg/kg) is based upon the protection of small children in a residential setting. Therefore, while the 400 mg/kg soil lead criterion may not be directly applicable to commercial exposures, potential risks could be managed through exposure controls.

3.1.2.4 Commercial Land Use - Subcategory IV

MDEQ's generic cleanup criteria for subcategory IV commercial land use are designed to protect workers at a facility where public access is unrestricted and the majority of business transactions are conducted indoors (e.g., professional office, indoor restaurant, health club). A comparison of MDEQ's generic cleanup criteria for commercial subcategory IV to average and 95% UCL concentrations is presented in Table 3-1. Exceedences are observed for the following substances:

- Lead (95% UCL; average)
- Benzo(a)pyrene (95% UCL)
- PCBs - only Aroclor 1254 (95% UCL)

The exceedences for benzo(a)pyrene and PCBs are relatively minor (less than two times its respective direct contact criterion) and likely to represent minimal potential risks. It is noted that the generic commercial (subcategory IV) soil cleanup level for lead (400 mg/kg) is based upon the protection of small children in a residential setting. Any potential risks could be managed through exposure controls or remedial action.

3.1.2.5 Recreational Use

No generic direct contact criteria have been established by MDEQ specifically for this land use category. Given the range of possible exposures in a recreational setting, it is probable that the generic recreational cleanup criteria would range from residential standards to standards that are less stringent. Any proposed recreational land use at the site will include a review of appropriate cleanup standards.

3.1.3 Issues Not Addressed by Direct Contact Criteria

3.1.3.1 Inhalation

The MDEQ generic direct contact criteria do not address the potential for inhalation effects. The site, in its current condition, does not represent any significant risks via the inhalation pathway. The site is largely covered by vegetation in areas where VOCs were detected. In addition, VOCs were not detected at or near the saturation level. Air monitoring of organic vapors using a PID was conducted by WESTON during its investigations and no measurements above background in the breathing zone were detected unless soil boring or excavation was occurring. These physical characteristics indicate that criteria developed for direct contact exposure will be protective for the inhalation pathway.

3.1.3.2 Dermal Toxicity

The direct contact criteria do not address acute skin toxicity or skin sensitization. Of the substances found in on-site soil, PCBs, PAHs, arsenic, and solvents are dermally active compounds that have the potential for acute direct point of contact (skin) effects. Most dermally-active substances found at the site were measured at concentrations well below soil saturation concentrations, and therefore are entirely bound to soil particles in pore spaces. In this condition, they do not represent an acute skin toxicity concern.

3.1.3.3 Ecological Concerns

Ecological concerns were addressed in Subsection 6.5 of the *Interim Remedial Measures Evaluation and Site Investigation Report* (WESTON, 1992) and are summarized herein. The 40-acre site has been extensively disturbed by man. The site is a former sand and gravel source that was later converted into a landfill. Landfill activities ceased in 1969, and the property has been fenced and monitored but not used for any purpose since this time. Presently, the site is heavily vegetated, with mixed open field, scrub-shrub, and wooded habitats. There are several areas of surficial metal grinds which do not support vegetation and are characterized by a red color (i.e., Red Barren Areas). Within the landfill boundaries the topography is varied, with hillocks, depressions, and seasonally wet and ponded areas.

An evaluation of available surface water and groundwater (should groundwater discharge to surface water) data in comparison to water quality standards suggests that there is little to no potential impacts on aquatic life. The on-site surface water features are man-made and are not connected to any off-site surface water features. Elevated concentrations of substances in surface soil that have the potential to bioaccumulate, especially heavy metals, pesticides, and PCBs, may pose a threat to small mammals that inhabit the site. Larger, more mobile mammals, whose home range is larger and whose access to the site may be restricted by the fence, may only be exposed infrequently to site-related substances. Elevated concentrations of soil constituents may also produce phytotoxic effects, as evidenced in the red barren areas.

3.2 GROUNDWATER

Groundwater analytical data was compared to MDEQ's generic health-based and aesthetic drinking water values for residential and industrial/commercial exposure as contained in the 1995 amendments to Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451. Analytical data from sampling rounds 1, 2, 3, and 4 were included in this evaluation. Analytical data from the two upper-most water-bearing zones were examined separately [as identified by the monitoring well designations S (shallow) and D (deep)].

3.2.1 Shallow Water-Bearing Zone

Seven shallow monitoring wells and three piezometers were installed to monitor the thin shallow water-bearing zone which is unconfined and 0 to 6 feet in thickness. This shallow water-bearing zone of glacial sand and gravel located beneath the landfill waste material is directly underlain by a 8- to 13-foot-thick low permeability silty clay confining unit. The groundwater in this zone is of low yield and is of insufficient quantity for use as a resource. Furthermore, Michigan Act 368 (Public health Code Groundwater Quality Control, Part 127, Rule 131 and 133) restricts the installation of drinking water wells at depths of less than 25 feet below ground surface, which encompasses the depth range of the shallow water-bearing zone. Therefore, groundwater in the shallow zone would be classified as groundwater not in an aquifer pursuant to Part 201.

3.2.1.1 Generic Residential Criteria

The frequency of detection and the average and upper 95% UCL concentrations of the chemicals detected in shallow monitoring wells are presented in Table 3-2, along with the respective generic residential drinking water criteria. The on-site groundwater concentrations were calculated using the same methodology as presented for soil. For the shallow groundwater unit, results for the same well from different sampling rounds were treated as distinct data points. While it is technically inappropriate to evaluate the protectiveness of the shallow groundwater by comparing the results to generic residential criteria due to the nonpotable nature, the comparison is provided for information purposes.

This is a conservative comparison in that it does not consider the uncertainty associated with laboratory-estimated values, background values of inorganics, or the frequency of detection. Exceedences of drinking water criteria were noted for the following substances:

- bis(2-Chloroethyl)ether (95% UCL; average)
- bis(2-Ethylhexyl)phthalate (95% UCL)
- Indeno(1,2,3-cd)pyrene (95% UCL; average)
- Dibenz(a,h)anthracene (95% UCL; average)
- Barium (95% UCL)
- Iron (95% UCL)
- Manganese (95% UCL; average)
- Methylene chloride (95% UCL; average)
- 1,2-Dichloropropane (95% UCL; average)
- Trichloroethene (95% UCL; average)

Six of these substances were detected at a 95% UCL concentration that was less than two times its respective drinking water criterion and likely represent minimal potential health risks [bis(2-ethylhexyl)phthalate, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, 1,2-dichloropropane, and methylene chloride]. In addition, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and methylene chloride were detected in only one shallow groundwater sample. It should also be noted that bis(2-chloroethyl)ether and 1,2-dichloropropane, as well as the highest detected concentration of TCE, were each detected at only a single upgradient location (MW-01S and PZ-01, respectively). Therefore, these two substances are not attributable to the site. ^ No

For the reasons previously discussed, VOCs are the only substances in the shallow groundwater that are of potential interest. It is worth noting that no VOCs were detected in any of the newly installed shallow wells (MW-05S, MW-06S, and MW-07S), and the number of VOCs detected, as well as their levels have generally decreased over time in the shallow aquifer (Subsection 2.4.5). The only exceedence of generic residential criteria observed for the Round 4 analytical data was for trichloroethene (0.11 mg/L), which was detected at an upgradient location (MW-01) at the western site boundary. These data suggest that shallow groundwater quality at the site is improving through processes such as natural chemical and biological attenuation.

As previously stated, the shallow groundwater is not potentially useable for residential purposes. Michigan Act 368 (Public Health Code Groundwater Quality Control, Part 127, Rule 131 and 133) restricts the installation of drinking water wells at depths of less than 25 feet, which encompasses the depth range of the shallow saturated zone. Furthermore, the shallow zone is not saturated over the entire site and where it is, the water yield is extremely low (<5 gpm). Therefore, there is no potential human exposure to shallow groundwater at the site. It should also be noted that the origin of the substances in the shallow water-bearing zone is questionable. Some of the detected substances originate from an upgradient source based on the direction of groundwater flow, location of the well detecting the chemicals, and the absence of these substances in downgradient locations.

3.2.1.2 Generic Industrial/Commercial Criteria

The frequency of detection and the average and upper 95% UCL concentrations of the substances detected in shallow monitoring wells are presented in Table 3-2, along with the respective generic residential drinking water criteria. The on-site groundwater concentrations were calculated using the same methodology as presented for soil. For the shallow groundwater unit, results for the same well from different sampling rounds were treated as distinct data points. While it is technically inappropriate to evaluate the protectiveness of the shallow groundwater by comparing the results to generic residential criteria due to the nonpotable nature, the comparison is provided for information purposes.

This is a conservative comparison in that it does not consider the uncertainty associated with laboratory-estimated values, background values of inorganics, or the frequency of detection. Exceedences of drinking water criteria were noted for the following substances:

- bis(2-ethylhexyl)phthalate.
- Dibenz(a,h)anthracene.
- Barium.
- Iron.
- Manganese.
- Methylene chloride.
- 1,2-Dichloropropane.
- Trichloroethane.

Four of these substances were detected at a 95% UCL concentration that was less than two times its respective drinking water criterion and likely represent minimal potential health risks [bis(2-ethylhexyl)phthalate, dibenz(a,h)anthracene, 1,2-dichloropropane, and methylene chloride]. In addition, dibenzo(a,h)anthracene and methylene chloride were detected in only one shallow groundwater sample.

As previously stated, the shallow groundwater is not potentially useable for residential purposes. Michigan Act 368 (Public Health Code Groundwater Quality Control, Part 127, Rule 131 and 133) restricts the installation of drinking water wells at depths of less than 25 feet, which encompasses the depth range of the shallow saturated zone. Furthermore, the shallow zone is not saturated over the entire site and where it is, the water yield is extremely low (<5 gpm). Therefore, there is no potential human exposure to shallow groundwater at the site. It should also be noted that the origin of the substances in the shallow water-bearing zone is questionable. Some of the detected substances originate from an upgradient source based on the direction of groundwater flow, location of the well detecting the substances, and the absence of these substances in downgradient locations.

3.2.2 Deep Water-Bearing Zone

The deep water-bearing zone is confined and consists of thin (0.5- to 2.5-foot) isolated sand lenses in a low permeability silty clay matrix. The deep water-bearing zone is also of low yield and contains insufficient quantity of groundwater for use as a resource.

Based on results of previous deep well monitoring, there is no evidence that groundwater monitored by the deep wells and used as a potential drinking water source has been impacted by site constituents. No VOCs, semi-VOCs, PAHs, pesticides, or PCBs were found at levels of concern in any of the deep well samples. The 95% UCL concentration of lead, manganese, and thallium in the deep well exceeded their respective MDEQ residential drinking water criterion. However, they are not related to site activities.

3.3 SUMMARY

Substances measured in on-site soil and shallow groundwater were compared to MDEQ generic cleanup criteria. This analysis assumes no remedial actions or exposure controls would be implemented at the site during or after its development.

Near surface soils (0 to 10 feet) were used to evaluate potential health concerns because potential future residential, industrial, or commercial land use at the site requires site development activities that would be expected to include soil excavation. These data are the best representation of soils that might reasonably be expected to be brought to the surface during such site development. Under all future land uses evaluated, lead, PCBs, and benzo(a)pyrene exceed generic soil cleanup criteria based on direct contact. Several VOCs and chromium may exceed soil cleanup criteria based on inhalation in a residential land use scenario. Elevated concentrations of lead were found at two locations on the site [TP13G (4 ft) - 115,000 mg/kg and TP18G (10 ft) - 18,500 mg/kg]. If these anomalous data are not considered, the 95% UCL lead concentration is reduced to from 15,500 mg/kg to 4,700 mg/kg.

A preliminary screening of potentially applicable remedial technologies for the site indicated that containment (i.e., capping) and institutional controls were considered as the most appropriate technologies to meet all the remedial action goals in protecting human health and the environment in a cost-effective manner. Capping of impacted soils will address the potential for direct contact exposure, inhalation exposure, acute skin toxicity or skin sensitization and terrestrial receptor exposure.

Only shallow groundwater was evaluated because past investigations have indicated that the deep groundwater has not been impacted. However, installation of drinking water wells is the shallow groundwater is implausible due to State of Michigan regulations, insufficient yield, and the availability of municipally-supplied water. Several VOCs, especially trichloroethene, exceed generic drinking water criteria for residential or industrial/commercial use. The number of VOCs detected in the shallow groundwater, as well as their levels, have decreased over time. This suggests that groundwater quality at the site is improving through natural chemical and/or biological processes. The origin of the substances detected in the shallow water-bearing zone is also uncertain; some substances originate from an upgradient source, as evidenced by the isolated occurrence of these substances in an upgradient well location and the absence of these substances in downgradient locations.

Table 3-1

Comparison of Site Chemicals to MDEQ Generic Cleanup Criteria
Near-Surface Soil (0-10 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Average Concentration[a]	95 Percent UCL Concentration[b]	Generic Cleanup Criteria (Direct Contact)[c]			
				Residential (Commercial Subcategory I)	Industrial (Commercial Subcategory II)	Commercial Subcategory III	Commercial Subcategory IV
Inorganics							
Antimony	6/35	59	140	150	1,600	2,200	5,200
Arsenic	33/35	15	32	5.5 6.6	83	120	280
Barium	34/35	310	1,600	30,000	320,000	440,000	1,000,000
Beryllium	11/33	1.0	1.3	2.3	35	49	120
Cadmium	13/35	1.8	4.9	210	2,300	3,200	7,400
Chromium[d]	35/35	200	3,700	2,000	1,000,000	1,000,000	1,000,000
Cobalt	31/34	12	21	2,100	23,000	32,000	74,000
Copper	34/35	170	2,300	16,000	170,000	240,000	560,000
Lead	35/35	420	16,000	400	400	400	400
Magnesium	35/35	4,300	11,000	1,000,000	1,000,000	1,000,000	1,000,000
Manganese	35/35	920	3,800	2,000	22,000	30,000	71,000
Mercury	22/35	0.24	0.64	130	1,400	1,900	4,500
Nickel	33/35	190	3,100	32,000	340,000	480,000	1,000,000
Selenium	20/35	0.92	2.7	2,100	23,000	32,000	74,000
Sodium	33/35	230	460	1,000,000	1,000,000	1,000,000	1,000,000
Thallium	3/34	0.52	0.58	28	300	420	1,000

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Table 3-1 (Continued)

Comparison of Site Chemicals to MDEQ Generic Cleanup Criteria
Near-Surface Soil (0-10 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Average Concentration[a]	95 Percent UCL Concentration[b]	Generic Cleanup Criteria (Direct Contact)[c]			
				Residential (Commercial Subcategory I)	Industrial (Commercial Subcategory II)	Commercial Subcategory III	Commercial Subcategory IV
Vanadium	31/35	19	43	3,700	39,000	55,000	130,000
Zinc	35/35	220	1,400	140,000	1,000,000	1,000,000	1,000,000
Cyanide	14/35	0.73	2.3	9,300	99,000	140,000	330,000
Organics							
Phenol	3/35	1.2	1.2	66,000	450,000	620,000	1,000,000
4-Methylphenol	1/35	1.8	4.3	2,100	23,000	32,000	74,000
Benzoic acid	1/35	0.76	0.76	1,000,000	1,000,000	1,000,000	1,000,000
1,2,4-Trichlorobenzene	3/35	1.7	28	6,300	68,000	95,000	220,000
Naphthalene	23/35	2.0	120	15,000	160,000	230,000	540,000
Acenaphthylene	4/35	1.6	1.7	1,500	16,000	23,000	54,000
Acenaphthene	20/35	2.2	22	76,000	810,000	1,000,000	1,000,000
Fluorene	20/35	2.4	25	51,000	540,000	760,000	1,000,000
Phenanthrene	28/35	6.3	130	1,500	16,000	23,000	54,000
Anthracene	20/35	2.2	23	420,000	1,000,000	1,000,000	1,000,000
Di-n-butylphthalate	16/35	2.1	350	51,000	540,000	760,000	1,000,000
Fluoranthene	28/35	5.9	270	51,000	540,000	760,000	1,000,000
Pyrene	30/35	7.3	230	32,000	340,000	470,000	1,000,000
Benz(a)anthracene	23/35	4.4	190	14	210	290	680

Table 3-1 (Continued)

Comparison of Site Chemicals to MDEQ Generic Cleanup Criteria
Near-Surface Soil (0-10 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Average Concentration[a]	95 Percent UCL Concentration[b]	Generic Cleanup Criteria (Direct Contact)[c]			
				Residential (Commercial Subcategory I)	Industrial (Commercial Subcategory II)	Commercial Subcategory III	Commercial Subcategory IV
Chrysene	25/35	3.7	160	1,400	21,000	29,000	68,000
bis(2-Ethylhexyl)phthalate	20/35	1.7	35	700	11,000	15,000	35,000
Benzo(b)fluoranthene	12/35	3.7	120	14	210	290	680
Benzo(k)fluoranthene	12/35	2.9	68	140	2,100	2,900	6,800
Benzo(a)pyrene	10/35	3.3	99	1.4	21	29	68
Indeno(1,2,3-cd)pyrene	11/35	3.5	110	14	210	290	680
Dibenz(a,h)anthracene	6/35	2.5	50	1.4	21	29	68
Benzo(g,h,i)perylene	12/35	3.9	130	1,500	16,000	23,000	54,000
Methylene chloride	24/35	0.14	550	340	3,300	4,600	9,200
Acetone	20/35	0.16	17	11,000	74,000	100,000	210,000
Carbon disulfide	5/35	0.0077	0.13	12,000	82,000	110,000	230,000
1,1-Dichloroethane	3/35	0.0076	0.28	13,000	89,000	130,000	250,000
1,2-Dichloroethene (total)[e]	7/35	0.011	0.75	1,200	8,200	11,000	23,000
Chloroform	3/35	0.0076	0.34	420	4,100	5,700	11,000
2-Butanone	8/35	0.018	1.3	200,000	1,000,000	1,000,000	1,000,000
1,1,1-Trichloroethane	2/35	0.0081	0.39	3,100	21,000	29,000	58,000
Trichloroethene	24/35	0.033	13	160	1,600	2,200	4,300
Benzene	13/35	0.010	2.1	88	850	1,200	2,400

Table 3-1 (Continued)

Comparison of Site Chemicals to MDEQ Generic Cleanup Criteria
Near-Surface Soil (0-10 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Average Concentration[a]	95 Percent UCL Concentration[b]	Generic Cleanup Criteria (Direct Contact)[c]			
				Residential (Commercial Subcategory I)	Industrial (Commercial Subcategory II)	Commercial Subcategory III	Commercial Subcategory IV
4-Methyl-2-pentanone	1/35	0.015	1.4	5,500	37,000	52,000	100,000
Tetrachloroethene	14/35	0.013	0.071	50	490	680	1,400
1,1,2,2-Tetrachloroethane	12/35	0.012	0.094	13	120	170	350
Toluene	34/35	0.078	520	24,000	160,000	230,000	460,000
Chlorobenzene	3/35	0.005	0.005	2,100	14,000	20,000	39,000
Ethylbenzene	20/35	0.030	270	11,000	72,000	100,000	200,000
Xylenes (total)	25/35	0.10	12,000	200,000	1,000,000	1,000,000	1,000,000
alpha-BHC	5/35	0.07	0.32	1.6	24	33	79
4,4'-DDT	4/35	0.14	0.47	29	440	620	1,500
Aroclor-1248	1/35	0.89	4.8	2.3	21	30	58
Aroclor-1254	16/35	3.1	100	2.3	21	30	58
Aroclor-1260	2/28	1.7	3.7	2.3	21	30	58

[a] The average concentration is the arithmetic average of log-transformed data.

[b] The 95 percent upper confidence limit (UCL) concentration is the minimum of either the maximum detected concentration or the 95 percent UCL on the arithmetic (log-transformed) mean of the data.

[c] Source: Michigan Department of Environmental Quality (MDEQ), Environmental Response Division Operational Memorandum #8, Revision 4 (5 June 1995), and Operational Memorandum #14, Revision 2 (6 June 1995).

[d] Value presented is for hexavalent chromium (Cr^{+6}).

[e] Value presented is for cis isomer.

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Table 3-2

Comparison of Site Chemicals to MDEQ Generic Residential Drinking Water Criteria
Groundwater (Shallow Wells)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/L)

Chemical	Frequency of Detection	Average Concentration[a]	Upper 95% Confidence Limit Concentration[b]	MDEQ Drinking Water Criteria[c]	
				Residential	Industrial/ Commercial
Inorganics					
Arsenic	3/9	0.0014	0.0026	0.050	0.050
Barium	9/9	0.19	4.1	2.0	2.0
Iron	7/9	0.24	0.95	0.3	0.3
Magnesium	9/9	55	83	420	1,200
Manganese	9/9	0.50	1.8	0.050	0.050
Sodium	9/9	35	80	160	450
Nickel	3/9	0.013	0.022	0.10	0.10
Lead	4/9	0.0016	0.0035	0.004	0.004
Thallium	1/9	0.0012	0.0018	0.002	0.002
Selenium	1/9	0.0014	0.002	0.05	0.05
Zinc	4/9	0.0093	0.028	2.4	5.0
Organics					
Bis(2-chloroethyl)ether	2/9	0.002	0.002	0.00077	0.0032
Di-n-butylphthalate	2/9	0.003	0.003	0.88	2.5
1,2-Dichlorobenzene	1/9	0.003	0.003	0.60	0.6
Naphthalene	1/9	0.007	0.009	0.26	0.75

Table 3-2 (Continued)

Comparison of Site Chemicals to MDEQ Generic Residential Drinking Water Criteria
Groundwater (Shallow Wells)
Linden Road Landfill
Flint, Michigan
(All concentrations in mg/L)

Chemical	Frequency of Detection	Average Concentration[a]	Upper 95% Confidence Limit Concentration[b]	MDEQ Drinking Water Criteria[c]	
				Residential	Industrial/ Commercial
Acenaphthene	1/9	0.004	0.004	1.3	3.8
Fluorene	1/9	0.002	0.002	0.88	2.5
Bis(2-ethylhexyl)phthalate	3/9	0.004	0.0066	0.006	0.006
Indeno(1,2,3-cd)pyrene	1/9	0.002	0.002	0.0012	0.0048
Benzo(g,h,i)perylene	1/9	0.002	0.002	0.026	0.075
Dibenzo(a,h)anthracene	1/9	0.001	0.001	0.00012	0.00048
alpha-BHC	1/8	2E-05	2E-05	0.00014	0.0019
Aroclor-1254	1/8	0.00029	0.00029	0.0005	0.0005
1,1-Dichloroethene	1/20	0.0025	0.0026	0.007	0.007
1,1-Dichloroethane	4/20	0.0031	0.0044	0.88	2.5
1,2-Dichloroethene (total)	8/20	0.0049	0.019	0.070	0.070
1,2-Dichloroethane	1/20	0.0028	0.0031	0.005	0.005
2-Butanone	5/20	0.0046	0.0082	13	38
1,2-Dichloropropane	2/20	0.0098	0.0098	0.005	0.005
Trichloroethene	8/20	0.0072	0.21	0.005	0.005
Benzene	1/20	0.0027	0.0029	0.005	0.005
4-Methyl-2-pentanone	3/20	0.0058	0.0088	0.37	1.0
Methylene chloride	1/20	0.0054	0.0055	0.005	0.005

Table 3-2 (Continued)

Comparison of Site Chemicals to MDEQ Generic Residential Drinking Water Criteria
Groundwater (Shallow Wells)
Linden Road Landfill
Flint, Michigan
(All concentrations in mg/L)

Chemical	Frequency of Detection	Average Concentration[a]	Upper 95% Confidence Limit Concentration[b]	MDEQ Drinking Water Criteria[c]	
				Residential	Industrial/ Commercial
Toluene	6/20	0.0031	0.0045	0.79	0.79
Chlorobenzene	2/20	0.0026	0.0026	0.10	0.1
Ethylbenzene	2/20	0.003	0.0053	0.70	0.70
Xylene	2/20	0.0032	0.0088	0.28	0.28
1,1,1-Trichloroethane	1/20	0.0025	0.0026	0.20	0.20

[a] The average concentration is the arithmetic average of log-transformed data.

[b] The 95 percent upper confidence limit (UCL) concentration is the minimum of either the maximum detected concentration or the 95 percent UCL on the arithmetic (log-transformed) mean of the data.

[c] Source: Michigan Department of Environmental Quality (MDEQ), Environmental Response Division Operational Memorandum #8, Revision 4 (5 June 1995), and Operational Memorandum #14, Revision 2 (6 June 1995).

SECTION 4
DESCRIPTION OF REMEDIAL ACTION

In accordance with PA 451, GM has prepared this RAP to describe management of the Linden Road site's environmental conditions in the context of redeveloping and providing a productive end use for the property. This RAP should allow redevelopment of the property by implementation of a technically-sound and long-term solution to any environmental concerns at the site. GM's approach presented herein is consistent with the principles of brownfield redevelopment, namely the restoration/conversion of an environmentally-impaired property into a safe, productive resource benefiting the local residents and economy. The following sections provide a discussion of the components of the remedial action required to support beneficial reuse of the Linden Road property.

4.1 <u>LAND USE OPTIONS</u>

Land use of properties adjoining the site includes agricultural, residential, and commercial, and is characteristic of a developing suburban community adjacent to a large metropolitan area. Single family residences are located to the south of the site along the west of Dye Road. The land to the east of the site is presently used for agricultural purposes. An office complex is located to the north while the privately-owned "Dye Road Dump" (a Michigan Part 201 site) lies immediately to the west of the site. Most of the area surrounding the site is zoned R-1B, which is designated for single family dwellings and includes parks, play fields, playgrounds, and other recreational facilities; and public or parochial nonprofit schools.

GM believes the Linden Road site may be well-suited for redevelopment under the limited land/resources use categories in Section 20120a(1)(f through i) of PA 451. Land/resources use limitations will be placed on the property to restrict subsurface excavations and exposures, and prohibit use of the water table zone for drinking water purposes.

↑ drillers into aq zone

At the present time, GM has not chosen a specific end use for the site. However, the end use will be consistent with the limited industrial/commercial/residential cleanup criteria, as well as the limited recreational use provisions governing the remedial action.

GM intends to maintain control over the remedial action following completion of construction through continued direct ownership, and by instituting land use restrictions incorporated into the deed of the property. Deed restrictions will be instituted upon completion of the remedial action construction. The end use will also be consistent with the zoning designation for the property. A 300-foot-wide zone along Linden Road may be cleaned up to the unlimited Commercial Subcategory III Direct Contact Criteria for soil, if practical. Any soil removed from this area would be consolidated onto other select areas of the site prior to installation of the cover system.

In general, the remedial action for the site would include regrading and constructing a soil cover over the site that would consist of 2 feet of common fill and 6 inches of topsoil. If practical, waste material and contaminated soil from a 300-foot-wide zone fronting Linden Road may be removed and consolidated elsewhere on the site. This could facilitate commercial use (Subcategory II, III, IV) of this area without the need for a soil cover system, although a deed restriction would be implemented to preclude the shallow water-bearing zone for drinking water purposes. The major activities of the remedial action include:

- Site Preparations - This activity includes mobilization, clearing and grubbing of vegetation, and construction of a temporary access.
- Site Regrading - This activity includes regrading the site to promote positive drainage away from the waste material.
- Soil Cover System Placement - This activity includes the construction of a 2.5-foot soil cover that consists of 2 feet of common fill material and 6 inches of topsoil.
- Drainage/Stormwater Management - This activity includes the construction of channels and sedimentation basins to effectively manage and control the runoff from a storm event.

- Access Control Construction - This activity includes repairs to the perimeter fence, implementation of deed restrictions, modifications to site access roads, and construction of permanent warning markers.

The following subsections further describe these planned activities. Preliminary engineering drawings showing site layouts, proposed final grading plan, and cross sections related to the proposed remedial action activities are also referenced in the following subsections and are included with this RAP.

4.2 DESIGN

Upon approval of the RAP, GM will submit to the MDEQ detailed design specifications for a cover system, including an O&M Plan. In addition, the design plan will include results of, or a method for determining whether a 300-foot-wide zone along Linden Road can be cleaned up to the commercial Subcategory III, Direct Contact Criteria for Soil.

4.3 SITE PREPARATIONS

Site work will be conducted in accordance with Occupational Safety and Health Administration (OSHA) requirements and a site-specific Health and Safety Plan. Site preparations will begin with initial mobilization of construction equipment to the site. Temporary office/storage areas will be established on site to support administrative activities and to provide communications for effective management and safety during construction activities. Typical land-clearing methods and procedures described herein will be followed to clear trees and woody vegetation from designated areas. Trees will be cut to within 12 inches of the base of the trunk and staged. This material will be chipped and stockpiled for later use in constructing the cover system and general site landscaping. Trees less than 6 inches in diameter and stumps will be removed and staged separately. This material will be chipped or otherwise reduced in size and utilized as on-site mulch.

The site contains a mature stand of various hard- and soft-wood trees. Therefore, to the extent practical, only trees in those areas that need to be cleared for construction of the soil cover system and to support the planned end use for the site will be cleared. Drawing 2 shows the limits of the potential clearing operations. Temporary access to the site will be constructed along Linden Road to allow construction traffic to safely enter the site. GM will obtain the necessary access permits and will configure the construction entrance in accordance with township and Michigan Department of Transportation (MDOT) requirements. An additional discussion of vehicular access is presented in Subsection 4.7.

4.4 SITE REGRADING

Site regrading in cleared areas will provide for positive drainage and eliminate isolated areas of temporary ponding or depressions that would limit potential end uses for the site. Grading will be conducted using typical earthmoving techniques with equipment such as bulldozers and scrapers. Relocated and imported soils would be used to smooth out the topography prior to installation of the final cover system. Relocated and imported material will be placed in an engineered fashion and compacted as necessary to provide a stable working surface and to minimize post-operational maintenance of the site. Fill material will only be relocated/regraded within the limits of the current waste boundary of the site.

To determine the extent of waste within the proposed 300-foot redevelopment zone along Linden Road, confirmation sampling would be conducted in accordance with the MDEQ's "Guidance Document for Verification of Soil Remediation." Only those areas that exceed the commercial Subcategory III, Direct Contact Criteria for Soil, will be excavated and the soil relocated. Drawing 1 depicts the existing site conditions. A conceptual site regrading plan is presented on Drawing 2. Two cross-sections of the graded site are depicted in Drawing 3.

4.5 SOIL COVER SYSTEM

Following preparation, regrading, and relocation of landfilled material (if applicable), a minimum of 2.5-foot final soil cover system will be constructed across the surface of the site. The final soil cover would include a 6-inch topsoil layer and a minimum 2-foot fill material layer. Depth of cover will be determined based on location of area to be covered, use for the area, and grading required to provide for positive drainage of the site. The soil cover may be in excess of 4 feet in select areas of the site.

Soil cover may consist of a combination of general fill material (minimum 2 feet thick) with adequate stability to resist erosion and a 6-inch vegetative layer (topsoil) in order to promote a healthy vegetative cover. General fill material used for the cover system or regrading may include material designated as inert or low hazard pursuant to Part 115 (former Act 641) of PA 451.

The cover system will be placed using standard earthmoving equipment and methods. General fill cover soils placed in substantial thicknesses will be placed in lifts and compacted. Compaction of fill soils will increase soil strength and limit any post-closure settlement or subsidence. Maintenance of the cover system is addressed in Section 5.

Following placement and compaction of general fill cover soils, a vegetative layer will be placed. The vegetative layer will consist of cover soils rich in organic content and nutrients necessary to support vigorous plant growth. Vegetative soils will be placed in a loose, friable state. Compaction may be accomplished by using a cultipacker or by tracking in place using heavy earthmoving equipment. Higher degrees of compactive effort are not anticipated in order to allow the soil to remain aerated to absorb a certain degree of precipitation necessary for plant growth, and to allow vegetation to take root. The vegetative layer will be seeded and mulched as appropriate to begin establishment of vegetation. The seed mixture will be native to this region of the state and will be as recommended by the local soil conservation service. Fertilization and watering of the seeded areas will be completed directly following placement. Application rates will be as recommended by the soil conservation service. During the initial germination period, any portions of the cover system that suffer erosion or minimal vegetative growth will be repaired by replacing any eroded soils, recompacting, and reseeding at the prescribed rates. Mulch will be applied to maintain appropriate moisture content of the soil and to protect against the effects of erosion.

4.6 SITE DRAINAGE/STORMWATER MANAGEMENT

The soil cover system proposed for the Site will be designed to provide positive drainage in order to minimize ponding of precipitation and to control sedimentation of on-site and off-site stormwater drainageways. Based on the chosen end use for the Site, the cover system may be sloped to direct surface water from the cover as overland sheetflow or to drainage channels. These channels will then transfer the water to on-site sedimentation basins. Sedimentation basins will be located outside the limits of the landfill. The basins will be designed to retain the surface water runoff for a sufficient length of time to allow soil particles in suspension to settle out prior to discharge of the water into off-site drainageways. The locations of drainage channels and final slopes of the soil cover system will be designed to support the chosen end use for the Site and to minimize erosion and maintenance of the cover. Channels and sedimentation basins will be sized using standard engineering practice for determining runoff from small watersheds such as the Soil Conservation Services Technical Release No. 55 (SCSTR-55). Channels will be designed to pass the peak flows while maintaining velocities that will not cause excessive erosion or damage to drainage structures. Basins will be designed with outlet structures that will direct waters into downstream drainage systems. Riprap or other devices will be provided at culverts, changes in direction, or any other areas that may be prone to erosion damage.

The design of drainage structures will be dependent on the end use chosen for the Site and the detailed layout of that end use. Drawing 2 shows anticipated drainage patterns on and adjacent to the Site.

4.7 ACCESS CONTROLS

The Site is currently surrounded with a perimeter fence and locking entrance gates. GM conducts periodic inspections of the fence and gates for signs of unauthorized entry or damage. Any damage to the fence will be repaired or replaced to ensure security of the Site during the design phases of this project. During construction, the contractor will be required to maintain the perimeter fence network during implementation of this remedial action plan.

In addition, following completion of the remedial action, the barbed wire will be removed from the top of the fence.

Once the remedial action has been completed, the fence will no longer be necessary to protect human health and the environment. All portions of the fence may be moved or removed to facilitate reuse of the property.

The soil cover will provide a suitable barrier to public contact with the subsurface soils throughout the Site. In order to maintain the integrity of this barrier system, GM will initiate deed restrictions that will limit subgrade excavation and construction in excess of that necessary for development of the proposed end use for the Site.

Vehicular access to the Site following development will be determined by GM during the design phase. Based on the projected traffic mix and volume generated by the chosen end use, GM will design the appropriate entrance to safely manage traffic movements. GM will consult with County and MDOT officials to determine what additions/upgrades are necessary at the property entrance. GM will prepare design plans and obtain the necessary permits/approvals for any modifications and turn lanes necessary to provide for safe ingress and egress to the property.

SECTION 5
OPERATION AND MAINTENANCE PLAN

In accordance with Part 201 of PA 451, the final design of the Linden Road Landfill remedial action will include an operation and maintenance (O&M) plan to maintain the integrity of the remedial action following completion of construction activities. The following sections outline the monitoring and maintenance activities.

5.1 SITE INSPECTION PROGRAM

GM will prepare a site inspection program to detail the activities required to implement an O&M plan for the site. The plan will act as a stand-alone document and will include the following information:

- O&M schedule, as preliminarily identified in Table 5-1.
- Written and pictorial plan of operation and maintenance.
- Design and construction plans (record documents).
- O&M safety plan.
- Emergency/contingency plans (including emergency phone numbers).

The plan will detail the reporting requirements and inspection frequencies necessary for each component of the remedial action. Specific items to be observed during inspections are described in the following subsections.

5.2 SOIL COVER SYSTEM MAINTENANCE

The integrity of the soil cover system will be inspected periodically as shown in Table 5-1 during the O&M period. Results of inspection will be documented and submitted in accordance with Table 5-1. These documents will be kept on file for submission with the final closeout report. If inspections identify erosion or other damage such as settlement,

Table 5-1

Operation and Maintenance Schedule
Linden Road Landfill
Flint, Michigan

Year	Operation and Maintenance Activity				
	Soil Cover Inspection/ Maintenance (Frequency)	Access Control Inspection/ Maintenance (Frequency)	Drainage System Maintenance (Frequency)	Groundwater[1] Monitoring (Frequency)	Reporting (Frequency)
1	Quarterly	Quarterly	Quarterly	Annual	Annual
2	Semi-annual	Semi-annual	Semi-annual	Annual	Annual
3	Semi-annual	Semi-annual	Semi-annual	Annual	Annual
4	Semi-annual	Semi-annual	Semi-annual	Annual	Annual
5	Annual	Annual	Annual	Annual	Annual
6, 8, 10 ...[2]	Annual	Annual	Annual	Every two years	Annual

1 Monitoring parameters will include VOCs only.

2 During even numbered years, inspections will occur annually and will include groundwater monitoring until the criteria for groundwater not in an aquifer have been met for two consecutive sampling events.

subsidence, and/or evidence of burrowing animals to the soil cover system, the following steps will be instituted to correct the deficiency:

- Areas suffering from significant erosion or other damage will be repaired.
- Additional cover soils will be placed and compacted, if necessary, to bring the area up to an elevation consistent with the surrounding grades.
- Following repair, the area will be re-topsoiled and re-seeded.
- Additional mulch will be applied with particular care taken on upstream edges of the prepared surface.

If inspections indicate that erosion or other damage is reoccurring in areas, additional measures (e.g., adjusting ditch locations, more extensive erosion control structures, additional compaction, vector controls) may be implemented in order to alleviate the situation.

5.3 ACCESS CONTROL MAINTENANCE

During the O&M period, access controls into the property will be maintained through periodic inspections as shown in Table 5-1 and fence maintenance. The type and extent of fencing will be specific to the chosen end use for the site. Access control common to any proposed end use will be described herein.

If fences or gates are provided as part of the proposed end use, each segment of fence will be inspected for damage or inoperative components. Components that do not function properly will be repaired or replaced to restore security or safety to the site.

5.4 DRAINAGE SYSTEM MAINTENANCE

The stormwater management system will be designed to minimize post-construction maintenance during the O&M period. Drainage structures will be inspected periodically as shown in Table 5-1 to maintain proper functioning of the system. If inspections identify areas of significant erosion or lack of vegetation, the area will be repaired. Additional general fill will be brought in from off site, if necessary, to complete repair activities. Areas that continue to require maintenance and regrading may require riprap or other erosion control systems.

Stormwater basins will be monitored for erosion and sediment buildup. Basins will be designed for the peak discharge rates and will contain additional volume to account for sediment buildup. When sediment reaches a predetermined level, the sediment will be excavated and removed from the basin to return the basin to its original holding capacity.

5.5 GROUNDWATER MONITORING PLAN

As part of the final design of the remedial action, a groundwater monitoring plan will be developed. In general, the seven shallow monitoring wells will be sampled at the frequency identified in Table 5-1. The wells will be purged prior to sampling. During purging, specific conductance, pH, and temperature measurements will be taken. Once these measurements have stabilized, a groundwater sample will be collected and analyzed for VOCs. Analytical results will be included as part of the annual report.

5.6 HEALTH AND SAFETY PLAN

A site-specific health and safety plan (HASP) will be prepared for activities to be conducted during the operation and maintenance period. The HASP will be prepared in accordance with 29 CFR 1910 and 29 CFR 1926, OSHA and other local, state, and federal requirements. The HASP will be prepared for use by those personnel conducting inspection, maintenance, or construction activities on site. The plan will also include emergency response plans and public awareness information.

5.7 EMERGENCY PLANS

Site-specific contingency plans will be provided as attachment to the HASP. These plans will address potential issues relating to public safety and health and protection of the environment.

5.8 COMMUNITY RELATIONS ACTIVITIES

For the past several years, GM has maintained an effective community relations program to keep site neighbors and the general public informed of all activities conducted at the Linden Road site. GM will continue to ensure public awareness of activities under each phase of the remedial action at the Site. As in the past, these activities will be implemented by GM community relations personnel through periodic newsletters to site neighbors.

5.9 LAND/RESOURCE USE

Land/resource use of the site will be consistent with categorical uses in the approved RAP. A land/resource plan will be provided to the MDEQ upon selection of any initial land use, if other than "undeveloped." The purpose of the plan will be to identify the use of the property including any subsurface development, and any other modifications to the O&M of the cover system. Any significant modifications to the cover system necessary to account for future end uses (e.g., adding fill material to accommodate additional recreational areas) will be subject to prior approval by the MDEQ.

Land and groundwater use restrictions will be placed on the deed upon completion of the remedial action construction. The form of these restrictions will be approved by MDEQ.

SECTION 6
REMEDIAL ACTION IMPLEMENTATION SCHEDULE

6.1 REGULATORY REVIEW AND APPROVAL

GM has submitted this Remedial Action Plan to the MDEQ for review and approval. GM is continuing to evaluate appropriate end uses for the site which are consistent with the RAP.

6.2 IMPLEMENTATION SCHEDULE

Following approval of the RAP and subsequent detailed design plans, GM will contract with a general earthwork contractor to construct the soil cover system and associated appurtenances. Construction activities will be conducted using typical earthmoving equipment and methods. Specific components of the remedial action are discussed in Section 4. Other components may be added based on the selected end-use chosen for the property. Construction is expected to take one full construction season.

6.3 OPERATION AND MAINTENANCE SCHEDULE

The O&M portion of this plan will be implemented immediately following completion of construction activities. The specific tasks included in the O&M program are detailed in Section 5. The task list may be adjusted based on the components included in the chosen end-use. Operation and maintenance duties may begin incrementally as individual portions of the site development design are deemed to be complete. O&M activities will be conducted according to the schedule presented in Table 5-1. A detailed O&M plan will be included as part of the detailed design that will be submitted to the MDEQ following approval of the RAP.

SECTION 7

COST ESTIMATE AND FINANCIAL ASSURANCE

7.1 OPERATION AND MAINTENANCE COST

Operation and maintenance costs associated with the remedial action described in this plan were prepared during the alternatives analysis previously conducted and are included in Appendix C. The alternatives analysis determined that a soil cover system with associated access and stormwater control components was an appropriate and cost-effective solution for the conditions present at the Linden Road Site. Based on the assumptions presented in the Site Investigation Report and the Risk Assessment, the annual cost for conducting O&M could range from $15,000 to $25,000. GM will prepare a detailed cost estimate as part of the final design.

7.2 FINANCIAL ASSURANCE MECHANISM

GM will provide financial assurance for the operation and maintenance of the remedial action in a form acceptable to the MDEQ. The financial assurance mechanism will be included as part of the final design and will be updated, as necessary.

SECTION 8
DOCUMENTATION AND REPORTING

A Construction Report will be prepared by GM following completion of construction. This report will document remedial construction activities, significant events, and changes to the remedial action approved during implementation. Copies of the record documents will be supplied with the submittal to the MDEQ. The submittal will include information necessary for the MDEQ to conclude that the remedial action was implemented in accordance with the approved RAP and applicable state and federal regulations.

SECTION 9

REFERENCES

Michigan Department of Environmental Quality. June 1995. Environmental Response Division Operational Memorandum #14, Revision 2: Remedial Action Plans Using Generic Industrial or Generic Commercial Cleanup Criteria and Other Requirements.

Michigan Department of Environmental Quality. June 1995. Interim Environmental Response Division Operational Memorandum #8, Revision 4: Generic Residential Cleanup Criteria.

Michigan Department of Environmental Quality. June 1994. Environmental Response Division. Operational Memorandum #14: Generic Remedial Action Plans Using Generic Industrial or Generic Commercial Cleanup Criteria and Other Requirements for Type C Remedial Action Plans.

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WESTON. March 1992. Interim Remedial Measures Evaluation and Site Investigation, Linden Road Landfill Site, Flint Township, Michigan.

WESTON. July 1990. Site Investigation Work Plan for Linden Road Landfill Site, Flint Township, Michigan.

WESTON. July 1990. Interim Remedial Measures Evaluation Work Plan for Linden Road Landfill Site, Flint Township, Michigan.

WESTON. February 1990. Phase I Environmental Assessment of Linden Road Landfill, Flint Township, Michigan.

— — — —— — — — APPROXIMATE LIMITS OF FILL

NOTE: FINAL GRADES – ADD 2.5 FEET TO REGRADING PLAN CONTOURS FOR FINAL COVER SYSTEM.

SCALE

WESTON
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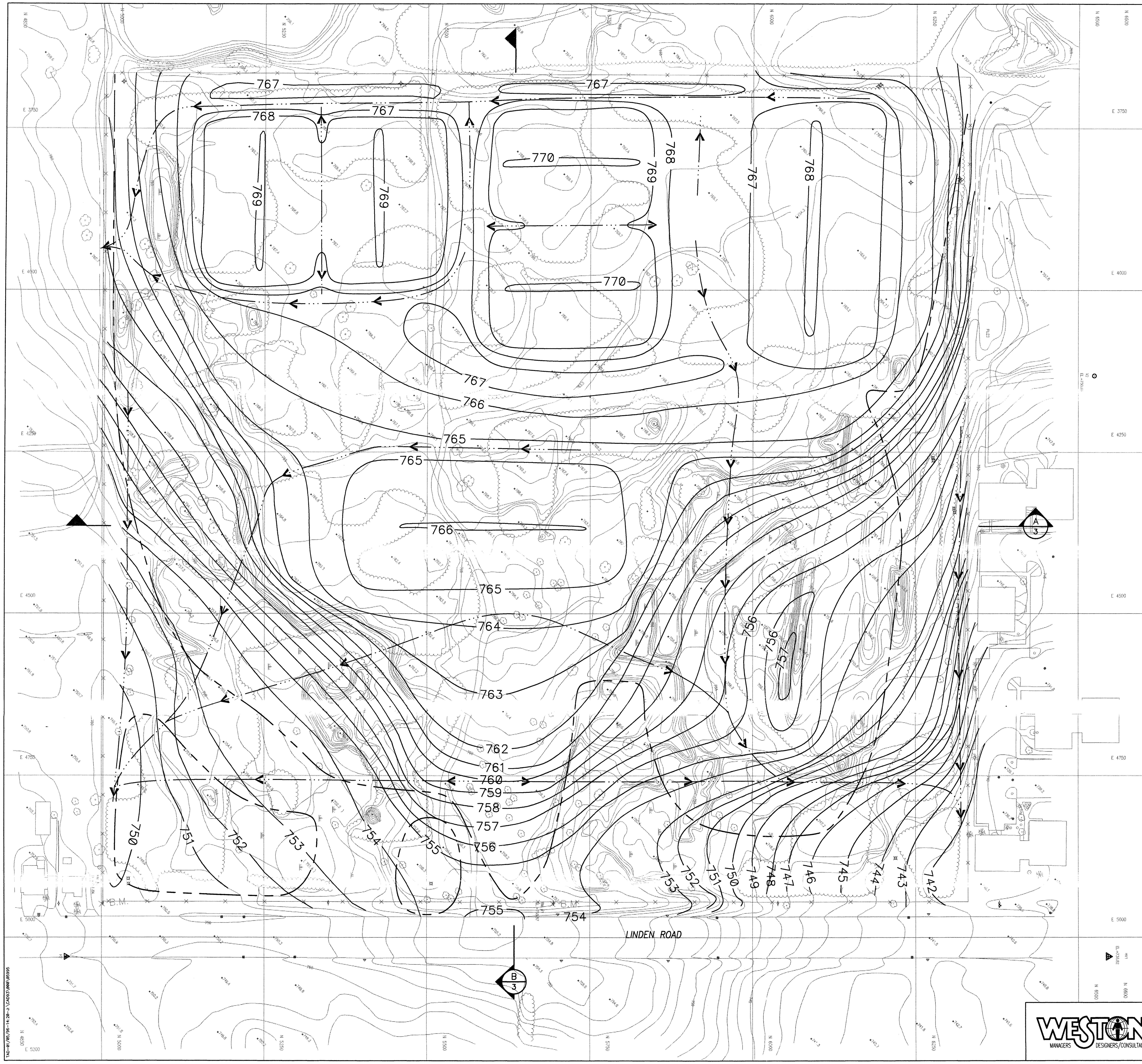
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

EXISTING SITE MAP

LINDEN ROAD SITE
Flint, Michigan

SCALE:	DRAWN:	DATE:	DWG. NO.	
1"=60'	T.A.D.	DEC 95	05995	DRAWING 1



APPROXIMATE LIMITS OF FILL

STORMWATER DRAINAGE PATHWAYS

NOTE: FINAL GRADES – ADD 2.5 FEET TO REGRADING PLAN CONTOURS FOR FINAL COVER SYSTEM.
– ASSUMES THAT A 300' WIDE ZONE FRONTING LINDEN ROAD WILL ALSO BE CAPPED.

0 60'
SCALE

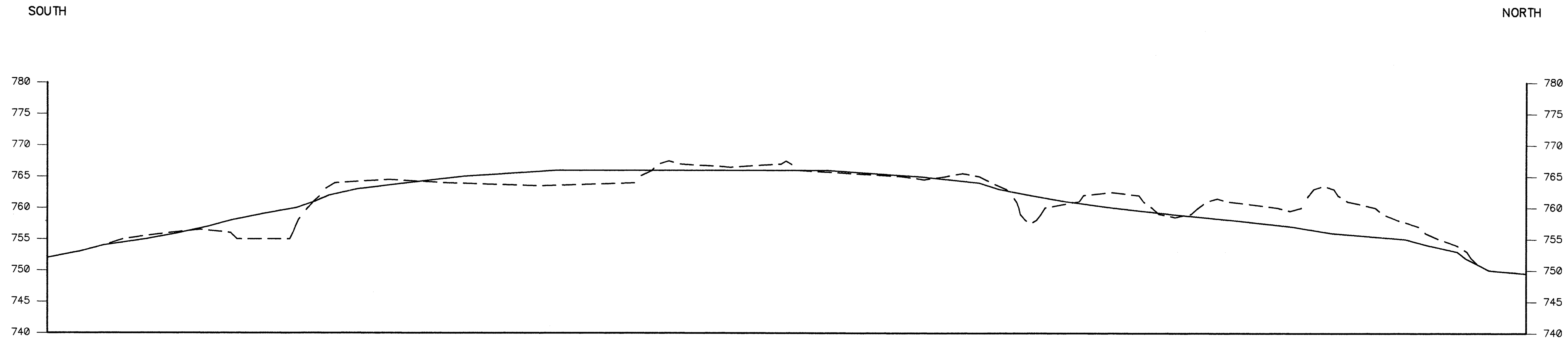
WESTON MANAGERS DESIGNERS/CONSULTANTS

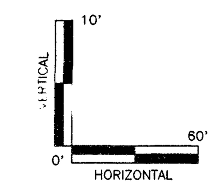
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

CONCEPTUAL SITE REGRADING PLAN

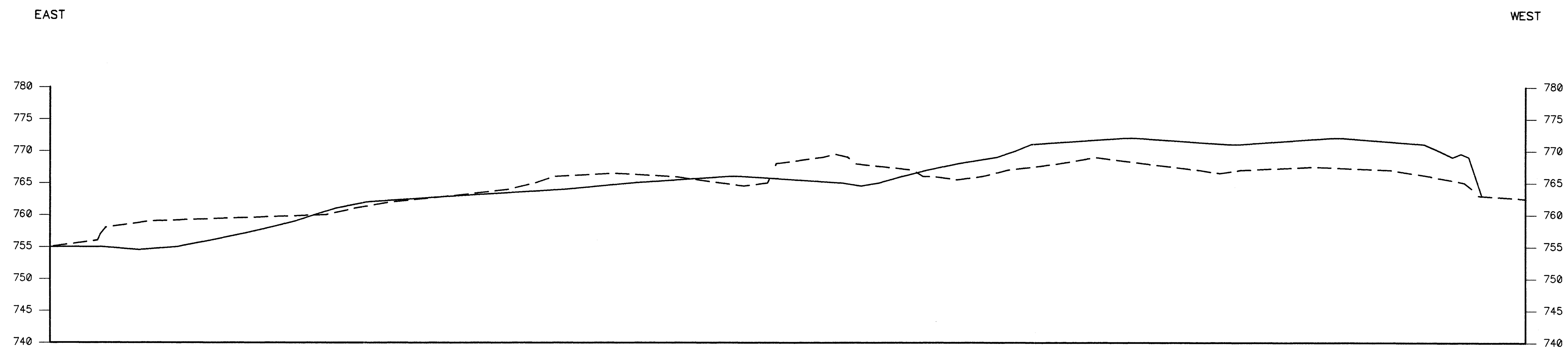
LINDEN ROAD SITE
Flint, Michigan

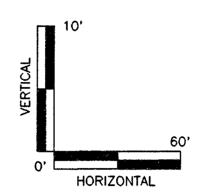
SCALE:	DRAWN:	DATE:	DWG. NO.	
1"=60'	T.A.D.	DEC 95	05995	DRAWING 2





SECTION A/3





SECTION B/3

- - - - - - - - - - EXISTING GRADE CONTOUR ELEVATION

———————— REGRADING CONTOUR ELEVATION

NOTE: FINAL GRADES – ADD 2.5 FEET TO REGRADING PLAN CONTOURS FOR FINAL COVER SYSTEM.

WESTON MANAGERS DESIGNERS/CONSULTANTS	Three Hawthorn Parkway Vernon Hills, Illinois 60061	CROSS SECTIONS LINDEN ROAD SITE Flint, Michigan

SCALE:	DRAWN:	DATE:	DWG. NO.	
AS NOTED	T.A.D.	DEC 95	10895	DRAWING 3

APPENDIX A

EVALUATION OF FINDINGS
(SECTION 7 OF IRME AND SI REPORT)

SECTION 7

EVALUATION OF FINDINGS

This section presents an evaluation of findings based upon the results of the IRME and SI discussed in Section 3, 4, and 5. Subsections 7.1 and 7.2 discuss the extent of contamination and characterize surface material and subsurface soils at the Site. Subsection 7.2 also includes a discussion on the estimated volume of subsurface waste material at the Site. Subsections 7.3 and 7.4 discuss groundwater quality and surface water quality, respectively. Relevant regulatory limits and health-based comparisons are also discussed where applicable in this section. A regulatory requirement analysis consistent with State of Michigan regulations is presented in Section 7.5.

7.1 CHARACTERIZATION OF SURFACE MATERIAL

As discussed in Section 3, representative samples were collected from five surface waste areas including Red Barren Areas, Wood Block Areas, Drum Areas, Surface Sludge Areas, and the Oil Disposal Area.

7.1.1 Red Barren Areas (RBAs)

Analytical results (Table 5-1) indicate clearly that surface composite samples collected from the RBAs have metal concentrations significantly lower than the limits for hazardous waste classification under RCRA. PCBs (Aroclor-1248 and Aroclor-1254) were present at levels that are significantly lower than the 50 mg/kg TSCA limit for disposal of soils contaminated with PCBs. VOCs and semivolatile compounds were not detected in any samples.

Based on the results of sampling, it can be concluded that the surface soils associated with the RBAs are not hazardous waste. The RBAs occupy an area of 3.5 acres based on distribution of these areas as shown in Figure 2-3. The RBAs cover approximately 9 percent of the Site.

7.1.2 Wood Block Areas

No VOCs, semivolatiles, and metals were detected in the TCLP extract of composite samples of wood blocks taken from the various Wood Block Areas. Aroclor-1254 was present in all samples, but at levels lower than the 50 mg/kg TSCA limit for the disposal of PCB-contaminated soil. Based on the analytical results, the Wood Block Areas are minimally contaminated and are not classified as hazardous waste. The Wood Block Areas are generally contiguous to the Red Barren Areas and cover approximately 4 acres of the 40-acre site.

7.1.3 Drum Areas

Approximately 250 drums and drum remnants were distributed randomly at several locations as discussed in Subsection 3.5.1 and shown in Figure 3-2. Analytical results presented in Section 5 (Tables 5-3 and 5-4) indicate that, except for one sample, metals, VOCs, and semivolatile compounds in the TCLP extract were present at concentrations that are lower than the limits for classification as a hazardous waste. A single composite sample representing Areas 1 and 20 contained trichloroethene in the TCLP extract at a concentration that exceeded the regulatory limit for hazardous waste classification. PCBs were present in two composite samples collected from Areas 15, 21, 27, 35 at levels exceeding the 50 mg/kg TSCA limit for disposal of PCB-contaminated soils. The total volume of the hazardous waste and the material with elevated PCB levels referenced above is estimated to be 10 cubic yards.

7.1.4 Surface Sludge Areas

Thirteen Surface Sludge Areas were identified and sampled at the site. There was no organic contamination (VOCs or semivolatiles) in any of the areas. Metals concentration in the TCLP extract exceeded the RCRA hazardous waste criteria only in a single sample (Area 32B). At this location (32B), PCBs were present at a concentration exceeding the 50 mg/kg TSCA limit for the disposal of PCB-contaminated soils. Supplementary sampling of Area 32B indicated that the source for the high PCB concentrations was a dark yellowish-brown greasy waste material (wrapped in foil) present in a drum. The maximum volume of this waste material in Area 32B is an estimated 4 cubic yards.

7.1.5 Oil Disposal Area

The Oil Disposal Area occupies approximately 14 square yards. Sample analytical results from this area indicate that the contents of the Oil Disposal Area are hazardous waste based on trichloroethene concentration that exceeded the RCRA regulatory limit. At this location, PCBs were also present at concentrations exceeding the TSCA limit of 50 mg/kg for disposal of PCB-contaminated soils. Based upon an estimated maximum thickness of 3 feet, the volume of the contents of the Oil Disposal Area and associated contaminated soils is approximately 14 cubic yards.

7.1.6 Summary

Based upon the evaluation of surface material present at the Site, the RBA soils and the Wood Block Areas do not warrant any interim remedial measures. Limited quantities of drum wastes, sludges and the material associated with the Oil Disposal Area are potential candidates for removal and off-site disposal. It is estimated that the total volume of surface waste material that may require remediation is 28 cubic yards.

7.2 CHARACTERIZATION OF SUBSURFACE SOIL

During the SI, soil and waste samples were collected from test pits and soil borings to determine the nature and extent of waste disposal and potential impacts to subsurface soils. The subsurface investigation also included auger probes, but no samples were collected for analysis. This subsection discusses the nature and extent of waste constituents in the subsurface soils based on the analytical results. Also included in this section is an estimate of the volume of waste material present in the Site subsurface.

7.2.1 Subsurface Soil/Waste

Test pits were excavated at locations that were selected based upon the results of soil gas screening (where organic vapors were encountered above background levels), areas with unique surface features (such as Red Barren Areas), and using information from previous investigations. The Geophysical Survey did not yield useful information because of interference caused by the widespread occurrences of ferrous material at the Site.

Waste material was encountered in all the test pits at varying thicknesses. A review of the analytical results of test pit samples indicated wide ranging levels of organic and inorganic compounds in waste samples. However, the higher levels of constituents were generally restricted to the grab samples collected from waste. As stated earlier, grab samples were collected only from specific material in some test pits, based on appearance and screening with air monitoring instruments. The grab samples were collected independent of the quantity of the specific material referenced above. Analytical results of grab samples therefore are not representative of the entire landfill. The test pit locations were selected primarily based upon soil gas screening. Therefore, it is likely that material with high concentrations of organic and inorganic constituents similar to those detected in grab samples would be limited in extent within the Site. The organic and inorganic compounds in the composite samples are more representative of the landfill mass and are generally low in concentrations. The test pit samples were representative of only waste material and associated fill because test pit excavations did not continue below the water table.

Samples collected from soil borings and monitoring well borings represented both waste material and natural soils. In general, the organic and inorganic compound concentrations in samples collected from waste material were low, similar to those of the composite sample of the test pits. However, trace levels of organic compounds were also detected in some of the "natural soil" samples collected from the confining silty clay layer and from units below the confining layer. Among the VOCs detected, methylene chloride and acetone were ruled out as a result of laboratory contamination. The other organic compounds detected in samples from the confining layer and from deeper units is probably due to field contamination. Although the augers were thoroughly decontaminated between drilling flushes, the probability of minor cross contamination is high because of the nature of the overlying waste material. Based on the demonstrated impermeable nature of the clay confining layer as well as the lithology observed below the confining layer, and the quality of groundwater as demonstrated by the analytical results, it is highly unlikely that the very low constituent concentrations observed in underlying natural soils reflect any contamination.

In summary, based on the SI findings, significant levels of subsurface organic and inorganic constituents at the Site are confined to the waste material and associated fill. Subsurface waste material appears to be present throughout the interior portions of the Site.

7.2.2 Waste Volume Estimation

Waste material thickness data gathered during the excavation of test pits, and drilling of auger probes, soil borings, monitoring wells, and piezometers were plotted on a base map to develop a waste-thickness isopach map (Figure 7-1). The isopach map indicates that the waste material is generally distributed in the central and western portions of the site. This distribution is generally consistent with the findings of the historical aerial photograph review (Phase I Assessment) and the geophysical survey. Generally, thicker accumulations of waste are present in the central portion of the Site and in the areas where trenches were observed in the historical aerial photographs (WESTON, 1991a). The greater fill thicknesses in the area of the above-referenced trenches are reflected in the northwest and northeast parts as indicated in Figure 7-1.

Four cross-sections of the Site were drawn to illustrate the distribution of waste material and the underlying natural soils. Figure 7-2 shows the locations and orientations of these cross-sections, and Figures 7-3 through 7-6 present the cross-sections. These cross-sections show the general distribution of waste material at different parts of the Site, and also demonstrate the lateral continuity of the confining clay layer across the Site.

A computer program (Surfer) was used to estimate the volume of Site subsurface waste material. This estimate was based on calculating the volume of material between topography of the "natural" soil and the overlying waste/fill material surface topography. With this information on the variable thickness of Site fill material, in conjunction with the Site's area, the computer program calculated a volume of approximately 275,000 cubic yards of waste/fill material.

The following assumptions were made in calculating the waste volume stated above:

- The subsurface data collected is representative of the conditions across the Site.
- Test pits and auger probes fully penetrated the waste material.
- The mounds and trenches at the Site will not have a significant impact on the volume calculations using this method.

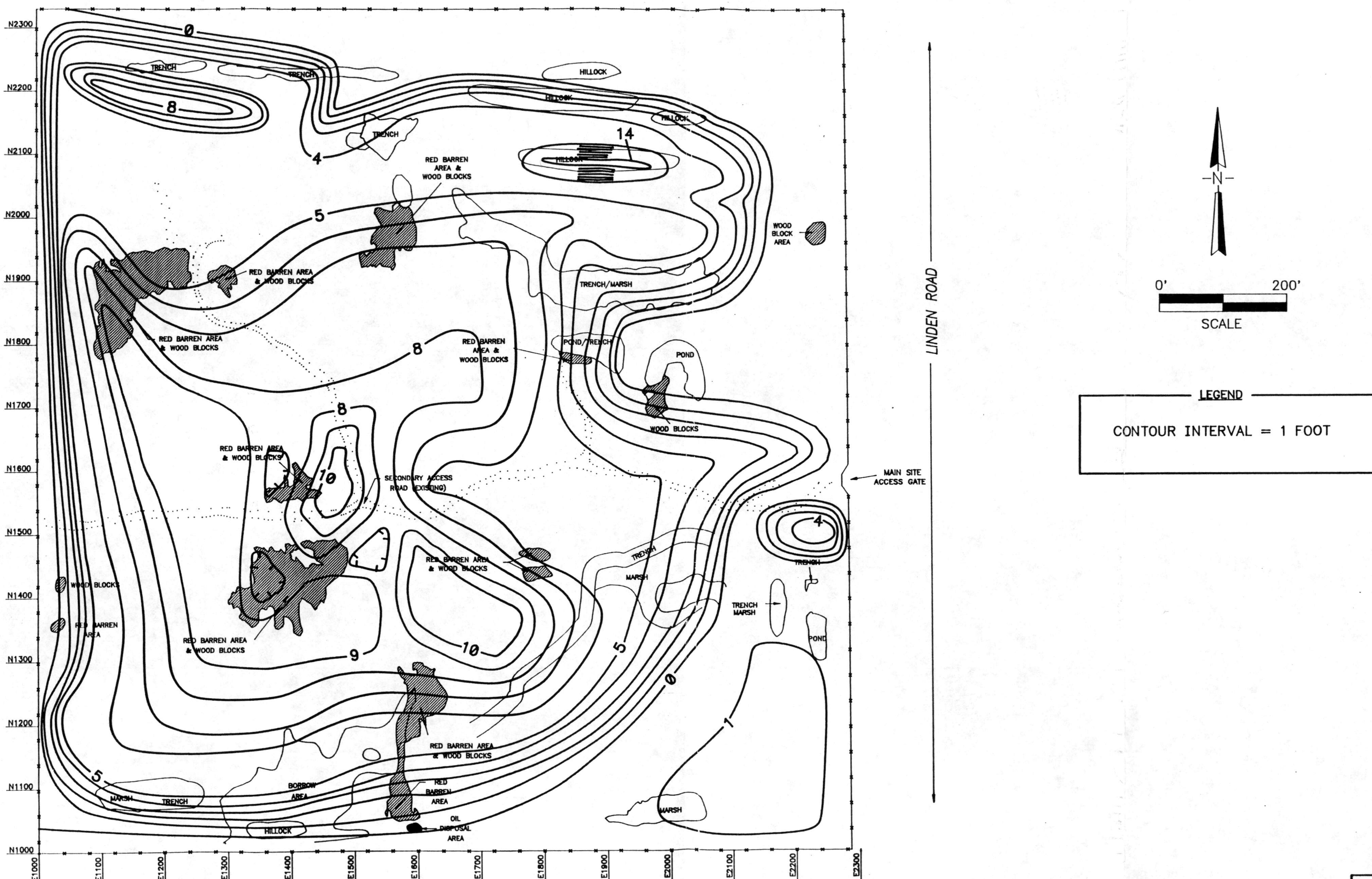


FIGURE 7–1

WESTON
MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway
Vernon Hills, Illinois
60061

WASTE THICKNESS ISOPACH MAP

LINDEN ROAD LANDFILL
Flint, Michigan

64391 D

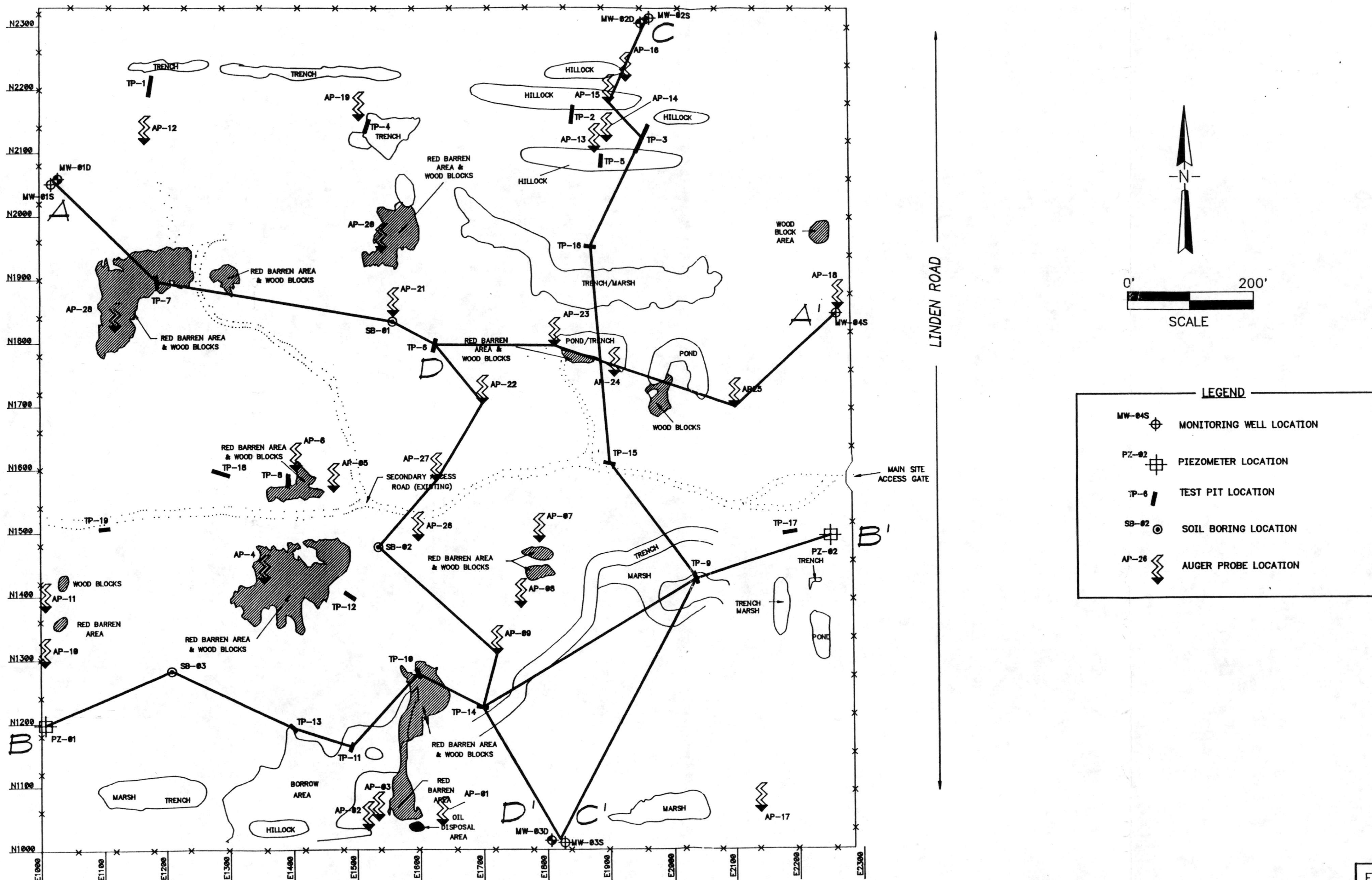


FIGURE 7-2

LOCATIONS & ORIENTATION OF CROSS SECTIONS
LINDEN ROAD LANDFILL
Flint, Michigan

WESTON
MANAGERS DESIGNERS/CONSULTANTS
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

65091 B

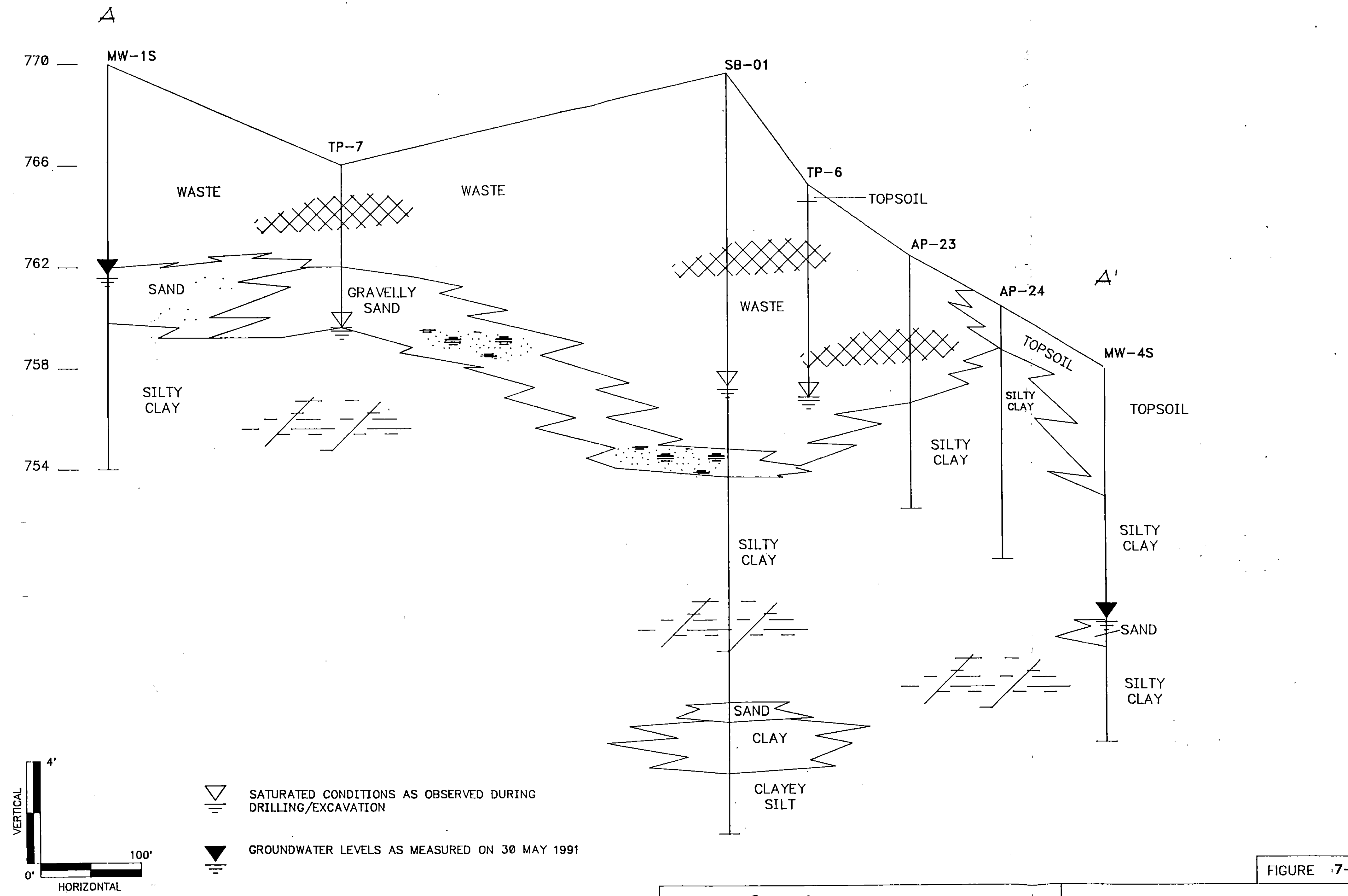


FIGURE 7-3

WESTON MANAGERS DESIGNERS/CONSULTANTS
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

CROSS-SECTION A – A'

LINDEN ROAD LANDFILL
Flint, Michigan

64791 B

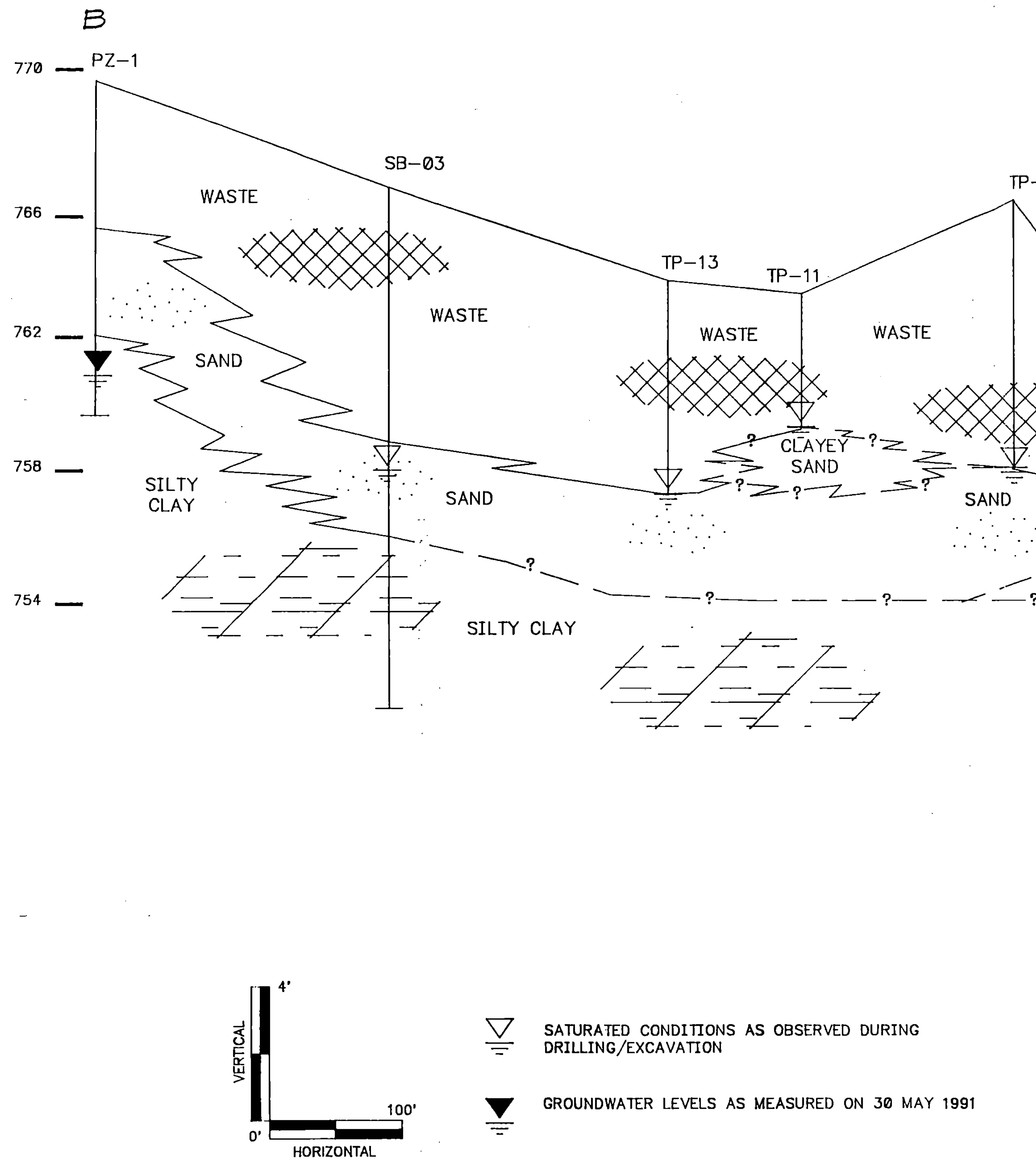
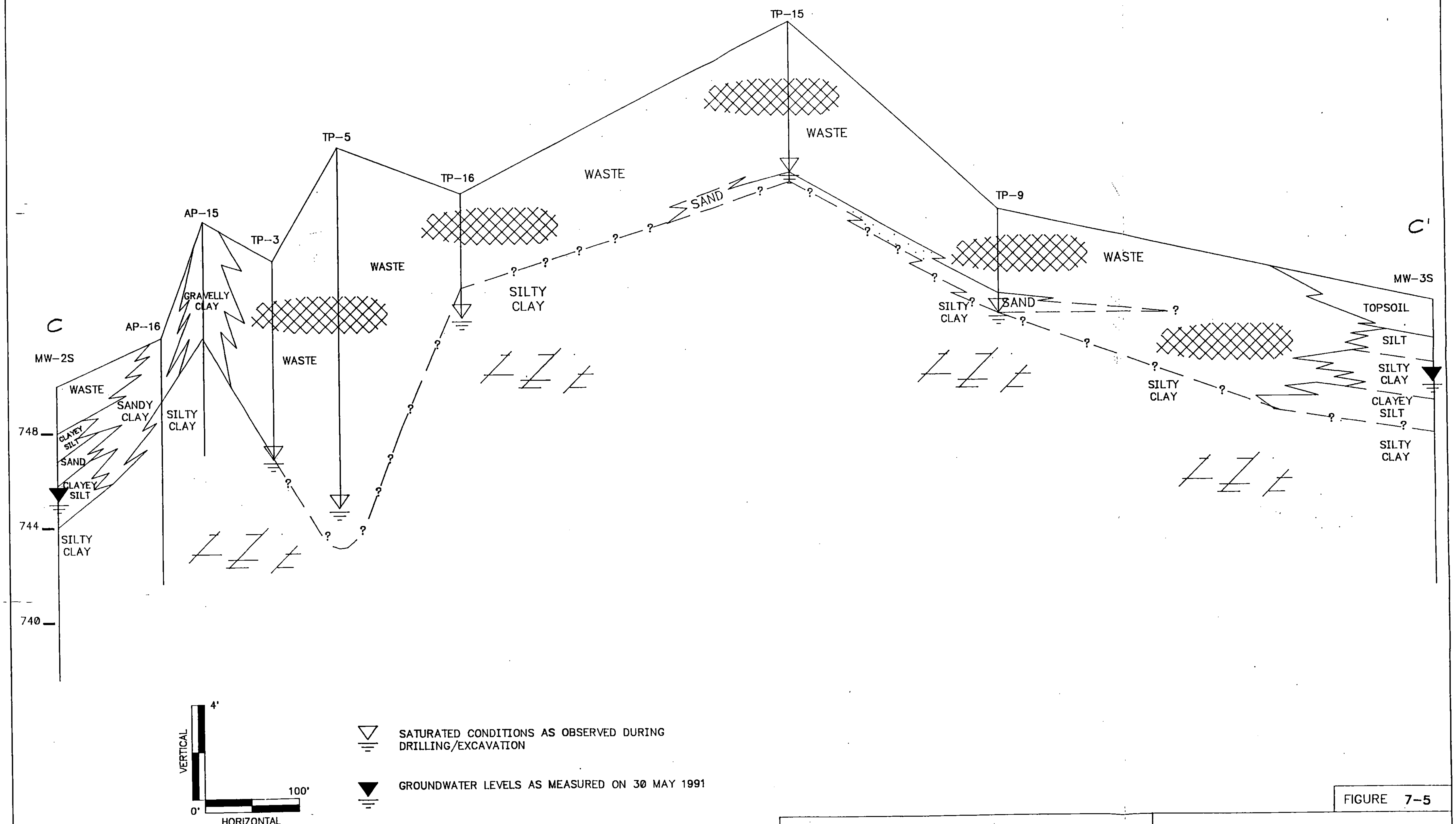


FIGURE 7-4

WESTON MANAGERS DESIGNERS/CONSULTANTS
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

CROSS-SECTION B – B'
LINDEN ROAD LANDFILL
Flint, Michigan

64791 B



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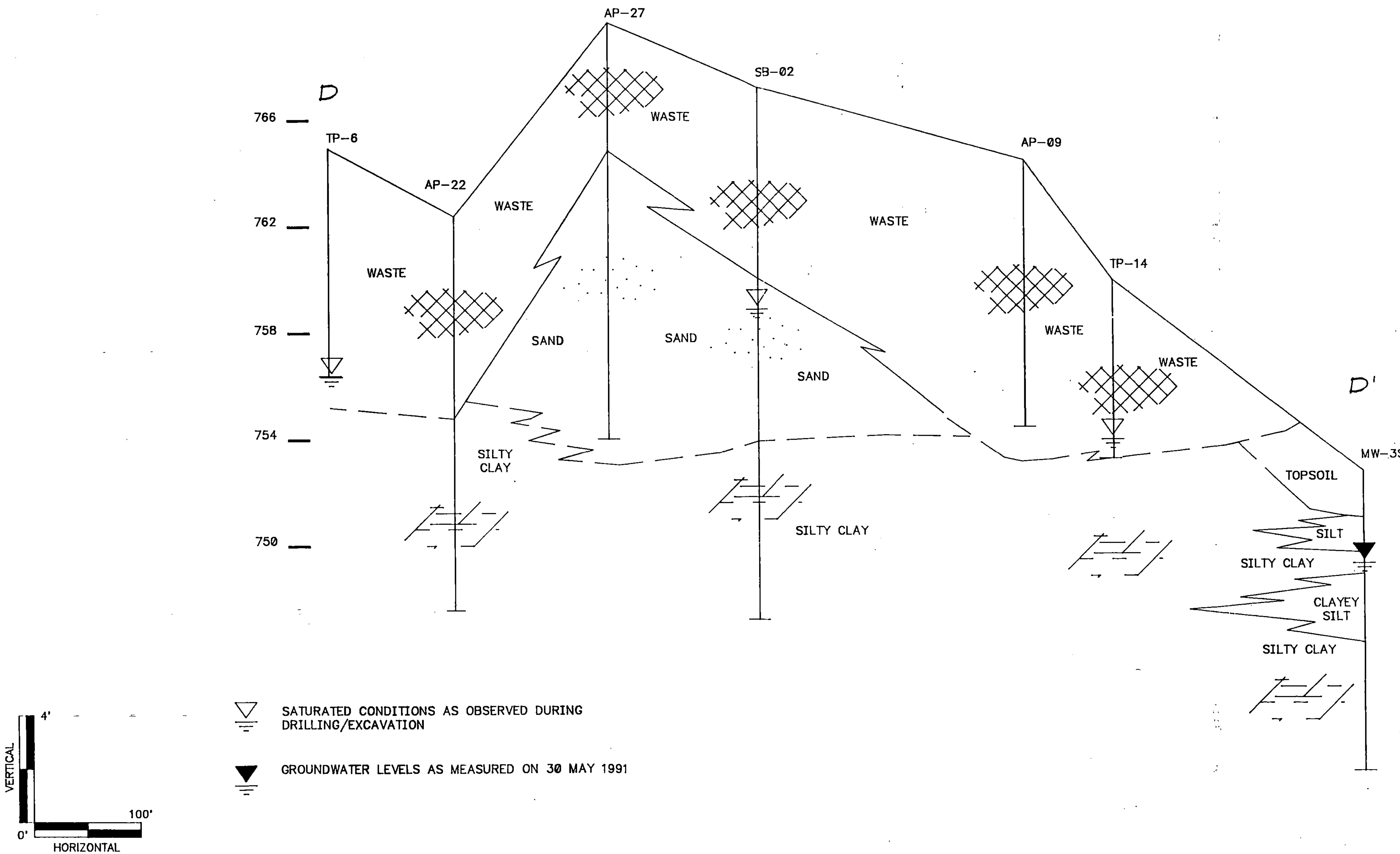
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

FIGURE 7-5

CROSS-SECTION C – C'

LINDEN ROAD LANDFILL
Flint, Michigan

64791 B



SATURATED CONDITIONS AS OBSERVED DURING DRILLING/EXCAVATION

GROUNDWATER LEVELS AS MEASURED ON 30 MAY 1991

WESTON MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway
Vernon Hills, Illinois
60061

FIGURE 7-6

CROSS-SECTION D – D'

LINDEN ROAD LANDFILL
Flint, Michigan

64891 C

The subsurface data were collected at a limited number of locations and may introduce a bias in the calculations. Based on field observations, the test pits and auger probes did not penetrate the entire thickness of the waste in all locations. Furthermore, the "Surfer" program tended to "smooth" topographic highs and lows. The maximum thickness of waste encountered at the Site was 15 feet in Soil Boring SB-01. The "Surfer" program eliminated this value based on the number of data points. The program also considered that waste was present along all the boundaries of the Site, which is not true as indicated by drilling. Therefore, the waste volume estimate of 275,000 cubic yards is considered strictly an estimate.

For comparison purposes, a simplistic situation was also considered. The average thickness of waste material, based on SI data, is 5.25 feet. Assuming that the Site was flat and the waste was evenly distributed, the volume of waste was calculated for the 40-acre Site using the average waste thickness. The volume of waste was calculated to be 340,000 cubic yards.

7.3 GROUNDWATER QUALITY

7.3.1 Shallow Water-Bearing Zone

Four wells were placed in the shallow water-bearing zone to assess shallow groundwater quality at the Site. Analytical results of samples collected from shallow wells during the first and second rounds of sampling indicate that in general only trace levels of organic and inorganic compounds were detected in samples from the shallow monitoring wells and piezometers. However, a single well (MW-01S) indicated the presence of trichloroethene at elevated concentrations during both rounds of sampling. This well (MW-01S) is located near the west boundary of the Site (Figure 4-6) which is an upgradient location with respect to shallow groundwater flow direction. During the drilling of this well, waste material was encountered from the surface to 8 feet below grade. A soil sample collected from a depth interval of 6 to 8 feet (in waste) did not contain any trichloroethene. However, a sample collected at a depth interval deeper (10 to 12 feet) in the saturated sand and gravel zone immediately above the confining layer indicated the presence of trichloroethene at a concentration of 0.140 mg/kg. This indicates that the contamination detected in the groundwater may be from a potential off-site source and that the TCE in the saturated soil is due to adsorption from groundwater. Based on flow directions and the above analyses, it is likely that the TCE contamination detected in MW-01S is contributed by Dye Road Dump or some other upgradient source(s).

TCE was also detected at trace levels in another upgradient well (MW-3S) located along the southern boundary of the Site, and in piezometer PZ-01 along the western boundary with the Dye Road Dump. Another compound, 1,2-dichloroethene, was also detected at trace levels in groundwater from all three upgradient locations (MW-01S, PZ-01, and MW-03S). The compound 1,1-dichloroethane was detected in trace levels in MW-03S and PZ-01, but not in any of the downgradient wells or piezometers. The compound 1,2-dichloropropane was detected only in PZ-01 at slightly elevated levels. None of the above compounds were detected in any of the downgradient wells (MW-02S, MW-04S) or the piezometer (PZ-02), which indicates that these compounds are probably the result of one or more off-site sources.

Among the downgradient monitoring wells, MW-02S did not detect any VOCs during either round of sampling. The groundwater sample for PZ-02 contained a few VOCs at trace levels (including benzene, 4-methyl-pentanone, chlorobenzene, ethylbenzene, and xylene) that were not detected in any of the other groundwater samples analyzed from either round. The presence of these compounds may be due to isolated sources within the Site near PZ-02.

Only trace levels of other organic and inorganic compounds were found in the groundwater samples from both rounds of sampling. Based upon the results of the groundwater sampling, it appears that the Site is not contributing to significant groundwater contamination.

7.3.2 Deep Water-Bearing Zone

Three deep wells were installed in the water-bearing zone underlying a silty clay confining unit. Laboratory permeability testing of the silty clay confining unit indicated permeabilities in the order of 10^{-8} cm/sec. These values indicate that the confining layer at the Site acts as an impermeable barrier to contaminant migration of the shallow water-bearing zone to the deeper water-bearing zone. The results of the monitoring well samples confirmed that the deeper water-bearing zone is not affected by Site waste and the confining clay unit is very likely continuous across the Site, protecting the deeper water-bearing zone from migration of contaminants. The clay confining unit probably extends to the west of the Site, as upgradient groundwater has not impacted deep groundwater at the Site.

The deep water-bearing zone is confined and consists of thin (0.5 - 2.5 ft.) isolated sand lenses in a low-permeability silty clay matrix. The groundwater in the deep water-bearing zone is of insufficient quantity for use as a resource. This deep water-bearing zone can be used to monitor groundwater quality beneath the clay confining layer and also can be an indicator of potential changes in water quality in the underlying aquifer(s).

7.4 SURFACE WATER QUALITY

Sampling investigations of surface water samples indicate that surface water quality from the on-site ponds has not been significantly impacted by the Site. Maximum concentrations for copper, lead, zinc, and nickel detected in the surface water samples exceed the U.S. EPA Ambient Water Quality Criteria (AWQC) for chronic toxicities. These minor exceedences may have resulted from runoff within the Site.

7.5 REGULATORY REQUIREMENT ANALYSIS

The goals of remedial action are determined in part by the statutory and regulatory requirements. The following State of Michigan Acts are considered in this analysis:

- Act 307 - Michigan Environmental Response Act; This Act applies to all sites of environmental contamination.
- Act 64 - The Hazardous Waste Management Act; This Act applies to generators, transporters, and facilities which treat, store, and dispose of hazardous waste after 1980.
- Act 641 - The Solid Waste Management Act; This Act applies to non-hazardous solid waste landfills, solid waste processing plants, solid waste transfer facilities, solid waste transporting units and other solid waste management activities after 1978.
- Act 368 - Public Health Code (1978)

Pursuant to these Acts, various regulations have been established by various agencies in the State of Michigan.

7.5.1 Chemical-Specific Regulations

In general, chemical specific regulations are health-based or risk-based standards or methodologies which may apply to the site. The chemical specific regulations are important to determining the extent of soil and groundwater remediation as well as determining the allowable residual levels of contaminants. Chemical specific regulations have not been established under Acts 64, 641 and 368 for the contaminated soils at the Site. Under Act 307, chemical-specific criteria have been established for soils and groundwater cleanup (Type B) based on standardized risk assessment procedures. Chemical-specific regulations for groundwater are not evaluated because the groundwater under the site is presently not impacted significantly by the material at the site.

7.5.2 Location-Specific Regulations

Location specific regulations are restrictions placed upon the concentrations of hazardous substances or the conduct of activities solely because they are in a specific location such as 100-year floodplain, wetland, historical sites etc., of the Site. There are location-specific regulations in Acts 64 and 641 which may apply to the Site.

7.5.3 Action-Specific Regulations

Action-specific regulations are applicable technology-based requirements for the implementation of a specific remedial action. Action-specific regulations pertaining to Acts 64, 641, and 368 will apply to the Site as presented in Tables 7-1 and 7-2.

TABLE 7-1

STATE OF MICHIGAN POTENTIAL REGULATIONS APPLICABLE TO SOIL

REQUIREMENTS	DESCRIPTION	COMMENTS
HAZARDOUS WASTE REQUIREMENTS		
Hazardous Waste Management Act, PA 64.	This act establishes requirements for the facilities treating, generating, storing, disposing, or transporting the hazardous waste.	This act was not in place when the Site was operational (i.e., prior to 1980) and hence the applicability is not well defined unless the materials were to be removed for off- site disposal.
Hazardous Waste Management Act, PA 64, Generator of Hazardous Waste, Rule R299.9305, R299.9307 and R299.9308.	These rules establish the requirements for generators of hazardous waste.	This is potentially applicable if waste on the site is removed and transported to an off-site TSD facility for treatment or disposal.
Hazardous Waste Management Act, PA 64, Transporters of Hazardous Waste, Rule R299.9402 through R299.9412.	These rules establish the requirements for transportation of hazardous waste.	This is a potentially applicable if waste disposed on-site prior to 1980 is removed and transported to an off-site facility for treatment or disposal.

TABLE 7-1 (Cont.)

STATE OF MICHIGAN POTENTIAL REGULATIONS APPLICABLE TO SOIL

REQUIREMENTS	DESCRIPTION	COMMENTS
Hazardous Waste Management Act, PA 64, Owners and Operators of Hazardous Waste TSD Facility, Rule R299.9619.	This rule provides the regulatory requirements for closure of the landfill.	This is potentially applicable if the remedial action selected for the Site requires final cover in accordance with this act.
Hazardous Waste Management Act, PA 64, Owners and Operators of Hazardous Waste TSD Facility, Rule R299.9602, R299.9623 through R299.9625.	These rules provide requirements for operating an on-site incinerator.	This is potentially applicable if the on-site contaminated materials are excavated and incinerated on-site.
ENVIRONMENTAL CONTAMINATION RESPONSE ACT, ACT 307 OF 1982	This Act regulates sites with known contamination.	This rule is applicable since the on-site contamination at the site is known through investigations.
Environmental Contamination Response Act, Act 307, Part 5, Response Activity, Rule R299.5509.	The rules in Part 5 of this act describes the regulatory response activities at the site in order to reduce or eliminate potential exposure (to on-site contaminants) of nearby population, animals and food chain.	This is potentially applicable since response activities, such as further remedial action, may be required to reduce or eliminate potential exposure to on-site contaminants of nearby population, and animal and food chain.

\WO\W1000\5130T.7-2

TABLE 7-1 (Cont.)

STATE OF MICHIGAN POTENTIAL REGULATIONS APPLICABLE TO SOIL

REQUIREMENTS	DESCRIPTION	COMMENTS
Environmental Contamination Response Act, Act 307, Part 5, Monitoring Requirements, Rule R299.5519.	This rule in Part 5 of this act describe the regulatory requirements for long-term monitoring of the environmental media in order to determine the effectiveness of response activities in protecting the human health and the environment.	This is potentially applicable to the site since monitoring may be required at the site in order to determine the effectiveness of the response activity performed at the Site.
Environmental Contamination Response Act, Act 307, Part 7, Cleanup Criteria, Rule R299.5717 and R299.5719.	This part of the Act describes the clean up criteria requirements.	This is potentially applicable to the site. The cleanup criteria for the site may be according to the type C criteria described in the rules. A site-specific assessment has been done for the Site. If containment is the only remedial action selected for the site, long-term monitoring and land use restrictions may be required.
<u>MICHIGAN SOLID WASTE MANAGEMENT RULES, ACT 641</u>	This act describes the final cover requirements for a sanitary/solid waste landfill.	This act is potentially applicable for the final cover of the landfill.

TABLE 7-1 (Cont.)

STATE OF MICHIGAN POTENTIAL REGULATIONS APPLICABLE TO SOIL

REQUIREMENTS	DESCRIPTION	COMMENTS
Michigan Solid Waste Management Rules, Act 641, Part 3, Sanitary Landfills, Rule 299.4305.	This rule describes the long-term monitoring requirements at the Site.	This rule is potentially applicable if the remedial action selected for the Site requires final cover in accordance with this rule.

\WO\W1000\5130T.7-2

TABLE 7-2

STATE OF MICHIGAN POTENTIAL REGULATIONS FOR GROUNDWATER

REQUIREMENTS	DESCRIPTION	COMMENTS
MICHIGAN GROUND WATER QUALITY CONTROL ACT, ACT 368	The act regulates construction of public water supply wells and water works systems, and establishes criteria for drinking water.	This act is potentially applicable for the wells installed in future in the areas around the site.
Michigan Groundwater Quality Control Act, Act 368 Public Health Code Ground Water Quality Control, Part 127, Rule, 131 and 133.	These rules provide requirements for future installation of drinking water wells.	These rules are potentially applicable for the Site for installation of future drinking water wells in the vicinity of the Site. The rules require the casings to extend at least 25 feet below the established ground surface and be grouted in place. The well cannot be used if constructed to a depth less than 25 feet without the written approval of the health officer.
ENVIRONMENTAL CONTAMINATION RESPONSE ACT, ACT 307	This act is applicable to the sites with known contamination.	This act is potentially applicable to the site in order to monitor if the contaminants are migrating into the groundwater after remedial action of on-site materials.

\WO\W1000\5130T.7-3

TABLE 7-2 (Cont.)

STATE OF MICHIGAN POTENTIAL REGULATIONS FOR GROUNDWATER

REQUIREMENTS	DESCRIPTION	COMMENTS
Environmental Contamination Response Act, Act 307, Part 5, Monitoring Requirements Rule R299.5519 and Part 7, Rule R299.5719.	These rules describe the long-term monitoring requirements at the Site.	These rules may be applicable requiring long-term groundwater monitoring in order to determine the effectiveness of the remedial action selected at the site in order to protect the groundwater.

7.5.4 Summary

A summary of the applicable or relevant and appropriate requirements of the current Michigan regulations that may apply to the Site is presented in Table 7-1 for soils and Table 7-2 for groundwater. The preliminary remedial alternatives evaluations for source control and containment developed for the Site are, in general, consistent with the Michigan regulations. The site specific public health evaluation has addressed the potential risks in the absence of any remedial action at the Site.

APPENDIX B

PUBLIC HEALTH EVALUATION
(SECTION 6 OF IRME AND SI REPORT)

SECTION 6

PUBLIC HEALTH EVALUATION

This public health evaluation assesses the potential human health risks associated with the Site after completion of a limited removal. Samples collected during the Interim Remedial Measures Evaluation indicated that a limited quantity of dark yellowish-brown greasy waste material (wrapped in foil) with a high PCB content existed at the surface in Area 32B. In addition, a small oil disposal area was found to contain trichloroethene above the TCLP regulatory limit. This risk assessment assumes that these materials have been removed from the site. No other remedial actions are considered to have occurred at the Site for the purpose of evaluating the potential human health risks for both present and future uses of the Site. In addition, potential health effects associated with the earthmoving activities assumed to precede any land development are evaluated for the Site. Also included is an evaluation of the ecological risks associated with the Site.

The scope of this risk assessment includes an evaluation of both current and future human health and environmental risks. Current risks are based on measured environmental monitoring results. Future risks can be based either on environmental modeling predictions of future chemical concentrations, or on the assumption that current chemical concentrations will persist in the future. The future risks presented in this report are based on current chemical levels, both because this is a conservative assumption and because environmental modeling was not within the scope of this study.

This risk assessment summarizes and interprets the data collected during the SI in order to characterize the surface water and soil quality at the Site, and also identifies known and potential chemical exposure pathways and receptors. Finally, it assesses quantitatively the actual and potential adverse impacts on human health and the environment that are associated with the Site. The risk assessment includes four major components:

- Identification of chemicals of potential concern.
- Exposure assessment.
- Toxicity assessment.
- Risk characterization.

The primary guidance documents used in the preparation of this report were Risk Assessment Guidance for Superfund -- Volume I (Human Health Evaluation Manual), Volume II (Environmental Evaluation Manual) and its Supplemental Guidance (U.S. EPA, 1989c, 1989d, and 1991b). Other documents that were used included the Endangerment Assessment Handbook (U.S. EPA, 1985b), the Superfund Exposure Assessment Manual (U.S. EPA, 1988b), and the Exposure Factors Handbook (U.S. EPA, 1989b).

6.1 <u>IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN</u>

The environmental media at the site were characterized by sampling soil, surface water, and groundwater. The chemicals that were found included volatile organic compounds (VOCs), semivolatile organic compounds, pesticides, and inorganic (metal) compounds. The following subsections describe the assessment of the various media, the evaluation of data quality, the chemical screening, and the identification of the chemicals of potential concern.

6.1.1 <u>Quality Control</u>

Laboratory analyses were performed according to RAS procedures by a CLP-approved laboratory. Data validation (i.e., coordination, tracking, and data package review) was performed by WESTON's Sample Management Coordinator.

CLP laboratory data qualifiers were provided by the laboratory along with the raw data, and the qualified raw data were used based on established criteria (U.S. EPA, 1989c).

Three types of blank samples were used to aid in the QA/QC effort: trip blanks, field blanks, and laboratory blanks. A trip blank is used to indicate potential contamination due to migration of VOCs from the air at the Site or in the sample shipping containers, through the septum or around the lid of the sampling vial, and into the sample. It consists of distilled, deionized water in a glass vial that has been sealed with a teflon septum, and it accompanies the sample vials into the field and back to the laboratory for analysis. A field blank is used to determine whether certain field sampling or cleaning procedures result in cross-contamination of the site samples. It is similar to a trip blank, except in that it is opened in the field and used as a sample would be. A laboratory blank sample is used to indicate potential contamination during laboratory analysis. It results from the treatment in the laboratory of a sample of distilled, deionized water with all of the reagents and manipulations to which the site samples are subjected (U.S. EPA, 1989c).

6.1.2 <u>Data Evaluation</u>

The analysis of the data obtained from the Site was based on guidance presented in <u>Risk Assessment Guidance for Superfund</u> (U.S. EPA, 1989c).

If data were qualified by the CLP laboratory as unusable, they were eliminated from the data set. If data were qualified as being estimated or diluted, they were used as presented. Thus, in general, data with qualifiers that indicate uncertainty in concentration but not in identification were included in the data set. If a sample was re-analyzed, the data from the re-analysis were used in place of the data from the initial analysis. If a sample was duplicated (i.e., in the field), then, depending on the analytical results, one of the following occurred: if both duplicates had positive detections, the two values were averaged; if only one duplicate had a positive detection, that value was used in the data set and the nondetect was ignored; or, if both duplicates were nondetect, the lower sample quantitation limit was used in the data set. The sample quantitation limit (SQL) is the lowest concentration that can be accurately and reproducibly quantitated in a particular sample. It depends on such things as the sample matrix, preparation, and handling, as well as on the detection limit of the analytical method used. The SQL is usually equal to three to five times the instrument detection limit, but this varies for different chemicals and different samples (U.S. EPA, 1989c). A sample is considered to be "nondetect" for a particular chemical when that chemical is not detected at a concentration above the SQL. When a nondetect was encountered in the data, one-half of the SQL was used in subsequent calculations as a "proxy," or estimated, concentration for that chemical in that sample. However, if such a proxy concentration exceeded the highest positively detected concentration for the chemical, then that large proxy concentration was eliminated from further calculations. If a chemical was not found in any sample at a detectable concentration, that chemical was eliminated from further quantitative consideration.

Acetone, 2-butanone (methyl ethyl ketone), methylene chloride, toluene, and the phthalate esters are commonly used in analytical laboratories; these chemicals are termed "common laboratory contaminants" by U.S. EPA. In accordance with U.S. EPA guidance (U.S. EPA, 1989c), if a trip, field, or laboratory blank sample contained a detectable level of a common laboratory contaminant, then detections of that contaminant in corresponding site samples were considered to be positive only if they exceeded 10 times the maximum amount detected in any associated blank. If a blank contained an organic or inorganic chemical that is not considered to be a common laboratory contaminant, then the site sample results were considered to be positive only if they exceeded 5 times the maximum amount detected in any associated blank. If a sample concentration did not exceed 5 times the blank concentration (or 10 times, for common laboratory contaminants), then the sample was considered to be nondetect for that chemical, and the blank-related concentration was used as the quantitation limit for the contaminant in that sample.

6.1.3 Characterization of Site Media

The purpose of this subsection is to describe the existing levels of chemicals in the environmental media of concern at the Site. A checklist of the chemical constituents detected in each medium is presented as Table 6-1.

After the initial data analysis, the chemicals found in each medium were summarized by frequency of detection (the ratio of the number of samples in which the chemical was positively detected to the number of samples available), the minimum and maximum positively detected concentrations, and the average and maximum exposure concentrations. The average exposure concentration was calculated as the geometric mean of all of the chemical concentrations (i.e., both positively detected and proxy concentrations), and the maximum exposure concentration was calculated as the minimum of either the upper 95 percent confidence limit on the arithmetic mean of the chemical concentrations, or the maximum positively detected concentration.

Table 6-1

Checklist of Detected Chemicals by Medium
Linden Road Landfill
Flint, Michigan

Chemical	Surface Soil (0-3 feet)	Near-Surface Soil (0-10 feet)	Surface Water	Groundwater (Shallow)	Groundwater (Deep)
<u>Inorganics</u>					
Aluminum	✓	✓	✓		
Antimony		✓			
Arsenic	✓	✓	✓	✓	✓
Barium	✓	✓	✓	✓	✓
Beryllium	✓	✓			
Cadmium	✓	✓			
Calcium	✓	✓	✓	✓	✓
Chromium	✓	✓			
Cobalt	✓	✓	✓		
Copper	✓	✓	✓		
Iron	✓	✓	✓	✓	✓
Lead	✓	✓	✓	✓	✓
Magnesium	✓	✓	✓	✓	✓
Manganese	✓	✓	✓	✓	✓
Mercury	✓	✓			
Nickel	✓	✓	✓	✓	
Potassium	✓	✓	✓	✓	✓
Selenium	✓	✓		✓	
Sodium	✓	✓	✓	✓	✓
Thallium		✓			
Vanadium	✓	✓			
Zinc	✓	✓	✓	✓	✓
Cyanide	✓	✓			

Table 6-1 (Continued)

Checklist of Detected Chemicals by Medium
Linden Road Landfill
Flint, Michigan

Chemical	Surface Soil (0-3 feet)	Near-Surface Soil (0-10 feet)	Surface Water	Groundwater (Shallow)	Groundwater (Deep)
Organics					
Methylene chloride	✓	✓			
Acetone	✓	✓			
Carbon disulfide	✓	✓	✓		
1,1-Dichloroethane	✓	✓		✓	
1,2-Dichloroethene (total)	✓	✓		✓	
Chloroform	✓	✓			
1,2-Dichloroethane				✓	
2-Butanone	✓	✓		✓	
1,2-Dichloropropane				✓	
1,1,1-Trichloroethane	✓	✓			
Trichloroethene	✓	✓		✓	
Benzene	✓	✓		✓	
Tetrachloroethene	✓	✓			
4-Methyl-2-pentanone		✓		✓	
1,1,2,2-Tetrachloroethane	✓	✓			
Toluene	✓	✓		✓	
Ethylbenzene	✓	✓		✓	
Chlorobenzene	✓	✓		✓	
Xylenes (total)	✓	✓		✓	
Phenol	✓	✓	✓		
bis(2-Chloroisopropyl)ether		✓		✓	
2-Methylphenol			✓		
4-Methylphenol	✓	✓	✓		

Table 6-1 (Continued)

Checklist of Detected Chemicals by Medium
Linden Road Landfill
Flint, Michigan

Chemical	Surface Soil (0-3 feet)	Near-Surface Soil (0-10 feet)	Surface Water	Groundwater (Shallow)	Groundwater (Deep)
bis(2-Chloroethyl)ether			✓	✓	
Diethylphthalate					✓
1,2-Dichlorobenzene				✓	
Benzoic Acid		✓			
1,2,4-Trichlorobenzene		✓			
Naphthalene	✓	✓	✓	✓	
2-Methylnaphthalene	✓	✓			
Acenaphthylene	✓	✓			
Acenaphthene	✓	✓		✓	
Dibenzofuran	✓	✓		✓	
Fluorene	✓	✓		✓	
Phenanthrene	✓	✓			
Anthracene	✓	✓			
Di-n-butylphthalate	✓	✓		✓	
Fluoranthene	✓	✓			
Pyrene	✓	✓			
Benz(a)anthracene	✓	✓			
Chrysene	✓	✓			
bis(2-Ethylhexyl)phthalate	✓	✓	✓	✓	✓
Benzo(b)fluoranthene	✓	✓			
Benzo(k)fluoranthene	✓	✓			
Benzo(a)pyrene	✓	✓			
Indeno(1,2,3-cd)pyrene	✓	✓		✓	

Table 6-1 (Continued)

Checklist of Detected Chemicals by Medium
Linden Road Landfill
Flint, Michigan

Chemical	Surface Soil (0-3 feet)	Near-Surface Soil (0-10 feet)	Surface Water	Groundwater (Shallow)	Groundwater (Deep)
Dibenz(a,h)anthracene	✓	✓			
Benzo(g,h,i)perylene	✓	✓		✓	
alpha-BHC	✓	✓	✓	✓	✓
delta-BHC	✓	✓			
4,4'-DDT	✓	✓			
Aroclor 1248	✓	✓			
Aroclor 1254	✓	✓		✓	
Aroclor 1260	✓	✓			

The soil samples were divided into three groups according to sampling depth. The samples in the first group were obtained primarily from a depth of 0-3 feet (i.e., surface soil), which is the depth to which a site trespasser could reasonably be expected to be exposed. The samples in the second group were obtained primarily from a depth of 0-10 feet (i.e., near-surface soil). This depth range accounts for the soil to which a potential on-site construction worker could be exposed during excavation activities. The samples in the third group were obtained primarily from a depth of greater than 10 feet. Since direct exposure to soil at this depth is very unlikely, samples in this group were not examined in the quantitative risk assessment. The chemicals detected in the on-site surface soil (0-3 foot depth) are presented in Table 6-2. The chemicals detected in the on-site near-surface soil (0-10 foot depth) are presented in Table 6-3.

Several surface water samples were collected from the trenches and ponded areas on the Site. The chemicals detected in the on-site surface water are presented in Table 6-4. The sediment associated with the on-site surface water features was not sampled during the SI.

In order to characterize the groundwater quality at the Site, monitoring well nests were installed that tapped into two vertical saturated zones. Thus, the quality in both the "shallow" and the "deep" groundwater was characterized. Several organic chemicals were detected in the shallow groundwater (Table 6-1), although the detected concentrations were relatively low. There were only three very low detections of organic chemicals in the deep groundwater, and two of these were of phthalate esters (at 0.001 mg/L), which are considered by U.S. EPA to be common laboratory contaminants. The third compound detected was alpha-BHC (at 0.000012 mg/L) in the upgradient well (MW-01D). No inorganic chemical was detected at an elevated concentration in either the shallow or the deep groundwater. A detailed summary of the chemicals detected in the groundwater is presented elsewhere in this document. As will be discussed in Section 6.2.1.6, no exposure to site groundwater is evident or anticipated in the future.

Surface waste samples were collected during the Interim Remedial Measures Evaluation at the Site in order to assess the need for any interim action at the Site. However, this risk assessment was based only on the data collected during the SI.

6.1.4 <u>Chemical Screening</u>

Over 70 chemicals (including volatile organics, semivolatile organics, pesticides, and inorganics) were detected in the various environmental media sampled at the Site. In addition, several tentatively identified compounds (TICs) were reported by the analytical laboratory. In order to provide a workable format for the detailed risk analysis, a reduced list of chemicals was developed that was used to estimate exposures and to characterize the risk associated with the Site. This list of chemicals of potential concern was developed by eliminating certain chemicals from the list of all chemicals detected at the Site according to risk assessment procedures. These chemicals were eliminated either because they have no associated health criteria or because, on the basis of concentration and toxicity

Table 6-2

Concentration and Frequency of Detection of Site Chemicals:
Surface Soil (0-3 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Range of Detected Concentrations		Exposure Concentration	
		Minimum	Maximum	Average[1]	Maximum[2]
Inorganics					
Aluminum	10/10	403	117,000	4,120	36,300
Arsenic	9/10	1.7	27.6	7.82	18.6
Barium	9/10	43.4	723	127	318
Beryllium	2/10	2.1	2.8	0.74	1.43
Cadmium	3/10	1.7	20.6	0.88	6.48
Calcium	10/10	423	79,600	12,800	45,800
Chromium	10/10	14.1	3,030	123	1,090
Cobalt	9/10	5.7	79.1	11.0	30.6
Copper	9/10	9.6	6,680	68.0	1,860
Iron	10/10	2,260	138,000	22,600	69,000
Lead	10/10	19.5	2,720	188	956
Magnesium	10/10	2,580	19,400	5,720	11,000
Manganese	10/10	21.5	7,510	492	2,740
Mercury	4/10	0.14	1.2	0.11	0.43
Nickel	9/10	11.1	797	96.9	392
Potassium	5/10	222	1,180	418	720
Selenium	5/10	0.25	2.7	0.54	1.34
Sodium	10/10	86.4	1,140	236	485
Vanadium	9/10	5.1	34.9	12.6	26.1
Zinc	10/10	9.3	1,480	90.1	501
Cyanide	3/10	0.88	65.9	0.81	19.3
Organics					
4-Methylphenol	1/8	4.3	4.3	0.90	262
Naphthalene	6/10	0.14	170	2.19	56.1
2-Methylnaphthalene	4/8	0.091	16.0	0.80	6.43
Acenaphthylene	2/6	0.53	0.66	0.37	0.57
Acenaphthene	5/8	0.53	6.5	1.19	4.07
Dibenzofuran	5/8	0.23	5.2	0.88	3.10

Table 6-2 (Continued)

Concentration and Frequency of Detection of Site Chemicals:
Surface Soil (0-3 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Range of Detected Concentrations		Exposure Concentration	
		Minimum	Maximum	Average[1]	Maximum[2]
Fluorene	5/8	0.42	7.6	1.12	4.30
Phenanthrene	7/9	0.97	130	4.54	50.4
Anthracene	5/8	0.56	23.0	1.40	9.76
Di-n-Butylphthalate	3/8	0.058	11.0	0.84	4.83
Fluoranthene	6/9	1.50	290	5.16	102
Pyrene	8/9	0.062	230	4.36	82.9
Benz(a)Anthracene	4/9	2.40	200	4.94	73.3
Chrysene	6/9	0.81	220	3.58	78.0
bis(2-Ethylhexyl)Phthalate	4/8	0.098	3.10	0.70	2.28
Benzo(b)Fluoranthene	4/9	2.30	240	4.63	84.7
Benzo(k)Fluoranthene	4/9	0.72	100	2.87	39.5
Benzo(a)Pyrene	4/9	1.60	210	4.14	74.7
Indeno(1,2,3-cd)Pyrene	4/9	0.75	170	4.15	63.1
Dibenz(a,h)Anthracene	3/9	2.70	75.0	2.78	33.0
Benzo(g,h,i)Perylene	4/9	4.60	200	5.46	73.8
Methylene Chloride	9/10	0.021	56,000	0.42	15,900
Acetone	6/10	0.12	130	0.15	37.1
Carbon Disulfide	1/9	0.13	0.13	0.0054	0.044
1,1-Dichloroethane	1/9	1.20	1.20	0.0069	0.384
1,2-Dichloroethene (total)	3/9	0.009	0.19	0.011	0.073
Chloroform	1/10	100	100	0.012	28.3
2-Butanone	4/10	0.009	1,900	0.038	538
1,1,1-Trichloroethane	2/10	1.10	92.0	0.018	26.2
Trichloroethene	8/10	0.003	47.0	109	14.7
Benzene	3/9	0.004	0.26	0.0073	0.088
Tetrachloroethene	7/9	0.007	0.066	0.017	0.042
1,1,2,2-Tetrachloroethane	4/9	0.018	0.094	0.011	0.046
Toluene	10/10	0.006	18,000	0.229	5,100

Table 6-2 (Continued)

Concentration and Frequency of Detection of Site Chemicals:
Surface Soil (0-3 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Range of Detected Concentrations		Exposure Concentration	
		Minimum	Maximum	Average[1]	Maximum[2]
Chlorobenzene	3/8	0.003	0.005	0.0038	0.0044
Ethylbenzene	6/10	0.006	5,300	0.059	1.500
Xylenes (total)	7/10	0.004	34,000	0.192	9,630
alpha-BHC	2/7	0.033	0.21	0.030	0.108
delta-BHC	1/8	0.28	0.28	0.044	0.170
4,4'-DDT	1/7	0.47	0.47	0.066	0.245
Aroclor-1248	1/7	4.80	4.80	0.458	2.60
Aroclor-1254	5/10	0.098	110	3.57	39.6
Aroclor-1260	1/6	3.70	3.70	0.584	2.26

[1]The average exposure concentration is the geometric mean of the data.
[2]The maximum epxosure concentration is the minimum of either the maximum detected concentration or the upper 95 percent confidence limit on the arithmetic mean of the data.

Table 6-3

Concentration and Frequency of Detection of Site Chemicals:
Near-Surface Soil (0-10 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Range of Detected Concentrations		Exposure Concentration	
		Minimum	Maximum	Average[1]	Maximum[2]
Inorganics					
Aluminum	35/35	403	117,000	4,710	14,100
Antimony	6/35	28.6	1,130	28.4	175
Arsenic	33/35	1.7	130	13.3	26.7
Barium	34/35	34.8	4,840	313	1,050
Beryllium	11/33	0.83	3.2	0.83	1.3
Cadmium	13/35	1.0	40.1	1.45	7.26
Calcium	35/35	423	79,600	15,100	29,100
Chromium	35/35	6.1	24,800	202	2,470
Cobalt	31/34	5.7	99.9	12.6	23.3
Copper	34/35	5.9	6,680	160	940
Iron	35/35	2,130	414,000	46,000	111,000
Lead	35/35	8.5	115,000	418	10,500
Magnesium	35/35	183	19,400	4,250	7,960
Manganese	35/35	21.5	8,660	915	2,270
Mercury	22/35	0.14	1.6	0.21	0.51
Nickel	33/35	11.1	5,470	183	905
Potassium	20/34	222	1,700	413	728
Selenium	20/35	0.25	40.2	0.72	4.18
Sodium	33/35	86.4	1,260	266	453
Thallium	3/34	0.77	1.1	0.41	0.49
Vanadium	31/35	5.1	311	22.7	50.4
Zinc	35/35	9.3	3,310	222	828
Cyanide	14/35	0.69	65.9	0.64	6.22
Organics					
Phenol	3/29	0.58	1.20	0.021	0.34
bis(2-Chloroisopropyl)Ether	1/10	0.46	0.46	0.24	0.30
4-Methylphenol	1/35	4.30	4.30	0.38	1.75
Benzoic Acid	1/1	0.76	0.76	0.76	0.76

Table 6-3 (Continued)

Concentration and Frequency of Detection of Site Chemicals:
Near-Surface Soil (0-10 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Range of Detected Concentrations		Exposure Concentration	
		Minimum	Maximum	Average[1]	Maximum[2]
1,2,4-Trichlorobenzene	3/35	0.67	87.0	1.17	12.0
Naphthalene	23/35	0.049	380	2.04	51.8
2-Methylnaphthalene	21/35	0.061	71.0	1.22	11.8
Acenaphthylene	4/18	0.16	1.7	0.13	0.57
Acenaphthene	20/35	0.060	22.0	0.82	4.26
Dibenzofuran	20/35	0.075	20.0	0.66	3.47
Fluorene	20/35	0.093	25.0	0.89	5.05
Phenanthrene	28/35	0.54	130	4.35	30.7
Anthracene	20/35	0.11	23.0	0.79	4.45
Di-n-Butylphthalate	16/35	0.058	4,700	2.15	387
Fluoranthene	28/35	0.078	290	4.06	38.2
Pyrene	30/35	0.062	230	5.02	39.5
Benz(a)Anthracene	23/35	0.078	200	3.01	27.5
Chrysene	25/35	0.090	220	2.57	28.0
bis(2-Ethylhexyl)Phthalate	20/35	0.093	35.0	0.87	6.52
Benzo(b)Fluoranthene	12/35	2.30	240	2.52	28.5
Benzo(k)Fluoranthene	12/35	0.72	100	1.98	17.3
Benzo(a)Pyrene	10/35	1.60	210	2.28	25.3
Indeno(1,2,3-cd)Pyrene	11/35	0.75	170	2.38	22.7
Dibenz(a,h)Anthracene	6/35	1.70	75.0	1.69	14.3
Benzo(g,h,i)Perylene	12/35	4.60	200	2.66	25.9
Methylene Chloride	24/35	0.021	56,000	0.14	4,340
Acetone	20/35	0.080	130	0.13	10.7
Carbon Disulfide	5/35	0.008	0.13	0.0043	0.016
1,1-Dichloroethane	3/35	0.005	1.20	0.0056	0.12
1,2-Dichloroethene (total)	7/35	0.009	15.0	0.0082	1.19
Chloroform	3/35	0.032	100	0.0076	7.84
2-Butanone	8/35	0.009	1,900	0.020	147

Table 6-3 (Continued)

Concentration and Frequency of Detection of Site Chemicals:
Near-Surface Soil (0-10 feet)
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Chemical	Frequency of Detection	Range of Detected Concentrations		Exposure Concentration	
		Minimum	Maximum	Average[1]	Maximum[2]
1,1,1-Trichloroethane	2/35	1.10	92.0	0.0075	7.19
Trichloroethene	24/35	0.003	47.0	0.035	4.66
Benzene	13/35	0.003	40.0	0.0081	3.32
4-Methyl-2-Pentanone	1/35	160	160	0.015	16.0
Tetrachloroethene	14/35	0.007	0.071	0.007	0.021
1,1,2,2-Tetrachloroethane	12/35	0.007	0.094	0.0065	0.021
Toluene	35/35	0.004	18,000	0.085	1,410
Chlorobenzene	3/35	0.003	0.005	0.003	0.0035
Ethylbenzene	21/35	0.002	5,300	0.033	419
Xylenes (total)	26/35	0.004	34,000	0.114	2.660
alpha-BHC	5/35	0.015	0.32	0.030	0.118
delta-BHC	3/35	0.023	0.83	0.053	0.206
4,4'-DDT	4/35	0.024	0.47	0.030	0.160
Aroclor-1248	1/35	4.80	4.80	0.23	1.38
Aroclor-1254	16/35	0.098	110	3.14	21.9
Aroclor-1260	2/28	0.12	3.70	0.158	1.15

[1]The average exposure concentration is the geometric mean of the data.
[2]The maximum exposure concentration is the minimum of either the maximum detected concentration or the upper 95 percent confidence limit on the arithmetic mean of the data.

Table 6-4

Concentration and Frequency of Detection of Site Chemicals:
Surface Water
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/L)

Chemical	Frequency of Detection	Range of Detected Concentrations		Exposure Concentration	
		Minimum	Maximum	Average[1]	Maximum[2]
Inorganics					
Aluminum	4/5	0.22	0.73	0.29	0.62
Arsenic	5/5	0.0027	0.0057	0.0041	0.0054
Barium	5/5	0.070	0.42	0.17	0.34
Calcium	5/5	75.2	238	122	193
Cobalt	1/5	0.030	0.030	0.012	0.022
Copper	1/5	0.025	0.025	0.012	0.019
Iron	5/5	0.82	4.10	1.48	3.06
Lead	4/5	0.0035	0.012	0.0045	0.010
Magnesium	5/5	23.8	88.2	59.5	88.2
Manganese	5/5	0.20	8.90	0.78	5.80
Nickel	2/5	0.0035	0.80	0.031	0.051
Potassium	5/5	13.8	24.5	19.7	23.9
Sodium	5/5	13.4	59.4	34.5	54.5
Zinc	5/5	0.014	0.044	0.029	0.042
Organics					
Carbon Disulfide	4/5	0.002	0.066	0.0094	0.045
Phenol	1/5	0.005	0.005	0.005	0.005
bis(2-Chloroethyl)Ether	1/5	0.013	0.013	0.0064	0.010
2-Methylphenol	1/1	0.001	0.001	0.001	0.001
bis(2-Chloroisopropyl)ether	1/1	0.002	0.002	0.002	0.002
4-Methylphenol	1/5	0.013	0.013	0.0062	0.010
Naphthalene	1/1	0.002	0.002	0.002	0.002
bis(2-Ethylhexyl)Phthalate	1/1	0.003	0.003	0.003	0.003
alpha-BHC	1/1	0.00001	0.00001	0.00001	0.00001

[1]The average exposure concentration is the geometric mean of the data.
[2]The maximum exposure concentration is the minimum of either the maximum detected concentration or the upper 95 percent confidence limit on the arithmetic mean of the data.

information, they were not expected to contribute significantly to the overall risks associated with the Site. It should be noted, however, that the majority of the chemicals detected at the Site were examined quantitatively in the risk assessment.

In accordance with the guidance provided in Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (U.S. EPA, 1989c), the list of chemicals of potential concern includes those that were:

(1) Positively detected in at least one sample in a given medium, including (a) chemicals with no qualifiers attached (excluding samples with unusually high detection limits), and (b) chemicals with qualifiers attached that indicate known identities but unknown concentrations (e.g., J-qualified data).

(2) Detected at levels significantly elevated above levels of the same chemicals detected in associated blank samples.

(3) Detected at levels significantly elevated above naturally occurring levels of the same chemicals.

(4) Only tentatively identified but possibly associated with the Site based on historical information, or that are classified as carcinogens.

(5) Transformation products of chemicals demonstrated to be present.

The remainder of this subsection describes the screening process that was used to identify the chemicals of concern at the Site.

6.1.4.1 Chemicals In Blanks

As part of the initial screening, the Linden Road data set was reviewed to identify chemicals detected in field and/or laboratory blanks. Although several chemicals were detected in blank samples during the data analysis, no chemicals were eliminated from the quantitative analysis for the Site based on their detection in blanks. Positive detections in a small number of samples were disregarded on this basis, however, as described in Subsection 6.1.3.

6.1.4.2 Comparison With Background Levels

There are two types of background levels of chemicals in environmental media:

- Naturally occurring levels, which are the ambient concentrations of chemicals present in the environment that have not been influenced by human activities, such as the naturally occurring levels of a wide variety of metals in soil.

- Anthropogenic levels, which are the concentrations of chemicals present in the environment that are due to common human activities unrelated to the Site.

The naturally occurring levels of inorganics in regional topsoil are compared with average on-site surface (0-3 feet) and near-surface (0-10 feet) soil concentrations in Table 6-5. U.S. background ranges are also reported. No inorganic chemicals were eliminated from consideration based on comparison with background levels.

In general, comparison with naturally occurring concentrations is only applicable to inorganic chemicals, because the majority of organic compounds are not naturally occurring. Although some organic compounds (e.g., PAHs) are ubiquitous in the environment and may be derived from non-point sources such as automobiles, it is difficult to demonstrate, based on the sampling plan implemented at the Site, that organic chemicals are not present due to site-related operations. Therefore, it was assumed in this risk assessment that all organic compounds detected is a result of past disposal activities at the Site.

6.1.4.3 Chemicals With No Health Criteria

A number of chemicals detected at the Site do not have U.S. EPA-established health criteria and therefore, it is not possible to quantify the risks associated with these chemicals. These chemicals were eliminated from the quantitative analysis. Chemicals eliminated for this reason from the list of chemicals of potential concern for the Site were:

Aluminum
Calcium
Cobalt
Iron
Magnesium
Potassium
Sodium
2-Methylnaphthalene
Acenaphthylene
Dibenzofuran
Phenanthrene
Benzo(g,h,i)perylene
Delta-BHC

Lead is a special case of a chemical with no U.S. EPA-established quantitative health criteria. It appears on the list of chemicals of concern for the Site because of its known toxicity, although the health risks associated with lead exposure cannot be assessed quantitatively. Therefore, the risks associated with lead at the Site were addressed qualitatively and described separately.

Table 6-5

Soil Background Data: Inorganic Chemicals
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Inorganic Contaminant	U.S. National Background Range (Median)	Michigan Regional Topsoil Background Level (Mean)	On-Site Surface Soil (0-3 Feet) Range of Detected Concentrations	On-Site Near-Surface Soil (0-10 Feet) Range of Detected Concentrations
Aluminum	10,000- 300,000 (71,000)	4267	403 - 117,000	403 - 117,000
Antimony	0.2 - 150 (6)	NA	ND	28.6 - 1,130
Arsenic	0.1 - 194 (11)	3.2	1.7 - 27.6	1.7 - 130
Barium	100 - 3,000 (500)	36.3	43.4 - 723	34.8 - 4,840
Beryllium	0.01 - 40 (0.3)	NA	2.1 - 2.8	0.83 - 3.2
Cadmium	0.01 - 7 (0.5)	1.0	1.7 - 20.6	1.0 - 40.1
Calcium	<150 - 500,000 (24,000)	NA	423 - 79,600	423 - 79,600
Chromium	5 - 3,000 (100)	12.4	14.1 - 3,030	6.1 - 24,800
Cobalt	0.05 - 65 (8)	2.5	5.7 - 79.1	5.7 - 99.9
Copper	2 - 250 (30)	10.0	9.6 - 6,680	5.9 - 6,680
Iron	100 - 550,000 (40,000)	7,508	2,260 - 138,000	2,130 - 414,000
Lead	<1 - 888 (29)	11.5	19.5 - 2,720	8.5 - 115,000
Magnesium	400 - 9,000 (5,000)	NA	2,580 - 19,400	183 - 19,400
Manganese	20 - 18,300 (1,000)	184.3	21.5 - 7,510	21.5 - 8,660
Mercury	<0.01 - 4.6 (0.098)	0.09	0.14 - 1.2	0.14 - 1.6
Nickel	0.1 - 1,523 (50)	6.0	11.1 - 797	11.1 - 5,470
Potassium	80 - 37,000 (14,000)	NA	222 - 1,180	222 - 1,700
Selenium	0.01 - 38 (0.4)	0.27	0.25 - 2.7	0.25 - 40.2

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Table 6-5 (Continued)

Soil Background Data: Inorganic Chemicals
Linden Road Landfill
Flint, Michigan
(All Concentrations in mg/kg)

Inorganic Contaminant	U.S. National Background Range (Median)	Michigan Regional Topsoil Background Level (Mean)	On-Site Surface Soil (0-3 Feet) Range of Detected Concentrations	On-Site Near-Surface Soil (0-10 Feet) Range of Detected Concentrations
Silver	<0.01 - 8 (0.4)	NA	ND	ND
Sodium	150 - 25,000 (5,000)	NA	86.4 - 1,140	86.4 - 1,260
Thallium	0.1 - 0.8 (0.2)	NA	ND	0.77 - 1.1
Vanadium	3 - 500 (100)	NA	5.1 - 34.9	5.1 - 311
Zinc	1 - 2,000 (90)	30.9	9.3 - 1,480	9.3 - 3,310
Cyanide	NA	0.14	0.88 - 65.9	0.69 - 65.9

Source: MDNR, 1988; Bowen, 1979; Ure et al., 1983; Parr et al., 1983.
NA - Not available.
ND - Not detected.

6.1.4.4 Tentatively Identified Compounds

A tentatively identified compound (TIC) is one whose assigned identity is uncertain. Although there is no historical information that suggests that the TICs found are site-related, a further examination of the TICs in relation to the remainder of the site data was made. Because the TICs were reported infrequently and at low concentrations, and were either relatively non-toxic or had no associated health criteria, it was concluded that they would not contribute significantly to the health risks associated with the Site. Therefore, all TICs were removed from consideration as chemicals of concern in the quantitative risk assessment.

6.1.4.5 Concentration-Toxicity Screening

A concentration-toxicity screening was performed for the chemicals detected in each environmental medium at the Site based on the guidance presented in U.S. EPA's Risk Assessment Guidance for Superfund. The objective of the concentration-toxicity screening is to identify the chemicals in a particular medium that, based on concentration and toxicity, are most likely to contribute significantly to the risks calculated for exposure scenarios involving that medium. Thus, the risk assessment is focused only on the "most significant" chemicals (U.S. EPA, 1989c).

In the screening process, each chemical is assigned a score, or risk factor, based on its toxicity and its highest detected concentration in the medium. In numeric form (U.S. EPA, 1989c),

$$R_{ij} = (C_{ij})(T_{ij})$$

where:

- R_{ij} = risk factor for chemical i in medium j;
- C_{ij} = concentration of chemical i in medium j; and
- T_{ij} = toxicity value for chemical i in medium j (i.e., either the cancer slope factor or 1/Reference Dose).

The chemical scores for each medium are summed separately for carcinogenic and non-carcinogenic health risks, and then the relative contribution of each chemical to each total is determined. For this risk assessment, however, only the relative contribution to the non-carcinogenic health risk was used as a screening parameter. Those chemicals that are not known or suspected human carcinogens (i.e., that are not in weight-of-evidence classes A, B, or C), and that, on the basis of the screening, were expected to contribute less than 0.1 percent of the total non-carcinogenic health risk, were eliminated as chemicals of potential concern for the medium. Every known or suspected carcinogen was retained as a chemical of potential concern. In several instances, a chemical might have been eliminated from one medium on the basis of concentration-toxicity screening, but not from another. In these cases, the chemical was included as a chemical of potential concern for all media.

Those chemicals that were eliminated from the list of chemicals of potential concern for the Site on the basis of concentration-toxicity screening were:

- 1,2-Dichloroethene
- 1,1,1-Trichloroethene
- 4-Methyl-2-pentanone
- Chlorobenzene
- Phenol
- bis(2-chloroisopropyl)ether
- Benzoic Acid
- Acenaphthene
- Fluorene
- Anthracene

The concentration-toxicity scoring for each medium is presented in Appendix H.

6.1.5 Final List of Chemicals of Concern

The final list of chemicals of concern for the Site represents the most hazardous chemicals present at the Site. The health risks associated with these chemicals are expected to be more significant than the risks associated with the other less toxic and less prevalent chemicals that were not included in the quantitative evaluation. All carcinogenic chemicals (i.e., those in weight-of-evidence classes A, B, or C) were included as chemicals of concern.

The final list of chemicals of concern for the Site is as follows:

ORGANICS

Volatiles

- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichoroethane
- Chloroform
- 2-Butanone
- Trichloroethene
- Benzene
- Tetrachloroethene
- 1,1,2,2-Tetrachloroethane
- Toluene
- Ethylbenzene
- Xylenes (total)

INORGANICS

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Thallium
- Vanadium
- Zinc
- Cyanide

Semivolatiles

- Bis(2-chloroethyl)ether
- 4-Methylphenol
- 1,2,4-Trichlorobenzene
- Di-n-butylphthalate
- Bis(2-ethylhexyl)phthalate
- PAHs (noncarcinogenic)
  - Naphthalene
  - Fluoranthene
  - Pyrene
- PAHs (carcinogenic)
  - Benz(a)anthracene
  - Chrysene
  - Benzo(b)fluoranthene
  - Benzo(k)fluoranthene
  - Benzo(a)pyrene
  - Indeno(1,2,3-cd)pyrene
  - Dibenz(a,h)anthracene

Pesticides and PCBs

- alpha-BHC
- 4,4'-DDT
- PCBs
  - Aroclor 1248
  - Aroclor 1254
  - Aroclor 1260

Table 6-6 lists the chemicals of concern by exposure medium. As this table shows, not every chemical of concern was detected in every environmental medium sampled at the Site. For each exposure pathway evaluated in this risk assessment, the health risks were characterized based only on the chemicals of concern that were detected in the associated medium.

6.2 EXPOSURE ASSESSMENT

The purpose of the exposure assessment is to quantitatively estimate the magnitude of human exposure to the chemicals of concern at the Site. The results of the exposure assessment are combined with chemical-specific toxicity information to quantitatively estimate the human health risks associated with the Site.

Table 6-6

Checklist of Chemicals of Potential Concern by Medium
Linden Road Landfill
Flint, Michigan

Chemical	Surface Soil (0-3 feet)	Near-Surface Soil (0-10 feet)	Surface Water	Groundwater (Shallow)	Groundwater (Deep)
Inorganics					
Antimony		✓			
Arsenic	✓	✓	✓		✓
Barium	✓	✓	✓	✓	✓
Beryllium	✓	✓			
Cadmium	✓	✓			
Chromium	✓	✓			
Copper	✓	✓	✓		
Lead	✓	✓	✓		✓
Manganese	✓	✓	✓	✓	✓
Mercury	✓	✓			
Nickel	✓	✓	✓	✓	
Selenium	✓	✓		✓	
Thallium		✓			
Vanadium	✓	✓			
Zinc	✓	✓	✓		
Cyanide	✓	✓			
Organics					
Methylene chloride	✓	✓			
Acetone	✓	✓			
Carbon disulfide	✓	✓	✓		
1,1-Dichloroethane	✓	✓		✓	
Chloroform	✓	✓			
2-Butanone	✓	✓			
Trichloroethene	✓	✓		✓	

Table 6-6 (Continued)

Checklist of Chemicals of Potential Concern by Medium
Linden Road Landfill
Flint, Michigan

Chemical	Surface Soil (0-3 feet)	Near-Surface Soil (0-10 feet)	Surface Water	Groundwater (Shallow)	Groundwater (Deep)
Benzene	✓	✓			
Tetrachloroethene	✓	✓			
1,1,2,2-Tetrachloroethane	✓	✓			
Toluene	✓	✓			
Ethylbenzene	✓	✓			
Xylenes (total)	✓	✓			
2-Methylphenol			✓		
bis(2-Chloroethyl)ether			✓	✓	
1,2,4-Trichlorobenzene		✓			
Naphthalene	✓	✓	✓		
Di-n-butylphthalate	✓	✓		✓	
Fluoranthene	✓	✓			
Pyrene	✓	✓			
Benz(a)anthracene	✓	✓			
Chrysene	✓	✓			
bis(2-Ethylhexyl)phthalate	✓	✓	✓		✓
Benzo(b)fluoranthene	✓	✓			
Benzo(k)fluoranthene	✓	✓			
Benzo(a)pyrene	✓	✓			
Indeno(1,2,3-cd)pyrene	✓	✓			

Table 6-6 (Continued)

Checklist of Chemicals of Potential Concern by Medium
Linden Road Landfill
Flint, Michigan

Chemical	Surface Soil (0-3 feet)	Near-Surface Soil (0-10 feet)	Surface Water	Groundwater (Shallow)	Groundwater (Deep)
Dibenz(a,h)anthracene	✓	✓			
alpha-BHC	✓	✓	✓	✓	✓
4,4'-DDT	✓	✓			
Aroclor 1248	✓	✓			
Aroclor 1254	✓	✓		✓	
Aroclor 1260	✓	✓			

6.2.1 Determination of Exposure Pathways

An exposure pathway generally consists of four elements: (1) a source and mechanism of chemical release, (2) a retention or transport medium, (3) a point of potential human contact with the contaminated medium (referred to as the exposure point), and (4) an exposure route (e.g., ingestion or inhalation) at the exposure point (U.S. EPA, 1989c). Thus, the determination of the exposure pathways that exist at the Site involves identifying source areas, predicting contaminant fate and transport, and identifying and characterizing potentially exposed populations.

6.2.1.1 Sources of Contamination

Site investigations at the Site have confirmed the presence of chemicals of concern in surface soil, near-surface soil, surface water, and groundwater. Other potential sources, notably the adjacent Dye Road Dump, may contribute to the decreased groundwater quality at the Site. This risk assessment will focus on the contamination that was found at the Site.

6.2.1.2 Fate and Transport Analysis

Chemicals detected at the Site could potentially migrate off site by physical or chemical processes or could be relatively immobile. Some chemicals of concern can reasonably be expected to be transported from soil and waste to the groundwater. Other chemicals are expected to be less mobile and to remain in the source areas for much longer periods of time. This subsection describes the fate and transport properties and processes which control the movement of VOCs, semivolatiles, polynuclear aromatic hydrocarbons (PAHs), pesticides, and inorganic chemicals in the environment. The purpose of this subsection is to provide a general discussion of the probable fate and transport of these classes of chemicals, and not to specifically describe the movement of the chemicals of concern at the Site.

Volatile Organic Compounds

The physical and chemical properties of the VOCs of concern are summarized in Table 6-7. Because these compounds have relatively high solubilities (i.e., they are soluble in water) and relatively low organic carbon partition coefficients (Kocs) (i.e., they partition more to water than to organic material), they are expected to be mobile in the aquatic environment. Biodegradation and volatilization are important fate processes which can affect the persistence of the volatile chemicals at the Site.

Semivolatile Organic Compounds/PAHs/Pesticides/PCBs

The physical and chemical properties of the semivolatiles, PAHs, and pesticides of concern are also summarized in Table 6-7. Semivolatile organic compounds possess a wide range of physicochemical properties, but generally have low vapor pressures and water solubilities

Table 6-7

Physical/Chemical Properties of Organic Chemicals of Concern
Linden Road Landfill
Flint, Michigan

Contaminant	Molecular Weight (g/mole)	Water Solubility (mg/L)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m³/mol)	Octanol/Water Partition Coefficient (log K_{ow})	Organic Carbon Partition Coefficient (K_{oc}, mL/g)
Semivolatile Organics						
bis(2-Chloroethyl)ether	143	1.02E+04	7.10E-01	1.31E-05	1.50	13.9
4-Methylphenol	108	2.26E+01	1.30E-01	9.60E-07	1.94	500
1,2,4-Trichlorobenzene	181	3.00E+01	2.90E-01	2.31E-03	4.30	9,200
Di-n-Butylphthalate	278	1.30E+01	1.00E-05	2.82E-07	5.60	170,000
bis(2-Ethylhexyl)phthalate	391	3.00E-01	6.45E-06	1.1E-05	5.11	NA
PAHs						
Naphthalene	128	3.17E+01	8.20E-02	5.53E-04	3.30	NA
Fluoranthene	202	2.06E-01	5.00E-06	6.46E-06	4.90	38,000
Pyrene	202	1.32E-01	2.50E-06	5.04E-06	4.88	38,000
Benz(a)Anthracene	228	5.70E-03	2.20E-06	1.16E-06	5.60	1,380,000
Chrysene	228	1.80E-03	6.30E-09	1.05E-06	5.61	200,000
Benzo(b)Fluoranthene	252	1.40E-02	5.00E-07	1.19E-05	6.06	550,000
Benzo(k)Fluoranthene	252	4.30E-03	5.10E-07	3.94E-05	6.06	550,000
Benzo(a)Pyrene	252	1.20E-03	5.60E-09	1.55E-06	6.06	5,500,000
Indeno(1,2,3-cd)Pyrene	276	5.30E-04	1.00E-10	6.86E-08	6.50	1,600,000
Dibenz(a,h)Anthracene	278	5.00E-04	1.00E-10	7.33E-08	6.80	3,300,000

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Table 6-7 (Continued)

Physical/Chemical Properties of Organic Chemicals of Concern
Linden Road Landfill
Flint, Michigan

Contaminant	Molecular Weight (g/mole)	Water Solubility (mg/L)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m^3/mol)	Octanol/Water Partition Coefficient (log K_{ow})	Organic Carbon Partition Coefficient (K_{oc}, mL/g)
Volatile Organics						
Methylene Chloride	85	2.00E+04	3.62E+02	2.03E-03	1.30	8.8
Acetone	58	1.00E+06	2.70E+02	2.06E-05	-0.24	2.2
Carbon Disulfide	76	2.94E+03	3.60E+02	1.23E-02	2.00	54
1,1-Dichloroethane	99	5.50E+03	1.82E+02	4.31E-03	1.79	30
Chloroform	119	8.20E+03	1.51E+02	2.87E-03	1.97	31
2-Butanone	72	2.68E+05	7.75E+01	2.74E-05	0.26	4.5
Trichloroethene	131	1.10E+03	5.79E+01	9.10E-03	2.38	126
Benzene	78	1.75E+03	9.52E+01	5.59E-03	2.12	83
Tetrachloroethene	166	1.50E+02	1.78E+01	2.59E-02	2.6	364
1,1,2,2-Tetrachloroethane	168	2.90E+03	5.00E+00	3.81E-04	2.39	118
Toluene	92	5.35E+02	2.81E+01	6.37E-03	2.73	300
Ethylbenzene	106	1.52E+02	7.00E+00	6.43E-03	3.15	1,100
Xylenes (total)	106	1.98E+02	1.00E+01	7.04E-03	3.26	240
Pesticides/PCBs						
alpha-BHC	291	1.63E+00	2.50E-05	5.87E-06	3.90	3,800
4,4'-DDT	355	5.00E-03	5.50E-06	5.13E-04	6.19	243,000
Aroclor 1248	300	5.40E-02	7.70E-05	3.50E-03	5.75	49,000

Table 6-7 (Continued)

Physical/Chemical Properties of Organic Chemicals of Concern
Linden Road Landfill
Flint, Michigan

Contaminant	Molecular Weight (g/mole)	Water Solubility (mg/L)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m³/mol)	Octanol/Water Partition Coefficient (log K_{ow})	Organic Carbon Partition Coefficient (K_{oc}, mL/g)
Aroclor 1254	328	1.20E-02	7.70E-05	8.40E-03	6.03	120,200
Aroclor 1260	376	2.70E-03	7.70E-05	7.10E-03	7.14	295,100

NA - Not available.
Sources: U.S. EPA, 1985a; U.S. EPA, 1986b.

and high Kocs. The available information suggests that these compounds are generally strongly adsorbed to soils and sediments. Therefore, their mobility in both aquatic and terrestrial environments is expected to be low. They can migrate to ground and surface waters by leaching from soil, but this is generally a slow process. Volatilization of these compounds from the aqueous phase is generally not expected to be a major fate process. Although the semivolatiles at the Site can be bioaccumulated to some extent, they are generally quickly metabolized and eliminated from most organisms. Biodegradation and biotransformation are probably the most important biological fate processes for this group of chemicals of potential concern; however, because of their high molecular weights, degradation is expected to be slow.

In general, PAHs have low water solubilities, tend to be immobile, and are fairly persistent in soil. Significant leaching of PAHs from soils into groundwater is not expected, especially if the soils in the area have high organic carbon contents. The most probable fate of most PAHs in the aquatic environment is sorption onto particulate matter and subsequent sedimentation and microbial degradation. Half-lives for various PAHs have been suggested to range from less than one day to several years (U.S. EPA, 1984a). Any PAHs dissolved in the water column are expected to undergo direct photolysis at a rapid rate (U.S. EPA, 1980).

Pesticide mobility is primarily related to the organic carbon content of the soil or to the amount of dissolved humic materials in natural waters. DDT and DDE have high Kocs and low water solubilities, indicating that these pesticides will have a greater tendency to be adsorbed than to exist in solution. Both DDT and DDE are known to bioaccumulate in aquatic and marine organisms, and have the potential to become concentrated in the food chain.

In general, PCBs have low water solubilities and high octanol-water partition coefficients, K_{ow}s, which indicates that they would bind tightly to the organic fraction of soils and would exhibit little tendency to desorb from soils and enter the groundwater. In aquatic systems, PCBs would be largely adsorbed to the bottom sediments or to suspended particulates. PCBs are relatively insoluble in water, but are freely soluble in nonpolar organic solvents and biological lipids; thus, they tend to accumulate in living organisms. They are also known to biomagnify in the food chain.

Inorganic Compounds

Some physical and chemical properties of the inorganic chemicals of concern are presented in Table 6-8. While the pure metallic forms of these compounds are insoluble in water, many of the salts are soluble in varying degrees. The most important fate process governing the transport of metals in aquatic media is adsorption. Inorganic compounds may or may not be released into solution, depending on the status of environmental parameters such as the pH and the ambient redox potential.

Table 6-8

Physical/Chemical Properties of Inorganic
Chemicals of Concern
Linden Road Landfill
Flint, Michigan

Inorganic Compound	Atomic Weight (g/mole)	Boiling Point (°C)	Melting Point (°C)	Water Solubility (mg/L)	Vapor Pressure (mm Hg)
Antimony	122	1,750	630	CS	0E+0
Arsenic	75	613	817	CS	0E+0
Barium	137	1,640	725	CS	0E+0
Beryllium	9	2,970	1,278	CS	0E+0
Cadmium	112	765	321	CS	0E+0
Chromium	52	2,672	1,857	CS	0E+0
Copper	64	2,567	1,083	CS	0E+0
Lead	207	1,740	328	CS	0E+0
Manganese	55	1,962	1,244	CS	0E+0
Mercury	201	357	-38.9	CS	2E-3
Nickel	58.7	2,732	1,453	CS	0E+0
Selenium	79	685	217	CS	0E+0
Thallium	204	1,457	304	CS	0E+0
Vanadium	51	3,380	1,890	CS	0E+0
Zinc	65	907	420	CS	0E+0
Cyanide	56	NA	NA	CS	0E+0

CS - Compound specific; salts are soluble, metallic forms are insoluble.
NA - Not available.
Source: U.S. EPA, 1985a; U.S. EPA, 1986b.

The following paragraphs discuss in general terms the environmental fate and transport of the inorganic chemicals of concern in this study. It should be noted that the information presented does not specifically describe inorganic contaminant movement at the Site.

Antimony. The extent to which sorption retards the aqueous transport of antimony is unknown, but it is clear that sorption to clays and minerals is generally the most important fate process that results in the removal of antimony from solution.

Arsenic. Arsenic is for the most part quite mobile and may be leached from soils into groundwater and surface water under favorable oxidation states.

Barium. Barium is generally present in solution in surface or groundwater only in trace amounts. Barium is not soluble at more than a few parts per million in water that contains sulfate; however, barium sulfate may become considerably more soluble in the presence of chloride and other anions.

Beryllium. Some common beryllium compounds are soluble in water; however, once in solution, these soluble salts are hydrolyzed to form beryllium hydroxide, which has low solubility. At low soil pH, beryllium adsorbs to clay particles, and at higher soil pH, beryllium forms insoluble complexes.

Cadmium. Cadmium is relatively mobile in the aquatic environment, but it is expected to move slowly through soil. In surface water and groundwater, cadmium can exist as the hydrated ion or in ionic complexes. Soluble forms may migrate, but insoluble complexes and cadmium adsorbed onto sediments are nonmobile. Cadmium tends to be bioaccumulated in the food chain.

Chromium. Chromium can exist in either the trivalent (III) or the hexavalent (VI) state. Chromium (VI) is quite soluble and is relatively mobile in the aquatic environment, but is quickly reduced to chromium (III) in poorly drained soils. Chromium (III) is strongly adsorbed onto clays and soils high in organic matter.

Copper. The concentrations of various copper compounds and complexes that exist in solution depend on the pH, the temperature, and the concentrations of the copper species present. Many copper compounds are readily soluble, and, as a result, copper is mobile in the soil system. Adsorption to organic matter and clays is the primary process which limits the mobility of copper in the environment.

Lead. Lead may exist in the environment in both organic and inorganic forms. Organic lead compounds (e.g., tetraethyl lead) are generally unstable and undergo rapid conversion to inorganic compounds. Inorganic lead is relatively insoluble and is not very mobile. The distribution of lead in the environment is dominated by sorption processes.

Manganese. In most natural aquatic systems, manganese is present predominantly in the suspended particulates and sediments as manganese (II) oxide and/or manganese (III) oxide. Small amounts of manganese may exist in aquatic systems for long periods. Manganese solubility in soil systems increases with acidity and with reducing conditions. In acidic, water-logged soils, manganese passes freely into solution and may leach into groundwater.

Mercury. Adsorption onto suspended and bed sediments is probably the most important process determining the fate of mercury in the aquatic environment. Mercury in soil is generally bound to organic material. Mercury and certain of its compounds can volatilize to the atmosphere from aquatic and terrestrial sources. Mercury is also strongly bioaccumulated by numerous organisms.

Nickel. Nickel is generally highly mobile in aquatic systems because of the high solubility of many nickel compounds. Mobility is limited by sorption processes and by precipitation of nickel with hydrous iron and manganese oxides.

Selenium. The fate of selenium in soils is pH and redox (Eh) dependent. In well-aerated alkaline soils, soluble species of selenium are formed which are subject to leaching or are readily taken up by plants. In poorly aerated acidic soils, insoluble forms of selenium predominate.

Thallium. In most aquatic systems, thallium remains in solution, though under reducing conditions, thallium precipitates as the metal or as thallium sulfide. Removal of dissolved thallium occurs through sorption to clay minerals and hydrous metal oxides present in bed sediments.

Vanadium. The extent to which vanadium is transported through aqueous media is largely dependent on the chemical species present and on the environmental factors which affect its solubility and its adsorption to organic materials.

Zinc. The relative mobility of zinc in soil and water is determined by pH, salinity, the concentration of complexing ligands, and the concentration of zinc. Zinc normally partitions to soil (sediments) to a greater degree than to solution.

6.2.1.3 Contaminant Migration Pathways

Chemicals detected at the Site may migrate toward downgradient receptor areas and into other environmental media within the Site. Chemicals in the soil or the buried wastes could potentially be transported via the following migration pathways:

- Soil (or buried wastes) to groundwater.
- Soil (or buried wastes) to surface water.
- Soil to air.

Soil to Groundwater Pathway

Based on the preliminary evaluation of Site characteristics and monitoring data, it has been determined that wastes have been disposed of at the Site and covered. During precipitation events, water may infiltrate through the surficial materials and carry with it dissolved organic and inorganic chemicals from the buried wastes. Some of these chemicals in the leachate would be adsorbed by the soil within or underneath the buried waste zone. The other part of the chemicals could continue to migrate downward and reach the groundwater. The current groundwater quality data do no indicate that such leaching of wastes into shallow groundwater is occurring.

Soil to Surface Water Pathway

Typically, when precipitation falls on the Site, surface run-off flows into the trenches and marshes that are contained within the Site. Chemicals could be leached from the soil by precipitation and runoff and be subsequently deposited in the surface water features on the Site.

Soil to Air Pathway

The presence of chemicals of concern in surficial soils at the Site may result in the release of these chemicals to the atmosphere via volatilization and/or dust entrainment. Air sampling for specific chemicals at the Site was not conducted during the SI field investigation, and, as a result, specific chemical analyses for potential air contaminants have not been performed.

Volatilization from soil into the atmosphere is a potential fate process for volatile organic chemicals (VOCs), whose relatively high vapor pressures and Henry's Law constants facilitate their release into the air as vapors. However, surface soils that have been exposed to natural weathering for some time are likely to have lost the bulk of their volatile contaminants as a result of historic volatilization to the atmosphere and other mechanisms of attenuation. VOCs were typically found in the surface soil at the Site at relatively low concentrations. However, during excavation of the test pits, a small number of surface samples containing higher levels of VOCs were encountered. Frequent air monitoring at the Site with a photoionization detector revealed no readings above background, except during excavation. Therefore, current on- and off-site exposures to volatile emissions from the Site are not expected to be significant.

Under the potential future use of the Site, which involves short-term excavation, exposure to chemical vapors could occur, however. It would be difficult to develop a reasonable estimate of the emission rate for each volatile, due in part to the localized nature of the elevated VOC contamination. Excavation activities might or might not disturb these locations. An additional measure of uncertainty would be associated with predicting the type of earthmoving activity that would occur at the Site. Soil excavation would be expected to have a much greater effect on volatile emissions than would soil grading, since excavation would potentially involve exposure of buried materials that have not released their volatile chemicals. Making assumptions regarding those factors would lead to large uncertainties in any calculated volatile emission rates. It is not appropriate to develop a sophisticated model of emission rates when the model would be characterized by a high level of uncertainty, particularly since risk management decisions at the Site are likely to be driven by other exposure pathways. Therefore, although exposure to volatile emissions from soils is a potential future exposure pathway, it was not examined quantitatively in this risk assessment.

Residual chemicals bound to surficial soils may also be transported into the atmosphere as suspended particulates or dust. Factors influencing the potential for dust entrainment into the atmosphere include surface roughness, surface soil moisture, soil particle sizes, type and amount of vegetative cover, amount of soil surface exposed to the eroding wind force or vehicular traffic, physical and chemical properties of the soil, wind velocity, and other meteorological conditions (U.S. EPA, 1983). While much of the surface at the Site is covered with vegetation, many areas are not. Dust formation may be significant during extended periods of dry weather. As a result, organics and inorganics bound to the soil matrix are expected to be present in the airborne dusts at the Site.

6.2.1.4 Characterization of Potentially Exposed Populations

Current potential receptors at the Site are expected to be limited to trespassers on the property. Since the Site is completely fenced, it was assumed that adolescents would be more likely than small children or adults to make their way onto the Site. It was assumed for the purposes of this risk assessment that a typical site trespasser is a 10-16 year old male. Exposure assumptions were made based on this receptor. The trespasser is expected to be on the Site infrequently and for short durations. It is important to note that WESTON personnel have not observed any signs of trespassing at the Site.

Because the Site is not anticipated to be used for residences in the future, future residential exposure is not considered in this study. A construction worker involved in preparing the Site for industrial or commercial use was chosen to represent a future receptor at the Site. Such a worker is assumed to be an adult male or female who is exposed to site chemicals during all working hours for one to two years (i.e., during the construction period).

The exposure pathways for trespassers and workers are expected to be the same. One significant difference in the exposure potentials of the two groups is that the future worker is expected to be exposed to near-surface soils (0-10 foot), while the current trespasser is expected to be exposed to surface soils (0-3 foot).

6.2.1.5 Identification of Exposure Points and Exposure Routes

The identification of human exposure points at the Site was based on an examination of the current extent of contamination in relation to current and potential future land uses, and of the results of the fate and transport assessment.

Potential exposure points on the Site include site-wide surface soils, pools of surface water, and groundwater. Exposure to subsurface soils would be likely if earthmoving activities were to occur in the future.

A conceptual exposure model for the Site, which integrates and summarizes the information for the potential exposure pathways is presented in Table 6-9. This model identifies the key potential release mechanisms, transport media, exposure points, exposure media, exposure routes, and receptors for each contaminated source.

6.2.1.6 Exposure Pathway Screening

The exposure pathway screening identifies those pathways that are complete (i.e., contamination is anticipated to reach receptors) and that will require detailed quantitative analysis to estimate the extent of exposure. This screening step eliminates from consideration those pathways through which there is little or no potential for exposure to receptors. The following paragraphs present the rationale for the selection of the pathways that are evaluated in the quantitative risk assessment.

Soil Pathway

Important exposure pathways of concern at the Site exist as a result of the environmental persistence of the chemicals of concern in the soil. Extensive contamination has been observed in the surface and subsurface soil samples collected from throughout the Site. Human receptors on the Linden Road property could be exposed to soil chemicals through dermal absorption or incidental ingestion. Thus, ingestion and dermal absorption of soil chemicals were included in the quantitative analysis.

Surface Water Pathway

The Site contains several bodies of standing water, but none is of large size, and together they comprise only a small portion of the surface area of the Site. Therefore, although exposure to surface water is expected to occur occasionally, such exposure is expected to be limited. The potential exists for exposure to chemicals in surface water through dermal absorption and incidental ingestion. But since incidental ingestion of surface water occurs primarily during swimming, which is not expected to occur at the Site, this exposure pathway was not included in the quantitative analysis. Exposure through dermal absorption was the only surface water exposure route that was evaluated quantitatively.

Table 6-9

Conceptual Exposure Model:
Potential Human Exposure Pathways
Linden Road Landfill
Flint, Michigan

Source Medium	Transport Mechanisms	Exposure Medium	Exposure Routes	Potential Receptors
Soil	Wind Erosion/ Mechanical Erosion	Soil	Incidental Ingestion Dermal Absorption	Current trespasser Future worker
Soil	Wind Erosion/ Mechanical Erosion	Air	Inhalation of Dust	Current trespasser Future worker
Surface Water	None	Surface Water	Incidental Ingestion Dermal Absorption	Current trespasser Future worker
Groundwater	None	Groundwater	Ingestion Dermal Absorption	Future

Air Pathway

The unvegetated areas throughout the Site may provide a source of dust emissions when environmental conditions are favorable. Thus, the inhalation of chemicals in airborne dust was evaluated in this risk assessment.

Groundwater Pathway

There are no current users of groundwater at the Site. Furthermore, no site impacts by or receptor exposure to this groundwater is expected in the future. Residential development at the Site is not anticipated. GM fully expects that deed restrictions at the Site will serve to prohibit residential development and corresponding residential exposures.

Groundwater investigations at the site have characterized two water-bearing zones. Groundwater quality has been adversely affected only in the shallow water-bearing zone. Exposure to these chemicals is considered unlikely since no potable wells are currently present and GM anticipates instituting restrictions to groundwater use in the future. Furthermore, Michigan Act 368 (Public Health Code Groundwater Quality Control, Part 127, Rule 131 and 133) restricts the installation of drinking water wells at depths of less than 25 feet, which encompasses the depth range of the shallow saturated zone. The origin of the chemicals in the shallow water-bearing zone is questionable. It is possible that some chemicals may originate from an upgradient source.

The deeper water-bearing zone is not presently affected and a reduction of the groundwater quality is not anticipated based upon Site groundwater conditions. Furthermore, the deeper water-bearing zone yields insufficient quantities of water for use as a useful resource.

Therefore, in view of the extremely limited potential for exposure and the likely origin of the detected chemicals, no quantitative evaluation was performed of the risks associated with exposure to groundwater at the site.

6.2.1.7 Summary of Exposure Pathways Selected for Evaluation

The preceding discussion identified those pathways that are potentially significant and that therefore were included in the quantitative analysis of exposure. The final list of exposure pathways and exposure routes of concern is as follows:

Soil Pathway

- Ingestion of chemicals in soil.
- Dermal absorption of chemicals in soil.

Surface Water Pathway

- Dermal absorption of chemicals in surface water.

Air Pathway

- Inhalation of chemicals in airborne dust.

All of these exposure routes were evaluated for both the site trespasser and site worker.

6.2.2 Quantification of Exposure

6.2.2.1 Estimation of Exposure Point Concentrations

Both an average and a maximum exposure point concentration are calculated for each chemical in each exposure medium in order to provide a conservative range of exposure values over which risks are subsequently calculated. As explained in Subsection 7.1.3, the average exposure concentration for a particular chemical is calculated as the geometric mean of the concentrations from all samples (i.e., both positively detected and proxy concentrations), and the maximum exposure concentration is calculated as the minimum of either the upper 95 percent confidence limit on the arithmetic mean of the chemical concentrations or the maximum positively detected concentration.

6.2.2.2 Determination of Exposure Parameters

In order to evaluate exposures over the range of possible conditions that may exist at the Site, two hypothetical exposure scenarios were considered in this study. These are a reasonable maximum exposure (RME) and a representative average exposure (RAE). The RME is the highest exposure that is reasonably expected to occur at a site. The RAE is intended to represent more typical exposure conditions.

Estimated daily intakes of the selected chemicals of concern are calculated for each of the receptors identified for each exposure pathway by multiplying the exposure point concentration of the chemical by a series of exposure parameters that quantify the magnitude, frequency, and duration of the exposure. The RAE utilizes the average exposure point concentration of the chemical, and the RME utilizes the reasonable maximum exposure point concentration. Daily intakes are calculated separately for carcinogenic and noncarcinogenic effects, in accordance with the methodology presented by U.S. EPA (1989c).

The degree of exposure to receptors that occurs through each exposure pathway is determined by behavioral, chemical, and physiological factors. Behavioral factors affecting trespasser exposure would include the amount of time spent on site, the activities engaged in while on site (which affects the amount of soil and surface water that is contacted), and the amount and type of clothing worn. Chemical factors affecting the degree of exposure would include the extent to which a chemical is absorbed through the skin (i.e., the absorption efficiency). Physiological factors affecting exposure would include the ability of the body to metabolize and eliminate the chemical(s). To quantify exposures in the risk assessment process, it is necessary to make assumptions concerning these factors in the absence of specific, detailed information. These assumptions are discussed in the following subsections for each exposure route that is examined quantitatively.

Ingestion of Chemicals in Soil

Daily chemical intakes via soil ingestion were calculated using the following equation (U.S. EPA, 1989c):

$$\text{Intake (mg/kg/day)} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Where:

CS = Chemical concentration in soil (i.e., exposure point concentration) (mg/kg)
IR = Ingestion rate (mg soil/day)
CF = Conversion factor (10^{-6} kg/mg)
FI = Fraction ingested from contaminated source (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged -- days)

The values for these exposure parameters that were used in this risk assessment for the current site trespasser are presented in Table 6-10; those for the future site worker are presented in Table 6-11.

The ingestion rate, IR, used for the current trespasser, 100 mg/d, is a soil ingestion rate for older children and adults from U.S. EPA, 1991. The IR for the future construction worker under the reasonable maximum exposure scenario was doubled to 200 mg/d to account for the additional potential for soil ingestion that exists for this receptor.

The fraction ingested, FI, is a factor that accounts for the fraction of the daily soil intake that is obtained from the contaminated source. This fraction was conservatively assumed to be equal to 1.0 for the future worker. For the current trespasser, FI was assumed to be 0.5.

The exposure frequency, EF, was assumed for the current trespasser to be an average of one day per month for six months per year or a maximum of two days per month for six months per year. Soil exposure was assumed not to occur during the winter months or during

Table 6-10

Exposure Assumptions Used for the Current Site Trespasser
Linden Road Landfill
Flint, Michigan

Exposure Pathway	Adolescent Exposure	
	Average	Maximum
Soil Ingestion		
IR (mg/d)[a]	100	100
FI (unitless)[c]	0.5	0.5
EF (d/yr)[b]	6	12
ED (yr)[c]	2	6
BW (kg)[d]	48	48
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x Ed, YL
Soil Dermal Absorption		
SA (cm^2)[g]	1560	3380
AF (mg/cm^2)[h]	1.45	1.45
ABS (unitless)	•	•
EF (d/yr)[b]	6	12
ED (yr)[c]	2	6
BW (kg)[d]	48	48
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x ED, YL
Dust Inhalation		
IR (m^3/hr)[i]	1.97	1.97
ET (hr/d)[c]	1	2
EF (d/yr)[b]	6	12
ED (yr)[c]	2	6
BW (kg)[d]	48	48
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x ED, YL

Table 6-10 (Continued)

Exposure Assumptions Used for the Current Site Trespasser
Linden Road Landfill
Flint, Michigan

Exposure Pathway	Adolescent Exposure Average	Adolescent Exposure Maximum
Surface Water Dermal Absorption		
SA (cm^2)[g]	1560	3380
ET (hr/d)[j]	0.1	0.2
EF (d/yr)[b]	6	12
ED (yr)[c]	2	6
BW (kg)[d]	48	48
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x ED, YL

[*]Chemical-specific value.
[a]U.S. EPA, 1991b.
[b]Average: 1 day/month for 6 months/year. Maximum: 2 days/month for 6 months/year.
[c]Best professional judgement.
[d]Average for 10-16 year old male (U.S. EPA, 1989b).
[e]U.S. average (U.S. EPA, 1989c).
[f]For carcinogenic effects, AT is calculated by multiplying 365 d/yr by YL; for noncarcinogenic effects, AT is calculated by multiplying 365 d/yr by ED.
[g]Average is based on exposure of forearms and hands. Maximum is based on exposure of foreams, hands, and lower legs.
[h]Based on potting soil (U.S. EPA, 1989c).
[i]Average for 13 year-old male engaged in moderate activity (U.S. EPA, 1989b).
[j]Receptor is assumed to be in contact with surface water for 10% of the time spent on site.

Table 6-11

Exposure Assumptions Used for the Future Site Worker
Linden Road Landfill
Flint, Michigan

Exposure Pathway	Adult Exposure	
	Average	Maximum
Soil Ingestion		
IR (mg/d)[a]	100	200
FI (unitless)[c]	1	1
EF (d/yr)[b]	125	125
ED (yr)[c]	1	2
BW (kg)[d]	70	70
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x Ed, YL
Soil Dermal Absorption		
SA (cm^2)[g]	1865	3870
AF (mg/cm^2)[h]	1.45	1.45
ABS (unitless)	*	*
EF (d/yr)[b]	125	125
ED (yr)[c]	1	2
BW (kg)[d]	70	70
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x ED, YL
Dust Inhalation		
IR (m^3/hr)[i]	2.02	2.02
ET (hr/d)[c]	8	10
EF (d/yr)[b]	125	125
ED (yr)[c]	1	2
BW (kg)[d]	70	70
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x ED, YL

Table 6-11 (Continued)

Exposure Assumptions Used for the Future Site Worker
Linden Road Landfill
Flint, Michigan

Exposure Pathway	Adult Exposure Average	Adult Exposure Maximum
Surface Water Dermal Absorption		
SA (cm^2)[g]	1865	3870
ET (hr/d)[j]	0.8	1.0
EF (d/yr)[b]	125	125
ED (yr)[c]	1	2
BW (kg)[d]	70	70
YL (yr)[e]	70	70
AT (d)[f]	365 x ED, YL	365 x ED, YL

*Chemical-specific value.
[a]Average based on U.S. EPA, 1991b. Maximum = (2) x Average to take into account additional potential for soil ingestion.
[b]One-half of an average work year.
[c]Best professional judgement.
[d]Adult average (U.S. EPA, 1989c).
[e]U.S. average (U.S. EPA, 1989c).
[f]For carcinogenic effects, AT is calculated by multiplying 365 d/yr by YL; for non carcinogenic effects, AT is calculated by multiplying 365 d/yr by ED.
[g]Average based on exposure of forearms and hands. Maximum based on exposure of forearms, hands, and lower legs.
[h]Based on potting soil (U.S. EPA, 1989c).
[i]Average for adult engaged in moderate activity (U.S. EPA, 1989b).
[j]Receptor is assumed to be in contact with surface water for 10% of the time spent on site.

periods of precipitation. The EF for the future worker, 125 days/year, is based on five days per week exposure for six months per year.

The exposure duration, ED, for the current trespasser was assumed to be an average of two years or a maximum of six years. The ED for the future worker was assumed to be an average of one year or a maximum of two years (the average and maximum expected times for a construction project to be completed).

The body weight, BW, used for the current trespasser, 48 kg, is an average value for a 10-16 year old male that is based on U.S. EPA, 1989a. The BW for the future worker, 70 kg, is a standard average value for an adult from U.S. EPA, 1989c.

For carcinogenic effects, exposures are averaged over an individual's lifetime. The number of years per lifetime, YL, was assumed to be 70 (U.S. EPA, 1989c).

The estimated daily chemical intakes that result from the ingestion of chemicals in soil are presented in Appendix H.

Dermal Absorption of Chemicals from Soil

The extent of chemical absorption through the skin is dependent on a number of factors, including the type(s) of protective clothing worn, the part(s) of the body exposed, the presence of open sores or abrasions on the skin, the degree of soil adherence to the skin, the duration of the exposure event (the contact time with contaminated soil), the chemical concentration in the soil, and the ability of the chemical to enter the body through the skin (the dermal absorption efficiency).

The following general equation, which is based on guidance provided in U.S. EPA (1989c), was used to estimate daily chemical intakes via dermal absorption from soil:

$$\text{Absorbed Dose (mg/kg/day)} = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

Where:

CS = Chemical concentration in soil (i.e., exposure point concentration) (mg/kg)
CF = Conversion factor (10^{-6} kg/mg)
SA = Skin surface area available for contact (cm^2/event)
AF = Soil to skin adherence factor (mg/cm^2)
ABS = Absorption factor (unitless)
EF = Exposure frequency (events/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged -- days)

The values for these exposure parameters that were used in this risk assessment for the current site trespasser are presented in Table 6-10; those for the future site worker are presented in Table 6-11.

The skin surface area available for contact, SA, was based on exposure of forearms and hands in the average scenario, and on exposure of forearms, hands, and lower legs in the maximum scenario. The surface skin area values used for the adolescent receptor and the adult receptor were derived from U.S. EPA, 1989b.

The adherence factor, AF, accounts for the amount of soil that adheres to the skin after contact. This parameter is dependent on the physical characteristics of the soil encountered. Site-specific soil adherence factors are not known, but on-site soils are believed to have less adherence than a typical potting soil (1.45 milligrams per square centimeter [mg/cm^2]) (U.S. EPA, 1989c). Therefore, 1.45 mg/cm^2 was used throughout this risk assessment as a conservative estimate of soil adherence.

The absorption factor, ABS, which accounts for the fraction of soil chemicals that are transferred through the skin, is a chemical-specific property. No toxicological studies were found that specifically addressed the dermal absorption efficiency of the chemicals of concern at the Site. Absorption of chemicals mixed in a medium such as soil or dust is inhibited by physicochemical bonding to the matrix, and by the fact that only a small portion of the chemicals is in direct contact with the skin. Based on Michigan Act 307, it was assumed in this risk analysis that the absorption factor for VOCs in soil is 10 percent, and that the absorption factor for all other organic chemicals is one percent.

For the inorganics, toxicological data indicate that skin absorption is an insignificant route of exposure. Metals and other inorganic compounds bind strongly to soil particles, greatly reducing their bioavailability. In addition, their ionic speciation and/or the formation of hydroxides or large organic complexes further inhibits their absorption potential. Pharmacokinetics data for many of the metals indicate that skin absorption does not occur. Other inorganics are known to be absorbed only when in the form of an applied skin ointment. In this risk assessment study, only mercury was assumed to be in an organic complex and thus able to penetrate the skin. The other metals were assumed to be in metallic or salt forms and not able to penetrate the skin. Therefore, soil dermal absorption was not quantified for any inorganic chemical except mercury.

The values used for the remaining exposure parameters in the dermal absorption equation, EF, ED, BW, and AT, are the same as those described under the soil ingestion route.

The estimated daily chemical intakes that result from the dermal absorption of chemicals from soil are presented in Appendix H.

Inhalation of Chemicals in Airborne Dust

Daily chemical intakes via inhalation of dusts are based on the duration of exposure, the inhalation rate during exposure, and the concentration of chemicals in the air. Inhalation intakes were calculated in this study using the following general equation (U.S. EPA, 1989c):

$$\text{Intake (mg/kg/day)} = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

CA = Chemical concentration in air (mg/m^3)
IR = Inhalation rate (m^3/hour)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged -- days)

The chemical concentration in the on-site air, CA, is calculated by multiplying the chemical concentration in the soil (mg/kg) by a conversion factor (kg/mg) and by the dust concentration in the air (mg/m^3). For the current trespasser exposure, the airborne dust concentration was assumed to be 0.026 mg/m^3, which is the annual arithmetic mean concentration for inhalable particulates (PM_{10}) for Flint, Michigan (MDNR,1989). It is conservatively assumed that all of the dust inhaled by the site trespasser while on the Site is derived from site soils.

For the future worker exposure, the airborne dust concentration was calculated based on fugitive dust releases associated with excavation activities. The model for inhalable particulate (<15 μm) release associated with bulldozer excavation is (U.S. EPA, 1989a):

$$E_{bd} = 0.45\,(s)^{1.5}\,(M)^{-1.4}$$

where:

E_{bd} = emission factor for bulldozer excavation (kilograms per hour);
s = silt content of material (percent);
M = moisture content of material (percent).

No site-specific information was available on the silt or moisture content of the 0 to 10 foot soil at the Site. It was assumed that the soil in this depth range is primarily clay loam, with a silt content of 40 percent and a moisture content of 25 percent, which are typical for this soil type (Donahue, et al, 1977). Substituting these values into the equation yields an inhalable particulate matter emission factor of 1.26 kilograms per hour. If we assume that one bulldozer is in operation during the entire construction period, and that the emissions from this activity are averaged over the entire 40-acre site, the resulting emission rate is 2.2E-03 milligrams per square meter per second ($mg/m^2/s$).

The ambient impact of dust generated from the Site was then evaluated by applying this emission rate to a box model with no transverse dispersion.

For a human potentially exposed at or near the source area, the following conservative assumptions were made:

- The source is infinitely wide in the cross-wind direction.
- The receptor is in the source area at the downwind edge.
- Vertical dispersion has resulted in uniform mixing of the chemicals from the ground to the breathing zone.
- No chemical has dispersed higher than the breathing zone.

These assumptions can be applied to a box model with no transverse dispersion in which the dust concentration in the box (C_b) is expressed as:

$$C_b = M_b/V_b$$

where:

M_b = chemical mass entering the box per unit time (mg/sec);

V_b = volume of air entering the box per unit time (m^3/sec).

For a box with a unit width of 1 m (the result does not depend on the assumed width) and with a given upwind source length, the mass of dust entering the box is given by:

$$M_b = E \times 1 \text{ m} \times \text{source length}$$

where:

E = emission rate ($mg/m^2/sec$)

Substituting E = 2.2E-03 $mg/m^2/s$ and source length = 400 m into the equation yields M_b = 0.86 mg/s.

The volume of air entering the box per unit time is conservatively assumed to be equal to:

$$V_b = (\text{wind speed}) \times (\text{breathing height}) \times (\text{unit width})$$

Wind speed data for Genesee County, Michigan were obtained from the U.S. Environmental Data Service (1975). The mean wind speed for the region was reported to be 9 miles per hour (4.023 m/sec). A breathing height of 6.5 feet or 2 m was assumed. Substituting these values into the equation yields V_b = 8.05 m^3/s.

Using these extremely conservative assumptions and solving for C_b, the on-site dust concentration was calculated to be 0.11 mg/m^3. The air concentration (particulate) for each site chemical was then estimated by assuming that the concentration in the dust is proportional to the concentration in the soil.

The inhalation rate, IR, that was used for the current trespasser, 1.97 m^3/hr, is an average inhalation rate for a 13-year-old male engaged in moderate activity (U.S. EPA, 1989b). The inhalation rate that was used for the future worker, 2.02, m^3/hr, is an average rate for an adult engaged in moderate activity (U.S. EPA, 1989b).

The exposure time, ET, used for the current trespasser assumes that a typical trespasser is on site for an average of one hour or a maximum of two hours per exposure event. The ET used for the future worker assumes that daily exposure would occur for an average of 8 hours (an average work day) or a maximum of 10 hours (a maximum work day).

The values used for the remaining exposure parameters in the inhalation exposure equation, EF, ED, BW, and AT, are the same as those described under the soil ingestion route. All of the exposure parameters used for the dust inhalation pathway for the current site trespasser are presented in Table 6-10. Those used for the future site worker are presented in Table 6-11.

The estimated daily chemical intakes that result from the inhalation of chemicals in dust are presented in Appendix H.

<u>Dermal Absorption of Chemicals from Surface Water</u>

The following general equation, which is based on guidance provided in U.S. EPA (1989c), was used to estimate daily chemical intakes via dermal absorption from surface water at the Site:

$$\text{Absorbed Dose (mg/kg/day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where:

CS = Chemical concentration in surface water (i.e., exposure point concentration) (mg/L)
SA = Skin surface area available for contact (cm^2/event)
PC = Chemical-specific dermal permeability constant (cm/hr)
ET = Exposure time (hours/day)

EF = Exposure frequency (events/year)
ED = Exposure duration (years)
CF = Volumetric conversion factor for water (L/cm^3)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged -- days)

The values for these exposure parameters that were used in this risk assessment for the current site trespasser are presented in Table 6-10; those for the future site worker are presented in Table 6-11.

The skin surface area available for contact, SA, was based on exposure of forearms and hands in the average scenario, and on exposure of forearms, hands, and lower legs in the maximum scenario. The surface skin area values used for the adolescent receptor and the adult receptor were derived from U.S. EPA, 1989b.

The dermal permeability constant, PC, is a chemical-specific parameter that accounts for the fraction of the aqueous chemical concentration that is absorbed through the skin. Chemical-specific permeability constants were used in this risk assessment whenever possible, but when they were not available, the permeability of water was used as a default.

The exposure time to surface water, ET, was conservatively assumed to be equal to 10 percent of the exposure time at the Site.

The values used for the remaining exposure parameters in the surface water absorption equation, EF, ED, BW, and AT, are the same as those described under the soil ingestion exposure route.

The estimated daily chemical intakes that result from the absorption of chemicals from surface water are presented in Appendix H.

6.3 TOXICITY ASSESSMENT

The toxicity assessment presents the available evidence concerning the potential for the chemicals of concern to cause adverse health effects in exposed individuals, and, when possible, provides a quantitative estimate of the relationship between the extent of chemical exposure and the increased likelihood of adverse effects occurring. This information is provided by federal agencies and other groups in the form of health-related exposure guidelines, which are used to evaluate the risks posed by exposure to chemicals at the Site. Existing, established health criteria were used whenever possible in this risk assessment, but when this was not possible, health criteria were derived from other existing criteria or from toxicity data.

6.3.1 Carcinogenic Versus Noncarcinogenic Health Effects Criteria

In evaluating potential health risks, both carcinogenic and noncarcinogenic health effects must be considered. Excessive exposure to any pollutant can potentially produce noncarcinogenic health effects, but the potential for carcinogenic effects is limited to exposure to certain substances (i.e., carcinogens). Therefore, in this risk assessment, non-carcinogenic health risks were evaluated for every chemical for which non-carcinogenic health criteria exist. Carcinogenic health risks, however, were evaluated only for those chemicals for which there is evidence of carcinogenicity and for which cancer slope factors were available.

The criteria that are used to quantify carcinogenic risks are carcinogenic slope factors, which have been developed by U.S. EPA for this purpose. Slope factors linearly relate the chemical dose to which a receptor is exposed (i.e., the chronic daily intake, CDI) to the probability, or risk, of a carcinogenic response to that exposure (Slope Factor x CDI = Risk). Table 6-12 summarizes the U.S. EPA weight-of-evidence categorization system for carcinogenic chemicals. Slope factors are typically calculated by U.S. EPA for potential carcinogens in weight-of-evidence classes A, B1, and B2 (i.e., human carcinogens and probable human carcinogens). The determination of slope factors for chemicals in class C (possible human carcinogens) is on a case-by-case basis.

It is assumed by U.S. EPA in developing carcinogenic slope factors that the risk of developing cancer is linearly related to the exposure dose. Although the cancer data from toxicological studies involving laboratory animals is usually obtained at relatively high doses, it is conservatively assumed that the risk at these high doses can be extrapolated down to extremely low doses, and that some risk of cancer is associated with even the smallest dose. This nonthreshold theory (i.e., no threshold dose exists below which there is no risk of carcinogenesis) is based on the assumption that even a small number of molecules (possibly even a single molecule) of a carcinogen might cause changes in a single cell that could result in the cell dividing in an uncontrolled manner, which could eventually lead to cancer.

In contrast to the nonthreshold theory used to determine carcinogenic risks, non-carcinogenic risks are based on the assumption that a threshold dose does exist below which adverse health effects are not expected to occur. The criteria used to evaluate the potential for noncarcinogenic health effects are generically referred to in this document as reference doses (RfDs). The term RfD was developed by U.S. EPA to refer to the chronic daily intake of a chemical that an individual can receive without any expectation of noncarcinogenic adverse health effects occurring (e.g., organ damage, biochemical alterations, birth defects). The term, as used in this risk assessment, applies to any established or derived criterion fitting this description. For inhalation exposure, this criterion is known as the reference concentration (RfC).

Table 6-12

U.S. EPA Categorization of Carcinogens
Based on Human and Animal Evidence

	Animal Evidence				
	Sufficient	Limited	Inadequate	No Data	No Evidence
Human Evidence					
Sufficient	A	A	A	A	A
Limited	B1	B1	B1	B1	B1
Inadequate	B2	C	D	D	D
No data	B2	C	D	D	E
No evidence	B2	C	D	D	E

Group A - Human carcinogen (sufficient evidence from epidemiological studies).
Group B1 - Probable human carcinogen (at least limited evidence of carcinogenicity to humans).
Group B2 - Probable human carcinogen (a combination of sufficient evidence in animals and inadequate data in humans).
Group C - Possible human carcinogen (limited evidence in animals in the absence of human data).
Group D - Not classified (inadequate animal and human data).
Group E - No evidence for carcinogenicity (no evidence for carcinogenicity in at least two adequate animal tests in different species, or in both epidemiological and animal studies).

Source: U.S. EPA, 1986b.

A variety of regulatory agencies have used the threshold approach in the development of health effects criteria for noncarcinogenic substances. These criteria include worker-related threshold limit values (TLVs), air quality standards, Food and Drug Administration (FDA) food additive regulations, and drinking water regulations.

6.3.2 Carcinogenic Slope Factors

The slope factors that are used to evaluate carcinogenic risks linearly relate the exposure dose to the probability, or risk, of a carcinogenic response to that exposure. This linear relationship identifies the plausible upper bound on the cancer risk. The true risk lies in the range defined by the upper limit as determined by the slope factor and a lower limit of zero. Since the true cancer risk is not expected to be higher than the upper bound, equating the true risk with the upper bound estimate, as is standard in risk assessments of this type, is an appropriate conservative assumption. It must be understood by decision makers, however, that the resulting risk is a reasonable maximum estimate, and is not necessarily a realistic prediction.

There is some dispute as to whether extrapolation of risks from high to low doses is a realistic approach. It has been argued that at low doses, cells may have the ability to detoxify carcinogens or to repair damage. Although it is important to recognize the possibility that some carcinogens may indeed have a threshold for toxicity, this issue is not evaluated in the present analysis. Since carcinogens are typically the major contributors to the total risk evaluated in a risk assessment, it is important that this and other risk assessments use the currently accepted health-related benchmarks, so that the risks predicted in this report can be reasonably compared with those from other risk assessments.

Every chemical of concern for which there is evidence of carcinogenicity in animals and/or humans and for which there is an established cancer slope factor is evaluated as a carcinogen in this risk assessment (IRIS, 1991; U.S. EPA, 1991a). Table 6-13 shows the carcinogenic chemicals of concern and their corresponding U.S. EPA carcinogenicity categories.

The carcinogenic slope factor for a substance depends, in part, on its route of entry into the body (e.g., ingestion, inhalation, or dermal absorption). Therefore, slope factors are classified according to the route of administration, which is determined by the experimental or epidemiological data from which the factors were derived. Ideally, route-specific slope factors should be used to evaluate the carcinogenic risk posed by each carcinogen through each exposure route of concern. However, only a limited number of slope factors have been derived. U.S. EPA has developed oral and/or inhalation slope factors for some carcinogens (U.S. EPA, 1991a; IRIS, 1991). Dermal slope factors have not been derived for any chemicals.

In the absence of dermal slope factors, slope factors for ingestion were used in this assessment for the dermal route, assuming an absorption efficiency for the oral route of 100

Table 6-13

U.S. EPA Weight-of-Evidence Classifications of the Carcinogenic Chemicals of Concern
Linden Road Landfill
Flint, Michigan

Contaminant	U.S. EPA Carcinogenicity Category
Volatile Organics	
Benzene	A
Methylene Chloride	B2
Trichloroethene	B2
1,1-Dichloroethane	C
Tetrachloroethene	B2
1,1,2,2-Tetrachloroethane	C
Chloroform	B2
Semivolatile Organics	
Bis(2-chloroethyl)ether	B2
Bis(2-ethylhexyl)phthalate	B2
Benz(a)anthracene	B2
Chrysene	B2
Benzo(b)fluoranthene	B2
Benzo(k)fluoranthene	B2
Benzo(a)pyrene	B2
Indeno(1,2,3-cd)pyrene	B2
Dibenz(a,h) anthracene	B2
Pesticides/PCBs	
Aroclor 1248	B2
Aroclor 1254	B2
Aroclor 1260	B2
alpha-BHC	B2

Table 6-13 (Continued)

U.S. EPA Weight-of-Evidence Classifications of the Carcinogenic Chemicals of Concern
Linden Road Landfill
Flint, Michigan

Contaminant	U.S. EPA Carcinogenicity Category
Inorganics	
Arsenic	A
Beryllium	B2
Cadmium	B1
Chromium (VI)	A
Lead	B2
Nickel (nickel refinery dust)	A

Source: IRIS, 1991; U.S. EPA, 1991a.

percent for VOCs and 50 percent for all other organic chemicals (as per Michigan Act 307). In practical terms, the oral slope factor for non-VOCs was divided by 50 percent (0.5) to obtain the dermal slope factor. Although few data are available concerning the carcinogenic activity of substances that are systemically absorbed through the skin, the applied oral slope factors, when used with conservative absorption factors, are expected to provide conservative estimates of the risks of systemic cancer through this route. In the absence of information to the contrary, it was assumed that all organic carcinogens are potentially carcinogenic through the dermal route.

Table 6-14 gives the oral and dermal cancer slope factors for the noncarcinogenic chemicals of concern. The inhalation slope factors are presented in Table 6-15.

Specific Notes Concerning the Carcinogenic Risk Evaluation

The carcinogenicity of cadmium, chromium (VI), and nickel have not been established for the oral exposure route. Therefore, these chemicals were evaluated for carcinogenic risk only under inhalation exposure pathways.

Slope factors have not been determined for lead for either ingestion or inhalation. Therefore, the cancer risk associated with lead exposure at the Site was evaluated qualitatively.

For nickel, the inhalation slope factor for nickel refinery dust was used.

Only total chromium was determined at the Site. Therefore, in this assessment, 10 percent of the total chromium concentration was assumed to be chromium (VI) and 90 percent was assumed to be chromium (III).

Slope factors for the carcinogenic PAHs were calculated based on the methodology developed by ICF-Clement Associates (1988) for the U.S. EPA Office of Health and Environmental Assessment. This approach takes into account the differences in the relative potencies of the carcinogenic PAHs. Using the relative potency estimates presented in Table 6-16, the slope factors for the carcinogenic PAHs observed at the Site were calculated based on the slope factor for benzo(a)pyrene. However, the revised estimate of the slope factor for benzo(a)pyrene via ingestion that was presented in the ICF-Clement report was not used in this risk evaluation.

6.3.3 Reference Doses for Noncarcinogenic Effects

As stated previously, the reference dose, or RfD, is that dose of a substance to which a human can be exposed on a daily basis without any appreciable risk of adverse health effects occurring over a lifetime. The RfD is assumed to be a critical dose, below which there is no potential for toxic effects and above which this potential exists.

Table 6-14

Oral and Dermal Cancer Slope Factors for the
Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Weight-of-Evidence Classification	Oral Slope Factor $(mg/kg/d)^{-1}$	Species/ Type of Cancer	Oral SF Basis/Source	Oral Adsorption Efficiency	Dermal Slope Factor $(mg/kg/d)^{-1}$
Inorganics						
Arsenic	A	1.75E+00	Human/Skin	0.01-1.8 mg/L in drinking water/IRIS	0.50	3.5E+00
Beryllium	B2	4.3E+00	Rat/Total tumors	5 ppm in drinking water for lifetime/IRIS	0.50	8.6E+00
Cadmium	ND	ND	–	–	–	–
Chromium(VI)	ND	ND	–	–	–	–
Nickel	ND	ND	–	–	–	–
Lead	B2	ND	–	–	–	–
Semivolatile Organics						
bis(2-Ehtylhexyl)Phthalate	B2	1.40E-02	Mouse/Liver	103 weeks dietary ingestion/ IRIS	0.50	2.8E-02
PAHs[a]						
Benz(a)Anthracene	B2	1.67E+00	Mouse/Stomach	–	0.50	3.34E+00
Chrysene	B2	5.06E-02	Mouse/Stomach	–	0.50	1.01E-01
Benzo(b)Fluoranthene	B2	1.61E+00	Mouse/Stomach	–	0.50	3.22E+00
Benzo(k)Fluoranthene	B2	7.59E-01	Mouse/Stomach	–	0.50	1.52E+00
Benzo(a)Pyrene	B2	1.15E+01	Mouse/Stomach	1-250 ppm in diet for 110 days/HEAST	0.50	2.30E+01
Indeno(1,2,3-cd)Pyrene	B2	2.67E+00	Mouse/Stomach	–	0.50	5.34E+00
Dibenz(a,h)Anthracene	B2	1.28E+01	Mouse/Stomach	–	0.50	2.56E+01

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Table 6-14 (Continued)

Oral and Dermal Cancer Slope Factors for the
Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Weight-of-Evidence Classification	Oral Slope Factor $(mg/kg/d)^{-1}$	Species/ Type of Cancer	Oral SF Basis/Source	Oral Adsorption Efficiency	Dermal Slope Factor $(mg/kg/d)^{-1}$
Volatile Organics						
Methylene Chloride	B2	7.5E-03	Mouse/Liver	Inhalation and drinking water studies/IRIS	1.00	7.5E-03
Chloroform	B2	6.1E-03	Rat/Kidney	200-188 ppm in drinking water for 104 weeks/IRIS	1.00	6.1E-03
Trichloroethene	B2	1.1E-02	Mouse/Liver	Two gavage studies/HEAST	1.00	1.1E-02
Benzene	A	2.9E-02	Human/Leukemia	Occupational/IRIS	1.00	2.9E-02
Tetrachloroethene	B2	5.1E-02	Mouse/Liver	Gavage/HEAST	1.00	5.1E-02
1,1,2,2-Tetrachloroethane	C	2.0E-01	Mouse/Liver	Gavage/IRIS	1.00	2.0E-01
bis(2-Chloroethyl)ether	B2	1.1E+00	Mouse/Liver	560 day oral study/HEAST	1.00	1.1E+00
Pesticides/PCBs						
Alpha-BHC	B2	6.3E+00	Mouse/Liver	24 week dietary study/HEAST	0.50	1.26E+01
4,4'-DDT	B2	3.4E-01	Mouse, Rat/Liver	Several dietary studies/IRIS	0.50	6.8E-01
Aroclor 1248	B2	7.7E+00	Rat/Liver	Aroclor 1260 in diet/IRIS	0.50	1.54E+01
Aroclor 1254	B2	7.7E+00	Rat/Liver	Aroclor 1260 in diet/IRIS	0.50	1.54E+01
Aroclor 1260	B2	7.7E+00	Rat/Liver	Aroclor 1260 in diet/IRIS	0.50	1.54E+01

*PAH slope factors are based on benzo(a)pyrene relative potency.
ND - Not determined.

Table 6-15

Inhalation Cancer Slope Factors for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Weight-of-Evidence Classification	Slope Factor (SF) $(mg/kg/d)^{-1}$	Species/ Type of Cancer	SF Basis/ Source
Inorganics				
Arsenic	A	5E+01	Human/Respiratory tract	100-5000 ug/m^3 continuous/IRIS
Beryllium	B2	8.4E+00	Human/Lung	Occupationa/IRIS
Cadmium	B1	6.1E+00	Human/Respiratory tract	Occupational/IRIS
Chromium (VI)	A	4.1E+01	Human/Lung	Occupation/IRIS
Lead	B2	ND	—	—/IRIS
Nickel (subsulfide)	A	1.7E+00	Human/Respiratory tract	Occupational/IRIS
Semivolatile Organics				
bis(2-chloroethyl) ether	B2	1.1E+00	Mouse/Liver	560 day oral study/ HEAST
bis(2-ethylhexyl) Phthalate	B2	ND	—	—/IRIS
PAHs[a]				
Benz(a)anthracene	B2	8.8E-01	Hamster/Respiratory tract	—
Chrysene	B2	2.7E-02	Hamster/Respiratory tract	—
Benzo(b) fluoranthene	B2	8.5E-01	Hamster/Respiratory tract	—
Benzo(k) fluoranthene	B2	4.0E-01	Hamster/Respiratory tract	—
Benzo(a)pyrene	B2	6.1E+00	Hamster/Respiratory tract	2.2-9.5 mg/m^3, 4.5 h/d for $\leq$ 96 weeks/HEAST
Indeno(1,2,3-cd) pyrene	B2	1.4E+00	Hamster/Respiratory tract	—
Dibenz(a,h) anthracene	B2	6.8E+00	Hamster/Respiratory tract	—

Table 6-15 (Continued)

Inhalation Cancer Slope Factors for Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Weight-of-Evidence Classification	Slope Factor (SF) $(mg/kg/d)^{-1}$	Species/ Type of Cancer	SF Basis/ Source
Volatile Organics				
Methylene chloride	B2	1.6E-03	Mouse/Lung, liver	Inhalation study/ IRIS
Chloroform	B2	8.1E-02	Mouse/Liver	138-477 mg/kg/d/ IRIS
Trichloroethene	B2	1.7E-02	Mouse/Lung	Two inhalation studies/HEAST
Benzene	A	2.9E-02	Human/Leukemia	Occupational/IRIS
Tetrachloroethene	B2	1.8E-03	Rat, mouse/ Leukemia, liver	Inhalation/HEAST
1,1,2,2-Tetrachloroethane	C	2.0E-01	Mouse/Liver	Gavage/IRIS
Pesticides/PCBs				
alpha-BHC	B2	6.3E+00	NA/NA	NA/HEAST
4,4'-DDT	B2	3.4E-01	Mouse, rat/Liver	NA/IRIS
Aroclor 1248	B2	ND	—	—/IRIS
Aroclor 1254	B2	ND	—	—/IRIS
Aroclor 1260	B2	ND	—	—/IRIS

*PAH slope factors are based on benzo(a)pyrene relative potency.
ND - Not determined.
NA - Not available.

Table 6-16

Summary of Relative Potency Estimates for Carcinogenic PAHs
Linden Road Landfill
Flint, Michigan

Carcinogenic PAH	BaP* Relative Potency
Benz(a)anthracene	0.145
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	0.140
Benzo(k)fluoranthene	0.066
Chrysene	0.0044
Dibenzo(a,h)anthracene	1.11
Indeno(1,2,3-c,d)pyrene	0.232

* Benzo(a)pyrene

Source: ICF-Clements Associates, 1988.

In simple terms, when developing an RfD, an experimental exposure level is selected from the toxicological database for a chemical of interest that represents the highest level tested at which "no adverse effect" was demonstrated in any of the test subjects (usually a group of laboratory animals). An RfD is developed from this highest "no-observed-adverse-effect level," or NOAEL, by the consistent application of uncertainty factors and a modifying factor. The uncertainty factors generally consist of multiples of 10, with each factor representing a specific area of uncertainty inherent in the extrapolation from the available data. For example, uncertainty factors are commonly employed to take into account the extrapolation of the dose-response data from laboratory animals to humans, and the variation in sensitivity that exists within the human population. A modifying factor ranging from >0 to 10 is included to reflect a professional assessment of the quality of the critical study from which the NOAEL was taken (U.S. EPA, 1989c). When more than one toxic effect is produced by a chemical, the critical level used for the development of an RfD is the lowest reported NOAEL.

Reference doses, like carcinogenic slope factors, are developed for specific exposure routes. Reference doses have been derived by U.S. EPA for a number of chemicals for the ingestion and/or inhalation routes, but none have been developed for the dermal route.

When available, route-specific RfDs were used for each chemical of concern. However, route-specific RfDs were generally available only for the ingestion route of exposure. Dermal RfDs were estimated from these oral RfDs, in a process similar to the estimation of dermal slope factors from oral slope factors (i.e., 50 percent oral absorption efficiency was assumed for non-VOCs and 100 percent for VOCs). Table 6-17 shows the oral and dermal chronic reference doses for the chemicals of concern at the Site. Subchronic reference doses are shown for the chemicals for which they are available.

Previously derived inhalation RfCs were used when available, but when these were unavailable, RfCs were estimated from threshold limit value-time weighted averages (TLV-TWAs). The TLV-TWA guideline is intended to protect healthy workers from adverse health effects when they are exposed to a substance in the work place air for 8 hours/day, 5 days/week. It is recognized that several factors limit the usefulness of these guidelines in the derivation of RfCs for use in risk assessments. First, the TLV-TWA for some chemicals may be based on an endpoint of toxicity other than chronic noncarcinogenic effects. Second, these guidelines assume intermittent exposure periods associated with worker activity, whereas RfCs are intended to protect against a continuous 24 hours/day, 7 days/week exposure period. Third, the TLV-TWAs may not incorporate the most current toxicological information, because they are not always reviewed on a regular basis. Also, the agency or organization deriving the TLV-TWA may apply uncertainty factors and weight-of-evidence classifications differently than U.S. EPA does. Finally, the TLV-TWAs are established to protect the average worker (ages 18 to 65 years), whereas RfCs are intended to protect the most sensitive subgroup of the population, which may be of any age and/or health status.

Table 6-17

Oral and Dermal Chronic and Subchronic Reference Doses (RfDs) for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Chronic (Sub-chronic) Oral RfD (mg/kg/d)	Species/ Critical Effect	Oral RfD Basis/Source	Uncertainty Factor	Oral Absorption Efficiency	Chronic (Sub-chronic) Dermal RfD (mg/kg/d)
<u>Inorganics</u>						
Antimony	4E-04	Rat/Reduced lifespan, altered blood chemistry	5 ppm in drinking water for lifetime/HEAST	1,000	0.50	2E-04
Arsenic	3E-04	Human/Keratosis and hyperpigmentation	NA/IRIS	1	0.50	1.5E-04
Barium	5E-02	Rat/Increased blood pressure	100 ppm in drinking water for ≤ 16 months/ HEAST	100	0.50	2.5E-02
Beryllium	5E-03	Rat/NA	5 ppm in drinking water for lifetime/IRIS	100	0.50	2.5E-03
Cadmium (food)	1E-03	Human/Renal damage	NA/HEAST	10	0.50	5E-04
Cadmium (water)	5E-04	Human/Renal damage	NA/HEAST	10	0.50	2.5E-04
Chromium (III)	1E+00 (1E+01)	Rat/ND	5% in diet, 5 d/wk, 600 feedings/HEAST	1,000	0.50	5E-01 (5E+00)
Chromium (VI)	5E-03 (2E-02)	Rat/ND	25 ppm in drinking water for 1 year/HEAST	500	0.50	2.5E-03 (1E-02)
Copper	3.7E-02	Human/Local GI irritation	Drinking water standard/ HEAST	–	0.50	1.8E-02
Manganese	1E-01	Human/NA	0.103-0.16 mg/kg/d chronic dietary intake/HEAST	1	0.50	5E-02
Mercury	3E-04	Rat/Kidney damage	NA/HEAST	1,000	0.50	1.5E-04
Nickel	2E-02	Rat/Reduced body and organ weight	100 ppm in diet for 2 years/ HEAST	300	0.50	1E-02

Table 6-17 (Continued)

Oral and Dermal Chronic and Subchronic Reference Doses (RfDs) for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Chronic (Sub-chronic) Oral RfD (mg/kg/d)	Species/ Critical Effect	Oral RfD Basis/Source	Uncertainty Factor	Oral Absorption Efficiency	Chronic (Sub-chronic) Dermal RfD (mg/kg/d)
Selenium[a]	3E-03	Human/Hair and nail loss, dermatitis	0.046 mg/kg/d/ HEAST	15	0.50	1.5E-03
Thallium	7E-05 (7E-04)	Rat/Increased SGOT and serum LDH levels, alopecia	0.2 mg/kg/d for 90 days/ HEAST	3,000	0.50	3.5E-05 (3.5E-04)
Vanadium	7E-03	Rat/NA	5 ppm in drinking water for lifetime/HEAST	100	0.50	3.5E-03
Zinc	2E-01	Human/Anemia	2.14 mg/kg/d theraputic dosage/HEAST	10	0.50	1E-01
Cyanide	2E-02	Rat/Weight loss, thyroid effects, myelin degeneration	10.8 mg/kg/d for 104 weeks/HEAST	500	0.50	1E-02
<u>Semivolatile Organics</u>						
4-Methylphenol	5E-02 (5E-01)	Rat/Reduced body weight gain, neurotoxicity	50 mg/kg/d for 90 days/ HEAST	1,000	0.50	2.5E-02 (2.5E-01)
1,2,4-Trichlorobenzene	1.3E-03 (1.3E-02)	Rat/Porphyria	22.3 mg/kg/d, 6 h/d, 5 d/wk, for 3 months/HEAST	1,000	0.50	6.6E-04 (6.6E-03)
Di-n-Butylphthalate	1E-01 (1E+00)	Rat/Morality	0.25% of diet for 52 weeks/ HEAST	1,000	0.50	5E-02 (5E-01)
bis-(2-Ethylhexyl)Phthalate	2E-02	Guinea pig/Increased relative liver weight	19 mg/kg/d for 1 year/ HEAST	1,000	0.50	1E-02

Table 6-17 (Continued)

Oral and Dermal Chronic and Subchronic Reference Doses (RfDs) for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Chronic (Sub-chronic) Oral RfD (mg/kg/d)	Species/ Critical Effect	Oral RfD Basis/Source	Uncertainty Factor	Oral Absorption Efficiency	Chronic (Sub-chronic) Dermal RfD (mg/kg/d)
PAHs						
Naphthalene	4E-03 (4E-02)	Rat/Decreased body weight gain	50 mg/kg/d by gavage for 13 weeks/HEAST	10,000	0.50	2E-03 (2E-02)
Fluoranthene	4E-02 (4E-01)	Mouse/Nephropathy, liver weight changes, hematological changes	125 mg/kg/d by gavage for 90 days/HEAST	3,000	0.50	2E-02 (2E-01)
Pyrene	3E-02 (3E-01)	Mouse/Renal effects	75 mg/kg/d by gavage for 13 weeks/HEAST	3,000	0.50	1.5E-02 (1.5E-01)
Volatile Organics						
Methylene Chloride	6E-02	Rat/Liver toxicity	Drinking water/HEAST	100	1.00	6E-02
Acetone	1E-01 (1E+00)	Rat/Increased liver and kidney weight, nephrotoxicity	100 mg/kg/d by gavage for 90 days/HEAST	1,000	1.00	1E-01 (1E+00)
Carbon Disulfide	1E-01	Rabit/Fetal toxicity, malformation	200 ppm inhalation, 6 h/d, during and before pregnancy/ HEAST	100	1.00	1E-01
1,1-Dichloroethane	1E-01 (1E+00)	Rat/NA	500 ppm inhalation, 6 h/d, 5 d/wk, 13 weeks/HEAST	1,000	1.00	1E-01 (1E+00)
Chloroform	1E-02	Dog/Liver lesions	15 mg/kg, 6 d/wk, for 7.5 years/HEAST	1,000	1.00	1E-02
2-Butanone	5E-02 (5E-01)	Rat/Fetotoxicity	235 ppm, 7 h/d, 5 d/wk, for 12 weeks/HEAST	1,000	1.00	5E-02 (5E-01)

Table 6-17 (Continued)

Oral and Dermal Chronic and Subchronic Reference Doses (RfDs) for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Chronic (Sub-chronic) Oral RfD (mg/kg/d)	Species/ Critical Effect	Oral RfD Basis/Source	Uncertainty Factor	Oral Absorption Efficiency	Chronic (Sub-chronic) Dermal RfD (mg/kg/d)
Tetrachloroethene	1E-02 (1E-01)	Mouse/Hepatotoxicity	20 mg/kg/d for 6 weeks/ HEAST	1,000	1.00	1E-02 (1E-01)
Toluene	2E-01 (1E+00)	Rat/Liver and kidney effects	312 mg/kg/d for 13 weeks/ HEAST	1,000	1.00	2E-01 (2E+00)
Ethylbenzene	1E-01 (1E+00)	Rat/Hepatotoxicity, nephrotoxocity	136 mg/kg/d for 182 days/ HEAST	1,000	1.00	1E-01 (1E+00)
Xylenes (total)	2E+00 (4E+00)	Rat/Hyperactivity, decreased body weight, mortality	250 mg/kg/d for 103 weeks/ HEAST	100	1.00	2E+00 (4E+00)
Pesticides						
4,4'-DDT	5E-04	Rat/Liver lesions	1 ppm in diet for 27 weeks/ HEAST	100	0.50	2.5E-04

ND - Not determined.
NA - Not available.
[a]Based on selenious acid.

In spite of these limitations, an inhalation RfC for a chemical that is derived from its TLV-TWA is deemed to be the best substitute for an experimentally derived RfC. Table 6-18 presents the approach that was used in this risk assessment to derive RfCs from TLV-TWA values. In the equation that is shown, the TLV-TWA is first normalized for a worker as a daily exposure limit, and is then adjusted to account for continuous exposure conditions (i.e., 24 hours/day, 7 days/week). A conservative modifying factor is included to account for discrepancies concerning the biological endpoints of toxicity, uncertainties about the quality and nature of the toxicological study on which the TLV-TWA is based, and the applicability of the TLV-TWA to highly sensitive subpopulations.

Table 6-19 shows the inhalation RfCs for the chemicals of concern at the Site. Subchronic reference concentrations are shown for the chemicals for which they are available.

The application of a route-specific RfD to another exposure route(s) and the derivation of RfCs from TLV-TWAs contribute additional uncertainty to the evaluation of risks. However, the use of adequately conservative uncertainty factors is expected to ensure that the health criteria used are adequately protective of human health.

The chronic RfDs and RfCs described above are established for lifetime or other long-term exposures. The values are expected to be overly protective if used to evaluate the potential for adverse health effects resulting from exposures lasting less than ten percent of a human lifetime (U.S. EPA, 1989c). In many cases, subchronic RfDs and RfCs have been established by U.S. EPA, and these are suggested for use when exposures are expected to last between 14 days and seven years. When available, subchronic RfDs and RfCs were used to evaluate the noncarcinogenic risks associated with the future site worker exposure scenario that is projected to last for one to two years.

<u>Specific Notes Concerning the Non-carcinogenic Risk Evaluation</u>

Ingestion RfDs for cadmium have been developed for both food and water intakes. For the water dermal contact exposure pathway, the ingestion RfD for water intake was used. For the soil ingestion and soil dermal contact exposure pathways, the ingestion RfD for food intake was used.

Although total chromium was determined at the Site, the RfDs for both chromium (III) and chromium (VI) were used in this assessment. Ten percent of the total chromium at the Site was assumed to be chromium (VI), and 90 percent was assumed to be chromium (III).

6.3.4 Lead

Infants and young children are the most vulnerable populations exposed to lead. The U.S. EPA considers it inappropriate to develop an RfD for inorganic lead because health effects in children may occur at blood lead levels so low as to be essentially without a threshold (IRIS, 1991). The U.S. EPA has identified 10 micrograms per deciliter (ug/dL) as a blood

Table 6-18

Approach to Deriving an Inhalation Reference Concentration (RfC) from a Threshold Limit Value Time-Weighted Average (TLV-TWA)

$$\textit{Inhalation RfC} = \frac{\textit{TLV-TWA x Air breathed per work day x Work week adjustment factor}}{\textit{Body weight x Uncertainty factor}}$$

Where:

Inhalation RfC (mg/kg/day)	=	Inhalation reference concentration.
TLV-TWA (mg/m^3)	=	Threshold limit value time-weighted average (ACGIH, 1989).
Air breathed per work day (m^3/day)	=	10 m^3. This value has been used by U.S. EPA when deriving an inhalation acceptable chronic intake (AIC) for the public from worker exposure levels (U.S. EPA, 1984b).
Work week adjustment factor	=	5 days/7 days (the fraction of the week that the worker is exposed). Because TLV-TWA is based on a 5-day work week, it is adjusted to assume continuous exposure (i.e., 7 days/week).
Body weight (kg)	=	70 kg (weight of an average adult) (U.S. EPA, 1991b).
Uncertainty factor	=	100. An uncertainty factor is included to protect sensitive members of the general population (e.g., children and elderly). A factor of 10 has been used by U.S. EPA when deriving an inhalation AIC for the public from worker exposure levels (U.S. EPA, 1984b). An additional factor of 10 is included to increase the certainty that the derived RfD is health-protective. Uncertainty factors of 10 to 100 are commonly used by government agencies when deriving public health criteria from TLV-TWAs (PAMs, 1983).

Table 6-19

Inhalation Reference Concentrations (RfCs) for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Chronic (Sub-chronic) RfC (mg/kg/d)	Species/ Critical Effect	RfC Basis/ Source	Uncertainty Factor
Inorganics				
Antimony	5.1E-04	—	TLV-TWA	100*
Arsenic	2.0E-04	—	TLV-TWA	100*
Barium	1.0E-04 (1.0E-03)	Rat/Fetotoxicity	1.15 mg/m^3, 4h/d, for 4 months/ HEAST	1,000
Beryllium	2.0E-06	—	TLV-TWA	100*
Cadmium	5.1E-05	—	TLV-TWA	100*
Chromium (III)	5.7E-07 (5.7E-06)	Human/Nasal mucosa atrophy	Inhalation/HEAST	300
Chromium (VI)	5.7E-07 (5.7E-06)	Human/Nasal mucosa atrophy	Inhalation/HEAST	300
Copper	1.0E-03	—	TLV-TWA	100*
Manganese	1.1E-04	Human/Respiratory symptoms and psychomotor dis-turbances	Occupational/HEAST	900
Mercury	8.6E-05	Human/Neurotoxicity	Occupational/HEAST	30
Nickel	1.0E-03	—	TLV-TWA	100*
Selenium	2.0E-04	—	TLV-TWA	100*
Thallium	1.0E-04	—	TLV-TWA	100*
Vanadium	5.1E-05	—	TLV-TWA	100*
Zinc	1.0E-02	—	TLV-TWA	100*
Cyanide	5.1E-03	—	TLV-TWA	100*

Table 6-19 (Continued)

Inhalation Reference Concentrations (RfCs) for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Chronic (Sub-chronic) RfC (mg/kg/d)	Species/ Critical Effect	RfC Basis/ Source	Uncertainty Factor
Semivolatile Organics				
4-Methylphenol	2.2E-02	—	TLV-TWA	100*
1,2,4-Trichlorobenzene	ND	—	—	—
Di-n-butylphthalate	5.1E-03	—	TLV-TWA	100*
Bis(2-ethylhexyl) phthalate	ND	—	—	—
PAHs				
Naphthalene	5.1E-02	—	TLV-TWA	100*
Fluoranthene	5.1E-02	—	TLV-TWA (naphthalene)	100*
Pyrene	5.1E-02	—	TLV-TWA (naphthalene)	100*
Volatile Organics				
Methylene chloride	8.6E-01	Rat/NA	200 ppm, 6 h/d, 5 d/wk, for 2 years/ HEAST	100
Acetone	1.8E+00	—	TLV-TWA	100*
Carbon disulfide	2.9E-03	Rat/Fetal toxicity	10 mg/m^3, 8 h/d during gestation/ HEAST	1,000
1,1-Dichloroethane	1.0E-01 (1.0E+00)	Cat/Kidney damage	500 ppm, 6 h/d, 5 d/wk, for 13 weeks/ HEAST	1,000
Chloroform	5.1E-02	—	TLV-TWA	100*
2-Butanone	9.0E-02 (9.0E-01)	—	235 ppm, 7 h/d, 5 d/wk, for 12 weeks/ HEAST	1,000

Table 6-19 (Continued)

Inhalation Reference Concentrations (RfCs) for the Chemicals of Potential Concern
Linden Road Landfill
Flint, Michigan

Chemical	Chronic (Sub-chronic) RfC (mg/kg/d)	Species/ Critical Effect	RfC Basis/ Source	Uncertainty Factor
Tetrachloroethene	3.4E-01	—	TLV-TWA	100[a]
Toluene	5.7E-01	Human/CNS effects, eye and nose irritation	40 ppm for 6 hrs/ HEAST	100
Ethylbenzene	2.9E-01	Rat, rabbit/ Developmental toxicity	100 ppm, 6-7 h/d during gestation/ HEAST	300
Xyelenes (total)	8.6E-02	Human/CNS effects eye and nose irritation	20 ppm, 7.5 h/d, for 5 days/HEAST	100
Pesticides				
4,4'-DDT	1.0E-03	—	TLV-TWA	100[a]

[a]Represents uncertainty factor employed in derivation of RfC from TLV-TWA.
ND - Not determined.
NA - Not available.

lead level of concern in young children. Blood lead levels above 10 ug/dL are associated with increased risks of potentially adverse effects on neurological development and diverse physiological functions (U.S. EPA, 1990a). Lead is also considered to be a probable human carcinogen (Group B2).

Correlation data between blood lead levels and lead concentrations in soil and air are available, but these are poor estimates with which to quantify risk. Correlations between blood lead levels and environmental concentrations are qualitative at best, since there are a large number of unknowns (i.e., variables affecting exposure, blood lead levels, and associated health effects) that could affect the probability of an adverse effect.

Therefore, due to the uncertainties inherent in quantifying the risks associated with lead exposure (which have resulted in the withdrawal of U.S. EPA-approved RfDs and cancer slope factors), a qualitative evaluation of the lead contamination at the Site will be performed.

6.4 RISK CHARACTERIZATION

The function of the risk characterization is to integrate the information from the toxicity assessment and the exposure assessment to quantitatively estimate both the current and potential future human health risks that are associated with exposure to the chemicals of concern at the Site.

Human health risks for carcinogenic and noncarcinogenic chemicals are discussed separately because of the different toxicologic endpoints involved and the different methods that are employed in characterizing the risks. Incidental human health risks associated with exposure to carcinogenic chemicals are calculated by multiplying chemical exposure levels (i.e., chronic daily intakes) by the corresponding cancer slope factors. The total combined cancer risk is estimated by summing the risk estimate derived for each chemical across all exposure routes. This approach is in accordance with U.S. EPA guidelines on chemical mixtures, in which risks associated with carcinogens are considered additive (U.S. EPA, 1989c). This approach assumes independence of action by the chemicals (i.e., that there are no synergistic or antagonistic interactions between the chemicals), and that all of the chemicals have the same toxicological endpoint of toxicity (i.e., cancer).

In assessing the carcinogenic risks posed by a site, the NCP establishes an excess cancer risk of 1.0E-06 as a "point of departure" for establishing remediation goals. Excess cancer risks lower than 1.0E-06 are not addressed by the NCP. Excess cancer risks in the range from 1.0E-04 to 1.0E-06 may or may not be considered acceptable, depending on site-specific factors such as the potential for exposure, technical limitations to remediation, and data uncertainties.

In evaluating noncarcinogenic health risks, a hazard index (HI) approach is followed. The hazard index for exposure to a single chemical is equal to the estimated exposure (i.e., the estimated daily intake) divided by the acceptable exposure (i.e., the reference dose). This approach assumes that exposure to multiple chemicals could result in an adverse effect, the magnitude of which is proportional to the sum of the ratios of the estimated exposures to the acceptable exposures. When the calculated HI for any individual chemical or the sum of the HIs for multiple chemicals exceeds a value of 1.0 (unity), there may be a potential health risk. Since the assumption of additivity is applicable to chemicals that induce the same type of effect, if the total (i.e., summed over all chemicals) HI is greater than one, then the chemicals are re-evaluated by critical effect, and separate HIs are calculated by type of effect. The possible effects of multimedia exposures are evaluated by summing the HI values across all relevant exposure routes.

6.4.1 Risks Associated with Current Trespasser Exposure

Current trespassers are assumed to be potentially exposed to chemicals in soil through ingestion or dermal absorption, to chemicals in surface water through dermal absorption, and to chemicals in airborne dust through inhalation.

6.4.1.1 Carcinogenic Health Risks

The total carcinogenic risks associated with trespasser exposure are summarized in Table 6-20. The total carcinogenic risk ranges from 1.5E-07 under the representative average exposure scenario to 2.2E-05 under the reasonable maximum exposure scenario. This range of risks falls within the range from 1.0E-06 to 1.0E-04, indicating that cancer risks associated with the Site may be acceptable for this exposure scenario.

The major exposure routes contributing to the total carcinogenic risk are ingestion and dermal absorption of chemicals in soil. These two routes account for 99.9 percent of the risk under both the reasonable maximum exposure scenario and the representative average exposure scenario. The chemicals contributing the majority of the risk under each of these exposure pathways are benzo(a)pyrene, dibenz(a,h)anthracene, and Aroclor 1254. These three chemicals account for 70 percent of the total RME risk and 65 percent of the total RAE risk for exposure via ingestion of chemicals in soil. They account for 61 percent of the total RME risk and 75 percent of the total RAE risk for exposure via dermal absorption of chemicals in soil (see Appendix H for detailed exposure tables).

6.4.1.2 Noncarcinogenic Health Risks

The total noncarcinogenic risks associated with current trespasser exposure are also presented in Table 6-20. The total noncarcinogenic risk ranges from 4.7E-03 for the representative average exposure to 2.7E-01 for the reasonable maximum exposure. Since this range lies below the critical hazard index value of 1.0, noncarcinogenic health effects are not expected to be significant for this exposure scenario.

Table 6-20

Summary of Human Health Risks Associated
with Current Site Trespasser Exposures
Linden Road Landfill
Flint, Michigan

Exposure Pathway	Cancer Risk Level RME	Cancer Risk Level RAE	Hazard Index RME	Hazard Index RAE
Soil ingestion	6.6E-06	8.1E-08	1.9E-02	8.1E-04
Soil dermal absorption	1.5E-05	6.5E-08	1.1E-01	2.3E-05
Dust inhalation	4.3E-08	5.7E-10	1.4E-01	3.9E-03
Surface water dermal absorption	1.8E-13	6.9E-15	5.4E-08	4.5E-08
Total	2.2E-05	1.5E-07	2.7E-01	4.7E-03

RME - Reasonable maximum exposure.
RAE - Representative average exposure.

The major exposure pathway contributing to the total noncarcinogenic risk is the inhalation of chemicals in airborne dust. This pathway accounts for 52 percent of the risk under the reasonable maximum exposure scenario, and 83 percent of the risk under the representative average exposure scenario. Further, the vast majority of the risk associated with the inhalation of chemicals in airborne dust (95 percent for RME and 97 percent for RAE) is due to the inhalation of chromium (see Appendix H for detailed exposure tables).

6.4.1.3 Lead Exposure Risks

There are currently no accepted carcinogenic or noncarcinogenic health criteria for lead exposure. However, since lead is considered to be highly toxic, a qualitative discussion of the risk associated with lead exposure at the Site is provided.

Lead was detected in 10 out of 10 surface soil (0-3 feet) samples collected from the Site. The range of detected concentrations was 19.5 to 2720 mg/kg. The average exposure concentration was 188 mg/kg, and the maximum exposure concentration was 956 mg/kg.

In comparison to average background soil lead concentrations, the lead levels in the surface soils are elevated (Table 6-5). The Agency for Toxic Substances and Disease Registry (ATSDR) has recommended a safe level of 500-1000 parts per million (ppm) lead in soil to protect children from adverse effects in residential exposure situations (ATSDR, 1988). No child exposures nor residential exposures are expected at this site.

By converting surface soil lead levels to lead levels in airborne dust (using the arithmetic mean of ambient inhalable particulated for Flint, Michigan [0.026 mg/m^3, MDNR, 1989]), the concentration of lead in air can be estimated to range from 4.9E-6 mg/m^3 for the average exposure concentration to 2.5E-5 mg/m^3 for the maximum exposure concentration. A TLV-TWA of 0.05 mg/m^3 for inhalation exposure to inorganic lead has been established. Thus, the potential for health risks resulting from inhalation exposure to lead is expected to be low.

Lead was detected in four out of five surface water samples collected from the Site. The range of detected concentrations was 0.0035 to 0.012 mg/L. The lead ambient water quality criterion (AWQC) for the protection of human health is 0.05 mg/L. The average (0.0045 mg/L) and maximum (0.010 mg/L) exposure point concentrations of lead in the surface water at the Site are well below the AWQC, suggesting that the health risks associated with exposure to lead in the surface water are low.

6.4.2 Risks Associated with Future Site Worker Exposure

Future construction workers at the Site could potentially be exposed to chemicals in soil through ingestion or dermal absorption, to chemicals in surface water through dermal absorption, and to chemicals in airborne dust through inhalation.

6.4.2.1 Carcinogenic Health Risks

The total carcinogenic risks associated with future site worker exposure are summarized in Table 6-21. The total carcinogenic risk ranges from 1.4E-06 under the representative average exposure scenario to 4.6E-05 under the reasonable maximum exposure scenario. This range of risks falls within range from 1.0E-06 to 1.0E-04, indicating that cancer risks associated with the Site may be acceptable for this exposure scenario.

Ingestion of chemicals in soil, dermal absorption of chemicals in soil, and inhalation of chemicals in airborne dust all contribute significantly to the total cancer risk calculated for the future site worker. Benzo(a)pyrene, dibenz(a,h)anthracene, and Aroclor 1254 account for the majority of the cancer risk associated with exposure to chemicals in soil via ingestion and dermal absorption. Chromium (VI), nickel, and arsenic account for the majority of the cancer risk associated with exposure to chemicals in airborne dust via inhalation.

6.4.2.2 Noncarcinogenic Health Risks

The total noncarcinogenic risks associated with future site worker exposure are also summarized in Table 6-21. The total noncarcinogenic risk ranges from 4.8E-01 for the representative average exposure to 6.2E+00 for the reasonable maximum exposure. This range extends above the critical hazard index value of 1.0, indicating that noncarcinogenic health effects could be significant for this exposure scenario.

The major exposure pathway contributing to the total noncarcinogenic risk is the inhalation of chemicals in airborne dust. This pathway accounts for 81 percent of the risk under the reasonable maximum exposure scenario, and 83 percent of the risk under the representative average exposure scenario. Further, the vast majority of the risk associated with the inhalation of chemicals in airborne dust (85 percent for the RME and 78 percent for the RAE) is due to the inhalation of chromium (see Appendix H for detailed exposure tables).

The hazard index for the inhalation of chemicals in dust is much greater in the future site worker scenario than in the current site trespasser scenario, primarily because of the increased on-site dust concentration and the increased exposure times that are assumed. Exposure to site chemicals during future site excavation could be addressed by the health and safety plan, and minimized by appropriate engineering controls.

6.4.2.3 Lead Exposure Risks

There are currently no accepted carcinogenic or noncarcinogenic health criteria for lead exposure. However, since lead is considered to be highly toxic, a qualitative discussion of the risk associated with lead exposure at the Site is provided.

Lead was detected in 35 out of 35 near-surface soil (0-10 feet) samples collected from the Site. The range of detected concentrations was 8.5 to 115,000 mg/kg. The average

Table 6-21

Summary of Human Health Risks Associated
with Future Short-Term Site Worker Exposures
Linden Road Landfill
Flint, Michigan

Exposure Pathway	Cancer Risk Level RME	Cancer Risk Level RAE	Hazard Index RME	Hazard Index RAE
Soil ingestion	2.6E-05	8.3E-07	7.4E-01	7.5E-02
Soil dermal absorption	1.6E-05	3.5E-07	4.1E-01	2.7E-04
Dust inhalation	4.2E-06	2.3E-07	5.0E+00	4.0E-01
Surface water dermal absorption	2.5E-12	4.7E-13	6.5E-07	2.8E-07
Total	4.6E-05	1.4E-06	6.2E+00	4.8E-01

RME - Reasonable maximum exposure.
RAE - Representative average exposure.

exposure concentration was 418 mg/kg, and the maximum exposure concentration was 10,500 mg/kg. In comparison to average background soil lead concentrations, the levels of lead in the near-surface soils are elevated (Table 6-5). ATSDR has recommended a safe level of 500-1000 ppm lead in soil to protect children from adverse effects of lead exposure in residential situations (ATSDR, 1988). No child exposures nor residential exposures are expected at this Site. However, the elevated lead levels in the near-surface soil at the Site are expected to present a potential health risk to site workers.

By converting near-surface soil lead levels to air lead levels using the inhalable particulate level derived for the excavation scenario (0.11 mg/m^3), the concentration of lead in air can be estimated to range from 4.6E-5 mg/m^3 for the average exposure concentration to 1.1E-3 mg/m^3 for the maximum exposure concentration. A TLV-TWA of 0.05 mg/m^3 for inhalation exposure to inorganic lead has been established. Therefore, the potential for health risks due to exposure to lead in air is expected to be low.

6.4.3 Uncertainty Analysis

The goal of the uncertainty analysis in a risk assessment is to provide to the appropriate decision makers (i.e., risk managers) a wide range of information about the risk assessment assumptions, their inherent uncertainty and variability, and the impact of this uncertainty and variability on the estimate of risk. The major impact of the uncertainty analysis is that the predicted risks are relative in nature and do not represent an absolute quantification. This is an important point that is vital to the proper interpretation and understanding of the risks presented in this report.

A number of areas of uncertainty are associated with the quantification of risks. Toxicological uncertainties primarily relate to the methodologies by which carcinogenic and noncarcinogenic health criteria are developed. Cancer slope factors are developed using a non-threshold theory, which assumes that there is no "safe" level of exposure to a carcinogen. The animal studies from which slope factors are usually derived are performed at relatively high doses. The dose vs. response data from these studies is extrapolated back many orders of magnitude to estimate the risks associated with the very low chemical doses that humans might be exposed to. As discussed in the Toxicity Assessment, this low-dose extrapolation process produces conservative estimates of cancer risks, but it has a large degree of associated uncertainty. Additional uncertainty is inherent in the use of data from animal studies to determine health criteria for humans. A variety of uncertainty factors are typically associated with noncarcinogenic reference doses, each of which adds to the total uncertainty in the quantitative assessment.

In addition to toxicological uncertainties, there are uncertainties associated with the exposure assessment. The exposure scenarios that were developed to calculate exposure doses and, ultimately, risks are based on a number of assumptions about the magnitude, frequency, and duration of the exposure. These exposure assumptions may or may not produce a realistic representation of the actual exposure conditions at the Site. In general, the assumptions that were made were conservative, so that exposures are more likely to be overestimated than underestimated.

There is also a measure of uncertainty associated with the exposure point concentrations used in the quantitative assessment. If insufficient samples were taken to fully characterize the contamination at the Site, then the actual chemical concentrations could be higher or lower than the exposure point concentrations that were calculated. Also, the exposure point concentrations do not take into account the possibility that some parts of the Site might be more or less contaminated and/or accessible than others, and therefore that the actual typical exposure concentrations might deviate from averages taken over the whole site.

Airborne chemical concentrations were not measured at the Site. The exposure point concentrations that were used in the current and future dust inhalation scenarios were estimated from contaminant transport models. These models are conservative, and probably produce overestimates of the exposure point concentrations.

A qualitative evaluation of the impacts of each of the key toxicological and exposure-related uncertainty elements on the estimation of risk for the Site is presented in Table 6-22. The risks presented in this report need to be viewed in light of the information presented in this table. Column 1 shows a significant number of assumptions that represent moderate overestimations of risk, while no significant underestimations of risk are noted in Column 2. Column 3 identifies several areas where the potential exists for low to moderate over- or underestimation.

Overall, the risks at the Site are probably overestimated to a moderate degree. Thus, they are conservative.

6.5 ECOLOGICAL RISK ASSESSMENT

A qualitative assessment of the potential impacts on aquatic and terrestrial life associated with the contamination at the Site was performed. This assessment is a limited evaluation of potential ecological impacts, because site-specific information and data on sensitive species present was not available.

The Site encompasses 40 acres; it is heavily vegetated, with mixed openfield, scrub-shrub, and wooded areas. Scattered throughout the Site are areas devoid of vegetation, which are characterized by a red color. Within the landfill boundaries the topography is varied, with numerous hillocks, trenches and ponded areas. There are also marshy areas and ponds associated with the trenches.

The ponds and trenches on the Site provide limited aquatic habitat. Frogs and ducks have been observed in these areas. Based on local topography, local groundwater flow is probably toward the Flint River in the east and north-northeast directions. Thus, aquatic life inhabiting the Flint River may also be potentially impacted in the future by site

Table 6-22

Summary of Uncertainty Analysis
Linden Road Landfill
Flint, Michigan

Uncertainty Element	Effect on Risk Estimate Potential for Overestimation	Potential for Underestimation	Potential for Over- or Underestimation
Environmental Data			
Insufficient samples to characterize the media being evaluated			Moderate
Systematic or random errors in the chemical analyses yielding erroneous data			Low
Current concentrations (soil, surface water) used as future concentrations			Moderate
Total chromium concentration estimated to be 10 percent chromium (VI) and 90 percent chromium (III)			Low
Fate and Transport Modeling			
Dust resuspension model	Moderate		
Exposure Parameter Estimation			
Standard assumptions regarding body weights, skin surface areas, inhalation rates, and life expectancy			Low
Media intake rates	Moderate		
Exposure frequencies	Moderate		
Exposure durations	Moderate		
Toxicity Data			
Use of U.S. EPA RfDs and slope factors	Moderate		
Use of adjusted oral toxicity criteria for dermal exposure			Moderate
Use of TLV-based inhalation criteria	Moderate		

Table 6-22 (Continued)

Summary of Uncertainty Analysis
Linden Road Landfill
Flint, Michigan

Uncertainty Element	Effect on Risk Estimate Potential for Overestimation	Potential for Underestimation	Potential for Over- or Underestimation
Use of BaP relative potencies for carcinogenic PAHs			Low
Use of current arsenic oral slope factor	Moderate		
Inability to quantitatively assess lead exposure		Magnitude unknown	

chemicals in groundwater discharging into the river. However, on-site chemical concentrations are expected to be significantly reduced in the groundwater discharging to the river through attenuation.

Potential impacts on aquatic species can be evaluated by a comparison of chemical concentrations in surface water to ambient water quality criteria (AWQC) or guidelines for the protection of aquatic life. Federal AWQC for the protection of aquatic life have been established under the Clean Water Act that are protective of 95 percent of all aquatic species, including fish, aquatic invertebrates, and plants (U.S. EPA, 1986a). Table 6-23 compares measured surface water and groundwater concentrations to available water quality criteria for the chemicals of potential concern detected at the Site. The chronic water quality criteria for copper, lead, zinc, and nickel are exceeded in the surface water. The maximum groundwater concentrations are all below the acute-to-chronic range of the available criteria. Therefore, groundwater which could potentially discharge into surface water will not pose any threats to aquatic life.

The ponded areas on the Site are small, shallow, man-made features that are scattered throughout the Site. They are not connected to any off-site surface waterbodies. In addition, those chemicals in the on-site surface water features that exceed water quality criteria are not known to biomagnify in the food chain. For groundwater potentially discharging to the Flint River, attenuation would lower the concentrations of chemicals significantly compared to the measured concentrations in the shallow groundwater. Thus, chemicals of potential concern in the ponded areas and trenches on the Site and in the groundwater are not expected to pose a significant hazard to aquatic life. Even though the maximum groundwater chemical concentrations are below the acute to chronic ranges of the aquatic criteria, attenuation will further reduce the concentrations discharging into the Flint River.

The Site is likely to support small herbivorous mammal populations, such as field mice, moles, shrews, voles, woodchucks, and rabbits, that live on the ground or burrow into it. A burrowing mammal would be more likely to be continuously exposed to chemicals than larger, more mobile mammals, whose home ranges would be larger and whose access to the Site would be somewhat restricted by the site fence. A burrowing mammal could be exposed to chemicals through incidental ingestion of soil, consumption of surface water from the ponded areas, and ingestion of browse grown in contaminated soils. Elevated concentrations of chemicals that have the potential to bioaccumulate, especially heavy metals, pesticides, and PCBs, may pose a threat to mammals with a small home range. In addition, elevated soil concentrations of organic chemicals may produce phytotoxic effects in plant species.

6.6 SUMMARY OF PUBLIC HEALTH EVALUATION

This section summarizes the key information presented in the previous sections, highlighting the chemicals selected, the approaches used for estimating exposure, the toxicological

Table 6-23

Comparison of Measured Surface Water and Groundwater Concentrations to Available Freshwater Aquatic Life Criteria
Linden Road Landfill
Flint, Michigan

Chemical of Potential Concern	Lowest Reported Toxic Concentration (μg/L)		Ambient Water Quality Criteria (μg/L)		Maximum Detected Concentration (μg/L)	
	Acute	Chronic	Acute	Chronic	Surface Water	Groundwater+
Organics						
Carbon Disulfide	–	–	–	–	66	ND
1,1-Dichloroethane	–	–	–	–	ND	12
Trichloroethene	45,000	–	–	–	ND	340
Di-n-butylphthalate	940	3.0	–	–	ND	1.0
Bis(2-chloroethyl)ether	238,000	–	–	–	13	0.9
4-Methylphenol	–	–	–	–	13	ND
Napthalene	2,300	620	–	–	2	ND
Bis(2-ethylhexyl)phthalate	238,000	–	–	–	3	ND
Alpha-BHC	100	–	–	–	0.01	0.02
Inorganics						
Arsenic	–	–	360	190	5.7	ND
Barium	–	–	–	–	420	190
Copper*	–	–	18	12	25	ND
Lead*	–	–	82	3.2	12	ND
Manganese	–	–	–	–	8,900	1,550
Nickel*	–	–	1,400	160	800	40
Zinc*	–	–	120	11	44	ND

+Based on shallow well samples.
*Hardness-dependent criteria; assumes 100 mg/L $CaCO_3$.
ND - Not detected.
Sources: IRIS, 1991; Vershueren, 1983.

assumptions used, and the total current and future carcinogenic and non-carcinogenic risks posed to each receptor population.

6.6.1 Chemicals of Potential Concern

Over 70 chemicals (including VOCs, semivolatiles, pesticides, and inorganics) were observed in the soil and surface water at the Site. After a screening of chemicals was conducted, in which blank-related concentrations, background levels, availability of health criteria, and concentration-toxicity scoring were considered, 49 chemicals were selected as chemicals of potential concern for the Site. These chemicals are:

ORGANICS

Volatiles

- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichoroethane
- Chloroform
- 2-Butanone
- Trichloroethene
- Benzene
- Tetrachloroethene
- 1,1,2,2-Tetrachloroethane
- Toluene
- Ethylbenzene
- Xylene

Semivolatiles

- Bis(2-chloroethyl)ether
- 4-Methylphenol
- 1,2,4-Trichlorobenzene
- Di-n-butylphthalate
- Bis(2-ethylhexyl)phthalate
- PAHs (noncarcinogenic)
  - Naphthalene
  - Fluoranthene
  - Pyrene

INORGANICS

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Thallium
- Vanadium
- Zinc
- Cyanide

PAHs (carcinogenic)
- Benz(a)anthracene
- Chrysene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene

Pesticides and PCBs

alpha-BHC
4,4'-DDT
PCBs
- Aroclor 1248
- Aroclor 1254
- Aroclor 1260

Not every chemical of concern was detected at every source area nor in every environmental medium sampled at the Site. As a result, for each exposure pathway evaluated in this baseline assessment, the health risks are characterized based only on the chemicals of concern that were detected in the relevant medium.

6.6.2 Exposure Assessment

The exposure assessment characterized the potentially exposed populations at the Site, identified actual or potential exposure pathways, and determined the extent of exposure. A fate and transport analysis of the chemicals of concern in conjunction with the Site characteristics identified the potential chemical migration and exposure pathways at the Site. An exposure pathway screening was then conducted to identify those pathways to be included in the detailed quantitative analysis.

The exposure pathways considered most significant for the Site are:

Trespasser - Current

- Ingestion of soil.
- Dermal absorption of soil.
- Inhalation of dust.
- Dermal absorption of surface water.

Industrial - Future

- Ingestion of soil.

- Dermal absorption of soil.
- Inhalation of dust.
- Dermal absorption of surface water.

6.6.3 Toxicity Assessment

The toxicity assessment presented the available toxicological health effects criteria for each chemical of concern and for each exposure route identified for the Site. For carcinogenic effects, the available oral and inhalation slope factors were identified for each chemical classified as a carcinogen by the U.S. EPA. For noncarcinogenic effects, the available oral and inhalation RfDs were identified. Because dermal health criteria were not available for any of the chemicals of concern, they were estimated based on oral health criteria.

6.6.4 Human Health Risk Characterization

The total carcinogenic and noncarcinogenic risks associated with each exposure pathway quantified in this risk assessment are presented for the current site trespasser in Table 6-20 and for the future site worker in Table 6-21. The carcinogenic risk associated with the potential current site trespasser exposure ranged from 1.5E-07 to 2.2E-05 for the RAE and RME, respectively. The carcinogenic risk associated with the potential future site worker exposure ranged from 1.4E-06 to 4.6E-05 for the RAE and RME, respectively. Cancer risks were found to exceed the 1.0E-6 "point of departure," for at least the RME, for ingestion of chemicals in soil, dermal absorption of chemicals in soil, and inhalation of chemicals in dust (future site worker scenario only).

As discussed in Subsection 6.4.3 ("Uncertainty Analysis"), the total cancer risks may be overestimated to a moderate degree, due to the uncertainty associated with various factors that were incorporated into the quantitative analysis.

The noncarcinogenic risks associated with current trespasser exposure to site chemicals were found to be potentially insignificant for all evaluated pathways.

The noncarcinogenic risks associated with future site worker exposure were found to be potentially insignificant for all pathways evaluated except the inhalation of chemicals in airborne dust, where the Hazard Index was greater than 1. The vast majority of the risk associated with this pathway is contributed by chromium.

Lead is present in the surface and near-surface soils at elevated levels. Repeated exposure to these soils may present a health risk that we are not, at this time, able to evaluate quantitatively.

6.6.5 Ecological Risk Characterization

Based on the qualitative analysis performed, the risks associated with exposure of aquatic receptors is expected to be acceptable, while some potential exists for adverse effects to terrestrial species, especially those with small home ranges.

APPENDIX C

REMEDIAL SCREENING ALTERNATIVES
(SECTION 8 OF IRME AND SI REPORT)

SECTION 8

REMEDIAL ALTERNATIVES SCREENING

8.1 INTRODUCTION

A remedial alternatives screening was conducted to identify and screen potential alternatives for remedial action (RA) at the Site. This screening was performed using an approach consistent with the Michigan Act 307 regulations. First, the remedial technologies and process options considered potentially applicable to the chemicals found at the Site were identified. These technologies and process options were then screened for the protection of human health and the environment, implementability, effectiveness, and cost in achieving the RA goals. The selected alternatives will protect human health and the environment, be cost-effective, and will meet regulatory requirements to the maximum extent practicable. Although this section is not a complete feasibility study, it does include an initial screening of remedial alternatives as described in State of Michigan Act 307, Rule 299.5513(1-3).

8.2 CONTAMINATION AND MIGRATION PATHWAYS

The waste materials and some of the contaminated soils contained within the boundary of the Site represent the source of contamination for purposes of this screening. This subsection summarizes the nature and extent to which the environmental media (soil, surface water, and groundwater) have been impacted by chemicals present at the Site.

8.2.1 Surface Materials

The IRME investigation determined that small quantities of surface waste material from specific areas within the Site could be classified as hazardous waste based upon RCRA hazardous waste limits and/or contained materials with PCB concentrations significantly higher than TSCA disposal criteria. These wastes include: approximately 4 cubic yards of material containing high PCB concentrations in Area 32B; approximately 10 cubic yards of drum contents containing RCRA hazardous waste and/or material with elevated PCB levels; and contents of the Oil Disposal Area (approximately 14 cubic yards).

The surface waste material specified above, the chemical characterization of which was not used in the public health evaluation, will be addressed during a surface material removal action that will be implemented prior to initiation of overall site remediation activities.

8.2.2 Subsurface Materials

The SI indicated that waste material containing elevated levels of VOCs, semivolatile organic compounds, PCBs, and metals is found widespread in the subsurface of the Site up to a depth of 15 feet from the ground surface. The waste material is composed of heterogeneous material, including metal grindings, oily materials, drums and drum remnants, and miscellaneous debris. There is no apparent pattern to the distribution of these materials in the subsurface of the Site.

The quality of groundwater and surface water at the Site does not appear to significantly impacted by the waste material. A detailed description of the extent of contamination is presented in Section 7.

8.2.3 Potential Routes of Migration

The potential migration pathways for contaminants at the Site include:

- Migration of soil/waste particulates into air by volatilization or by suspension.
- Migration of contaminants from soil/waste into groundwater.
- Migration of contaminants from soil/waste into surface water.
- Future migration of contaminants off site via groundwater.

8.3 PUBLIC HEALTH EVALUATION

The public health evaluation presented in Section 6 has identified ingestion, dermal adsorption, and inhalation as the major exposure routes at the Site. The control of chemicals of concern that contribute significantly to soil ingestion, soil dermal adsorption, and dust inhalation has been considered in the selection of remedial alternatives.

8.4 REMEDIAL ACTION GOALS

The remedial action goals for soil/waste and groundwater are defined below.

Soil/Waste

The remedial action goals for contaminated soil/waste at the Site are to:

- Limit direct contact, inhalation, or ingestion of contaminated soil or waste.

- Limit migration of contaminants in soil and waste to groundwater.

Groundwater

The groundwater in the shallow water-bearing zone does not appear to be significantly impacted by on-site chemicals. The groundwater in the deeper water-bearing zone has not been impacted by on-site chemicals. The remedial action goal for groundwater will be to reduce the potential for future migration of the on-site chemicals to groundwater.

8.5 IDENTIFICATION OF TECHNOLOGY TYPES AND PROCESS OPTIONS

Potentially applicable technologies and process options for soils and groundwater at the Site were screened utilizing the following criteria:

- Applicability of the technology to site conditions and waste characteristics.
- Past performance and reliability.
- Effectiveness.
- Potential costs.

8.5.1 Soil/Waste

The screening of technologies for soils/waste is summarized in Figure 8-1. The technologies potentially applicable to the Site are summarized in Table 8-1.

The potential exposure pathways identified for the Site are ingestion of soil, dermal adsorption of soil and inhalation of dust. Containment of soil/waste present at the Site will eliminate those exposure pathways. The removal and on-site disposal technologies identified in Figure 8-1a are not considered applicable because of the large waste volume involved and the potentially significant risks posed to the nearby residents during excavation activities. Similarly, the treatment technologies identified in Figures 8-1a and 8-1b are also not considered applicable because of the heterogeneous nature of the large quantity of waste material, ineffective treatment mechanisms to treat substances of concern at the Site, excessive costs involved, risks posed to nearby residents by activities related to the technology, and the risk associated with transportation. Therefore, removal, disposal and treatment technologies identified in Figure 8-1 will not be considered as potential remedial alternatives. Table 8-1 is a summary of technologies retained for further consideration, which include institutional controls and containment for on-site soils, and institutional controls for groundwater.

8.5.2 Groundwater

The groundwater beneath the Site is not significantly impacted by the on-site contaminated soil/waste. It appears that unaddressed upgradient sources have probably affected groundwater quality at the Site. Therefore, no direct groundwater remediation is necessary. Continued groundwater monitoring is recommended in order to observe groundwater quality trends.

8.6 IDENTIFICATION OF ALTERNATIVES

Based upon the screened technologies and process options listed in Table 8-1, a series of alternatives were developed and are listed in Table 8-2. These alternatives were selected for further consideration.

MEDIUM	GENERAL RESPONSE ACTION	PROCESS OPTION	REMEDIAL ACTION TECHNOLOGY	DESCRIPTION	APPLICABILITY
SOILS	NO ACTION	None		No remedial action will be undertaken at site.	Retained. Michigan Act 307 requires consideration of no action alternative for comparison with other alternatives.
	INSTITUTIONAL CONTROL	Access Control and Deed Restrictions		Fencing and other barriers would limit access to potentially contaminated area. Also, legal (deed) restrictions on use of property.	Potentially applicable.
	CONTAINMENT	Soil Cover using Native Soil		Placement of uncontaminated, locally available soil over contaminated areas to prevent erosion and direct contact exposure.	Potentially applicable, provided it meets the requirements of Michigan DNR.
		Caps	Act 641 Cap	Use of asphalt, sprayed asphalt, concrete, or a compacted clay in a single layer to prevent direct contact exposure and to reduce infiltration.	Only clay cap is potentially applicable. Others have limited use in application to landfill.
			Act 64 Cap	Use of two or more impermeable layers such as compacted clay layer, drainage layer to prevent direct contact and to minimize infiltration.	Potentially applicable.
	REMOVAL	Excavation		Excavation of contaminated soils with heavy equipment for treatment/disposal.	Not applicable. Difficult to implement due to large volume. Significant risks to nearby residents during excavation activities in addition to transportation risks.
	DISPOSAL	On–Site		Disposal of waste materials in on–site cell(s).	Not applicable. Difficult to implement due to large volume. Significant risks to nearby residents during excavation and on–site disposal.
	TREATMENT	Solidification/Stabilization	Pozzolonic Agents	Addition of lime, fly ash and cement kiln dust to waste to produce a concrete–like solid.	Not applicable. Not implementable due to large volume and heterogeneous nature of waste.
			Sorption	Addition of an inert, nondegradable sorbent to sorb moisture and reduce permeability of soil with high moisture content.	Not effective as a treatment or pretreatment mechanism. Furthermore, wastes on–site are heterogeneous in nature.

Continued on Sheet 2 of 2

FIGURE 8–1a

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Three Hawthorn Parkway
Vernon Hills, Illinois
60061

TECHNOLOGY SCREENING for SOIL REMEDIATION
SHEET 1 of 2
LINDEN ROAD LANDFILL
Flint, Michigan

64591 D

Continued from Sheet 1 of 2

MEDIUM	GENERAL RESPONSE ACTION	PROCESS OPTION	REMEDIAL ACTION TECHNOLOGY	DESCRIPTION	APPLICABILITY
SOILS	TREATMENT	Physical/Chemical Treatment	Supercritical Fluid Extraction	Addition of a gas (typically CO_2) at its critical point countercurrent to a contaminated waste for extraction of organics, which then separate from the gas at atmospheric conditions.	Not applicable because this technology requires soil to be finely ground and treated as an aqueous solution. The hetergenous character of the soil mixed with waste would make this very difficult to implement and control.
			Chemical Reduction	Addition of reduction agents to wastes to stabilize metals by converting them to a less soluble, more stable form.	Not applicable for organic wastes.
			Vitrification	Placement of graphite electrodes in a square array, and passing electric current through them to create high temperatures that melt the soil or waste solids into a block of glasslike material. Experimental process option.	Potentially applicable for contaminated soil above the water table. The technology will not be considered since it is under investigation by a congressional committee.
			Soil Vapor Extraction	Movement of large volumes of air through the soil through an injection well to strip volatile contaminants from the soil in a manner similar to air stripping.	Not applicable. Ineffective for substance of concern which include PNAs and metals as per public health evaluations.
			Soil Flushing	Flushing of contaminated soil with an appropriate solution and the collection of the elutriate in a series of shallow well points or subsurface drains.	Not applicable due to the heterogeneous nature of the landfill wastes.
		Biological Treatment	Slurry Bioreactor	Degradation and mineralization of organic wastes using a mixed culture of organisms under aerobic conditions in a batch reactor vessel.	Not applicable since metals may have an adverse impact on the process. Would require excavation of soil. Not widely used.
		Thermal Treatment	On-site Incineration	Thermal destruction of hazardous materials in a controlled, oxygen-sufficient environment. Generally, byproducts include carbon dioxide, water and ash. Many types of incinerators with varying capabilities exist. Transportable incinerators are available for use.	Not applicable. Capacity is limited if transportable incinerators are used. Significant risks to nearby residents during excavation activities. Permitting issues will cause delays. Will be excessively costly (> $200 M)
			Off-site Incineration	Same as above, but off-site location.	Not applicable. Off-site incineration capacity is limited. Significant risks to nearby residents during excavation activities in addition to transportation risks. Will be excessively costly (> $800 M)

FIGURE 8-1b

TECHNOLOGY SCREENING for SOIL REMEDIATION
SHEET 2 of 2

LINDEN ROAD LANDFILL
Flint, Michigan

WESTON
MANAGERS DESIGNERS/CONSULTANTS
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

64591 E

Table 8-1

Technologies Retained for Further Consideration
Linden Road Landfill
Flint, Michigan

General Response Action	Process Options
Soils	
Institutional Controls	Deed Restrictions
	Access Control
	Zoning Restrictions
Containment	Containment consistent with Michigan Act 64 (Act 64 cap)
	Containment consistent with Michigan Act 641 (Act 641 cap)
	Soil Cover
Groundwater	
Institutional Controls	Groundwater Monitoring

Table 8-2

List of Applicable Alternatives
Linden Road Landfill
Flint, Michigan

Alternative 1

No Action

Alternative 2 (Limited Action)

Access Control
Land Use Restriction
Groundwater Monitoring

Alternative 3

Access Control
Land Use Restriction
Groundwater Monitoring
Act 64 Cap

Alternative 4

Access Control
Land Use Restriction
Groundwater Monitoring
Act 641 Cap

Alternative 5

Access Control
Land Use Restriction
Groundwater Monitoring
Soil Cover

The alternatives developed for the site fall into two major classes:

- No Action alternative.

- Alternatives that provide containment of the waste and protect human health by preventing exposure, by reducing the exposure, and/or by reducing the mobility of the contaminants in the waste.

Five alternatives were identified for the Site. These alternatives focused on on-site soil/waste containment and groundwater monitoring. Alternatives 1 and 2 involve no action and limited controls, respectively. Alternatives 3, 4, and 5 involve containment of waste.

8.7 DESCRIPTION AND EVALUATION OF ALTERNATIVES

Alternative 1 - No Action

No remedial action would be performed under this alternative. All soils/waste and groundwater would remain at existing conditions. There would be no reduction in potential risks related to ingestion, inhalation, or dermal contact, and no additional monitoring will be conducted. The existing fence would be maintained.

The Michigan Act 307 requires that the "no action" alternative should be evaluated as the baseline for comparison with other remedial alternatives. This alternative is retained for future comparison.

Alternative 2 - Limited Action

This alternative consists of measures to reduce the risk of direct contact with the on-site waste. The existing fence would be maintained at the Site boundary to limit access to the Site by unauthorized personnel. A restriction would be placed in the deed to prevent unacceptable future uses of the facility, such as construction of buildings, development of recreational facilities, or installation of drinking water wells. A groundwater monitoring program would be conducted for 30 years. The groundwater monitoring program would be reviewed every five years for possible revision or discontinuation. This alternative would minimize the risk of direct contact with the on-site contaminants and, by the elimination of construction activities, would minimize the risk of inhalation or ingestion of suspended particulates in air.

This alternative does not meet all the remedial action goals. By itself, this alternative is not applicable to the Site and will not be retained. However, this alternative will be part of all other alternatives where waste containment is considered.

Alternative 3 - Containment Using Act 64 Cap

This alternative is designed to contain contaminated soils and waste material by using a cap consistent with Michigan Act 64 regulations (Act 64 cap). Prior to installation of the Act 64 cap, on-site vegetation requiring removal for construction would be cleared and managed appropriately. The surficial material would be regraded and compacted, and an acceptable subgrade would be established. The Act 64 cap would then be installed.

A compacted low-permeability clay barrier (90 centimeters thick) would be placed directly over the graded surface of the landfill. The surface of the low permeability clay barrier would be sloped towards the existing off-site drainage systems. A drainage layer would be placed over the clay barrier and would consist of a permeable sand layer or geogrid composite (higher permeable) layer. Geotextile fabrics would be placed as necessary over the permeable layer in order to restrict the movement of fine particles from the soil fill and vegetative cover soil into the drainage layer. This would protect the pores in the drainage layer from clogging by fine particles. A soil cover would be placed over the drainage layer in order to provide a rooting zone and frost protection. A vegetative cover would be placed over the soil cover to reduce infiltration and provide erosion control. The vegetative soil cover would be lightly compacted, and the surface would be fertilized as necessary, seeded, and mulched to provide a dense vegetation cover.

The Act 64 cap would limit infiltration of precipitation through the waste. This cap would therefore, reduce the migration of the contaminants in soil and waste material to groundwater. The Act 64 cap will also limit public health threats including direct contact, inhalation, and ingestion of contaminated soil or waste. The institutional controls will preclude future development at the Site. In addition, the cap would control the migration of surficial contaminants via surface runoff and suspension of soil particulates.

Other requirements of this alternative are the same as Alternative 2. This alternative meets the remedial action goals and hence will be retained for further consideration.

Alternative 4 - Containment Using Act 641 Cap

This alternative is designed to provide containment of contaminated soils and waste material by using a cap consistent with Michigan Act 641 regulations (Act 641 cap). Prior to installation of the Act 641 cap, on-site vegetation requiring removal for construction will be cleared and managed appropriately. The surficial material on site would be regraded and compacted, and an acceptable subgrade would be established. The Act 641 cap would then be installed.

A compacted two feet thick, low-permeability clay barrier would be placed directly over the landfill. The surface of the low-permeability clay barrier would be sloped towards the existing off-site drainage systems. A soil cover will be placed over the clay layer in order to provide a rooting zone and frost protection. The soil would be lightly compacted, and the surface would be fertilized as necessary, and seeded, and mulched to provide a dense vegetative cover. The vegetated cover will reduce infiltration and provide erosion control.

The Act 641 cap would limit infiltration of precipitation through the waste. This cap would therefore, reduce the migration of the contaminants in soil and waste material to groundwater contamination. The Act 641 cap will also limit public health threats including direct contact, inhalation, and ingestion of contaminated soil or waste. The institutional controls will preclude future development at the Site. In addition, the cap would control the migration of surficial contaminants via surface runoff and suspension of soil particulates.

Other requirements of this alternative are the same as Alternative 2. This alternative will be retained for further consideration.

Alternative 5 - Containment Using Soil Cover

This alternative is also designed to provide containment of contaminated soils and waste materials by the placement of a soil cover. Prior to placement of the soil cover, areas that lack vegetation and poor drainage will be identified. Areas of poor drainage within the Site would be regraded to promote runoff of precipitation. Clearing and grubbing will be required where significant vegetation currently exists. Depressions within the site will be filled to provide an acceptable grade. The final soil cover will be sufficiently vegetated to provide for erosion control, and will be sloped adequately to facilitate runoff in order to minimize infiltration of precipitation. Current site investigations have shown that the groundwater underneath the site has not been significantly impacted by on-site waste. The vegetated soil cover would limit infiltration of precipitation through waste materials by promoting evapo-transpiration and surface runoff. The soil cover will somewhat limit direct contact, inhalation and ingestion of contaminated soil or waste material.

Other requirements of this alternative are the same as Alternative 2. This alternative is also retained for further consideration as a potential remedial alternative for the Site.

8.8 SUMMARY OF REMEDIAL ALTERNATIVES SCREENING

A preliminary screening of potentially applicable remedial technologies for the Site indicated that containment and institutional controls were considered as the most appropriate technologies to meet all the remedial action goals in protecting human health and the environment in a cost-effective manner. Among the applicable alternatives considered (Table 8-2), Alternative 1 (no action) will not provide any protection to human health and the environment. Alternative 2, by itself, will not meet all the remedial action goals. All other alternatives (3, 4, and 5), which provide containment to the contaminated soils and waste materials, along with Alternative 2 (access control, land use restrictions, and groundwater monitoring) would meet all the remedial goals in a cost-effective manner and, therefore, are recommended for further consideration.

Table 8-3 summarizes the alternatives recommended for further consideration with reference to overall protection of human health and the environment, short-term and long-term effectiveness, and implementability. Also included in Table 8-3 are estimated capital costs and annual operation and maintenance costs for each alternative. The cost estimates are presented only for comparison purposes. A detailed cost estimate will be developed for the alternative selected for the Site.

Table 8-3
Evaluation of Alternatives
Linden Road Landfill
Flint, Michigan

CRITERIA	ALTERNATIVE 1	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5
Overall Protection to Human Health and Environment	Not protective since no remediation will be undertaken.	The fence will restrict unauthorized persons from entering the site. Land use restriction will reduce future excavation or construction at the site. Capping will eliminate direct contract, inhalation or ingestion of the contaminated materials and reduce infiltration and leachate generation.	The fence will restrict unauthorized persons from entering the site. Land use restriction will reduce future excavation or construction at the site. Capping will eliminate direct contract, inhalation or ingestion of the contaminated materials and reduce infiltration and leachate generation.	The fence will restrict unauthorized persons from entering the site. Land use restriction will reduce future excavation or construction at the site. Capping will eliminate direct contract, inhalation or ingestion of the contaminated materials and reduce infiltration and leachate generation.
Effectiveness				
Short-Term	Not applicable.	On-site workers may be affected by dust generated during site clearing. This can be reduced by taking measures to reduce dust generation during site work and taking adequate safety precautions. The risk to the community is minimal since dust generation will be controlled.	On-site workers may be affected by dust generated during site clearing. This can be reduced by taking measures to reduce dust generation during site work and taking adequate safety precautions. The risk to the community is minimal since dust generation will be controlled.	On-site workers may be affected by dust generated during site clearing. This can be reduced by taking measures to reduce dust generation during site work and taking adequate safety precautions. The risk to the community is minimal since dust generation will be controlled.
Long-Term	Not applicable.	The cap will be reliable as long as it is inspected and maintained regularly.	The cap will be reliable as long as it is inspected and maintained regularly.	The soil cover will be reliable as long as it is inspected and maintained regularly.
Implementability	No implementation is required.	This alternative can be implemented easily. The materials for the construction are readily available. Minimal lead time is required.	This alternative can be implemented easily. The materials for the construction are readily available. Minimal lead time is required.	This alternative can be implemented easily. The materials for the construction are readily available. Minimal lead time is required.
COST		Act 64 Cap	Act 641 Cap	Soil Cover
Capital Cost	$ 0	$ 13,661,181	$ 8,053,132	$ 5,828,235
Annual O & M Cost	$ 0	$ 125,400	$ 125,400	$ 125,400
Total Cost (Present worth) 30 Years	$ 0	$ 14,816,509	$ 9,208,460	$ 6,983,563

APPENDIX D

INTERIM REMEDIAL MEASURES REMOVAL ACTION REPORT

WESTON
MANAGERS DESIGNERS/CONSULTANTS
Roy F. Weston, Inc.
Suite 400
3 Hawthorn Parkway
Vernon Hills, Illinois 60061-1450
708-918-4000 • Fax 708-918-4055

20 December 1993

Mr. Edward E. Peterson
General Motors Corporation
Argonaut "A" - 1004H
485 West Milwaukee Avenue
Detroit, Michigan 48202

Work Order No. 01138-070-001

Re: Interim Remedial Measures Removal Action
Linden Road Landfill Site, Flint, Michigan

Dear Mr. Peterson:

On behalf of AC Rochester Division of General Motors Corporation (GM), Roy F. Weston, Inc. (WESTON®) conducted an Interim Remedial Measures (IRM) removal action at the Linden Road Landfill site, Flint Township, Michigan. This removal action, conducted on 30 November and 1 December 1992, was performed in accordance with the work plan entitled "Work Plan for Interim Remedial Measures Removal Action, Linden Road Landfill Site, Flint Township, Michigan" (WESTON, August 1992). This letter report describes the activities performed during the above-mentioned removal action and includes documentation associated with the transportation and disposal of removed material.

The objective of this removal action was to minimize or prevent potential accidental exposure to surface waste materials from specific areas of the site which may have posed a direct contact threat to human health and the environment. The need for this removal action was identified by an IRM evaluation (IRME) conducted in November 1990. During this evaluation, WESTON identified and characterized waste material and debris present on the surface of the Linden Road Landfill site. The findings of the IRME and recommendations were presented in a report entitled "Interim Remedial Measures Evaluation and Site Investigation Report" (WESTON, March 1992), submitted to the Michigan Department of Natural Resources (MDNR) in March 1992. This report recommended that the IRM removal action discussed in this letter be performed prior to capping and final closure of the Linden Road Landfill site.

In addition to the removal action described in this letter, a steep-sloped depression located on the north central portion of the site (coordinates of N2150, E1600 in Figure 1) was backfilled with clean fill material on 1 December 1992. This action was performed to minimize physical hazards posed by the above-referenced depression.

SURFACE WASTE MATERIAL REMOVAL

As indicated in the IRM Removal Action Work Plan (WESTON, 1992), waste material was removed from the following areas:

- Oil Disposal Area.
- Surface Waste Area 32B.
- Drum Areas 1 and 20.

The surface waste removal areas are shown in Figure 1. Removal activities were performed with a backhoe and a front-end loader operated by two health and safety-trained equipment operators. A WESTON project manager, who was also the site health and safety coordinator, directed the removal operations on site. All health and safety protocols outlined in the IRM work plan were followed. All waste materials removed were placed directly into Department of Transportation (DOT)-approved roll-off boxes positioned adjacent to each of the waste removal areas specified above. The following removal activities were performed at each of the specified areas.

Oil Disposal Area

The contents of the Oil Disposal Area were excavated and placed in three roll-off boxes. During the removal, flyash from the GM plant in Flint was used to solidify the Oil Disposal Area contents. In addition to removing the oily material, soils from the sidewalls and the bottom of the Oil Disposal Area were excavated (12 to 18 inches below the oily waste material) and removed until visually clean underlying soils were exposed. A total of approximately 45 cubic yards of material (including flyash used for solidification) was placed in three roll-off boxes. The excavation was then backfilled to grade with clean fill material obtained from an off-site source. A photoionization detector (HNu) was used to perform air monitoring during the removal action in this area. The HNu readings ranged from background to a maximum of one unit above background in the breathing zone within the Oil Disposal Area during the excavation.

Surface Waste Area 32B

Surface materials removed from this area included a drum containing waste with elevated PCB concentrations (32B/DRM-1), as identified in the IRME report, and drum remnants in the immediate vicinity. Surface soils in the vicinity of the drum containing PCB material were also removed by scraping surface soils to a depth of approximately 6 inches. Approximately 8 cubic yards of material was removed from this area and placed in a separate DOT-approved roll-off box. The excavated areas were backfilled to grade using clean fill.

Drum Areas 1 and 20

Removal activities in these areas included the excavation and removal of eight drums and drum remnants exposed at the surface at Area 1, and six drums, drum remnants, and associated sludge material from Area 20. Materials removed from Areas 1 and 20 were placed in a single DOT-approved roll-off box. A total volume of approximately 10 cubic yards of surface material was removed from Areas 1 and 20. The excavated areas were backfilled to grade using clean fill.

WASTE CHARACTERIZATION SAMPLING

Separate waste characterization samples were collected from the contents of each roll-off box. The roll-off box numbers and description of their contents are as follows:

Roll-off box No. 410310 (material from Areas 1 and 20).
Roll-off box No. 410380 (material from Area 32B).
Roll-off box No. 410302 (material from the Oil Disposal Area).
Roll-off box No. 410303 (material from the Oil Disposal Area).
Roll-off box No. 410316 (material from the Oil Disposal Area).

A single composite sample representative of the excavated material was collected from each roll-off box and analyzed for total cyanide, density, total solids, pH, ignitability, paint filter test, reactive sulfide, reactivity with water, acid, alkali, toxicity characteristic leachate procedure (TCLP) metals, TCLP volatiles, TCLP semivolatiles, and polychlorinated biphenyls (PCBs). Samples were analyzed by NET Laboratories of Auburn Hills, Michigan.

A copy of the analytical results, along with the chain of custody, is included as Attachment A to this letter. Analytical results indicated that all physical and chemical parameters were below their respective Resource Conservation Recovery Act (RCRA) regulatory limits for classification as hazardous waste pursuant to 40 CFR, Parts 261.20 through 261.24 in all the samples. TCLP metal concentrations were well below RCRA regulatory limits in all the samples. Trichloroethene (TCE) was detected in a representative sample from roll-off box No. 410303 (Oil Disposal Area). The TCE (TCLP) concentration in this sample was at 0.37 mg/L. The RCRA regulatory limit for TCE is 0.5 mg/L, and, therefore, this material is not classified as a characteristic hazardous waste and did not require special management pursuant to 40 CFR Part 268. No other volatile or semivolatile organic compounds were detected in any of the five samples representative of the waste materials in the roll-off boxes. The highest PCB concentration detected in any sample was 17.6 mg/kg (in a representative sample from roll-off box No. 410310) indicating that the materials did not require special management pursuant to 40 CFR 761 — Polychlorinated Biphenyls (PCBs) Manufacturing Processing, Distribution in Commerce, and Use Prohibitions.

TRANSPORTATION AND DISPOSAL

GM contracted USPCI to arrange transportation and disposal of the surface waste material. Copies of waste profile sheets prepared by GM are included as Attachment B. The waste materials contained in five roll-off boxes were transported off site and disposed of at two separate permitted land disposal facilities. Waste materials from Areas 1 and 20 and those from Area 32B (roll-off box Nos. 410310 and 410380) were disposed of at USPCI's Grassey Mountain facility located in Olive, Utah. Materials from the Oil Disposal Area contained in the three remaining roll-off boxes (roll-off box Nos. 410302, 410303, and 410316) were disposed of at Municipal Services Corporation's (a USPCI subsidiary) Echo Mountain facility, located in Sawyer, North Dakota. The shipping bills of lading for the five roll-off boxes are included as Attachment C. The Notifications of Waste Acceptance and Certifications of Disposal received from both facilities are included as Attachment D.

If you have any questions or require additional information regarding the IRM removal action at the Linden Road Landfill site, please call either of the undersigned at (708) 918-4000.

Very truly yours,

ROY F. WESTON, INC.

S. Babusukumar, P.G.
Project Manager

Scott D. Springer
Project Director

SB:SDS:amp
Attachments

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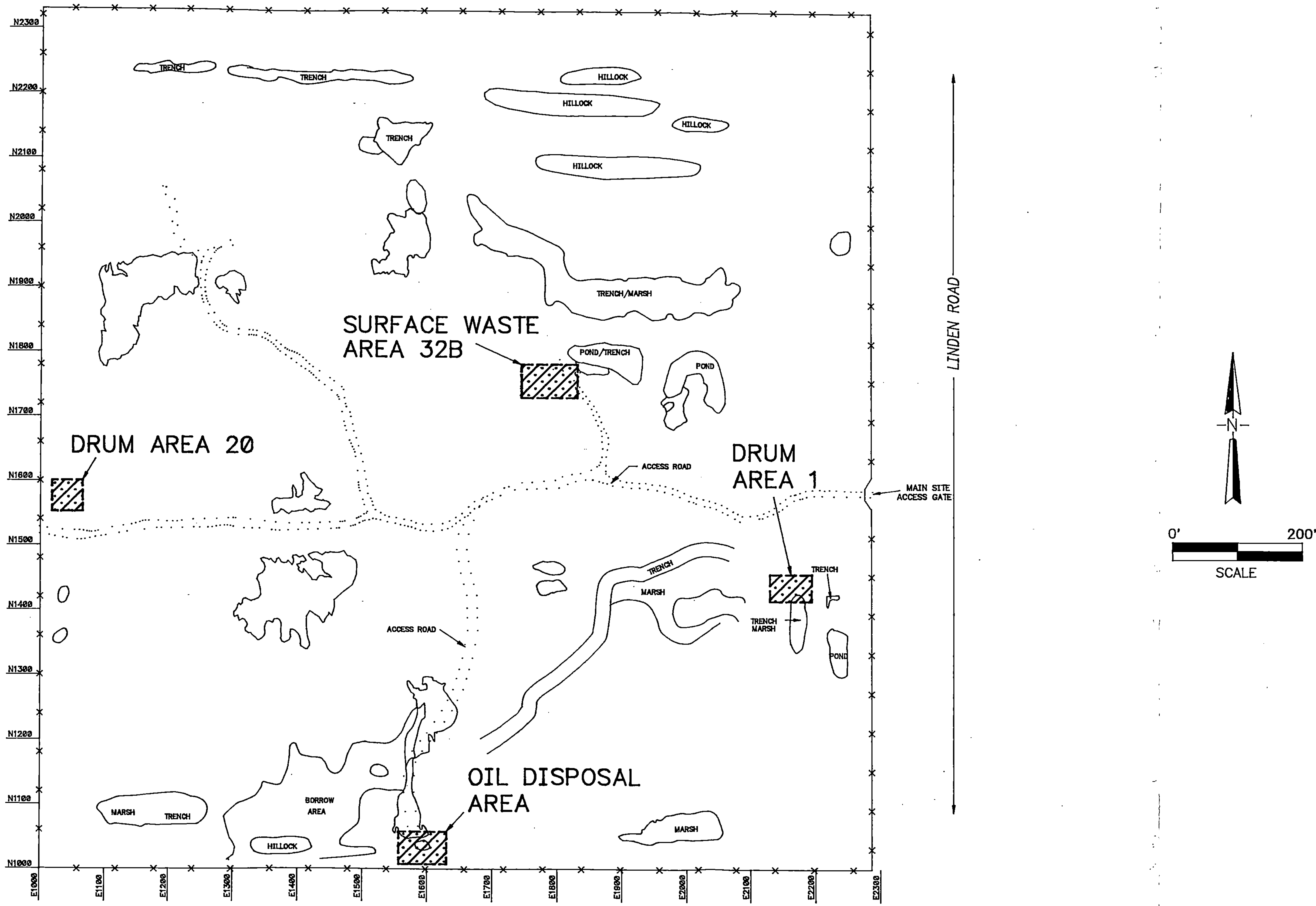

FIGURE 1

WESTON
MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway
Vernon Hills, Illinois
60061

61091 G

SITE LAYOUT & IRM WORK AREAS MAP
IRM REMOVAL ACTION

LINDEN ROAD LANDFILL
Flint, Michigan

APPENDIX E

OBSERVATION WELL DECOMMISSIONING REPORT

WESTON
MANAGERS DESIGNERS/CONSULTANTS

Roy F. Weston, Inc.
Suite 400
3 Hawthorn Parkway
Vernon Hills, Illinois 60061-1450
708-918-4000 • Fax 708-918-4055

24 January 1994

Mr. Edward Peterson
General Motors Corporation
Argonaut "A" - 1004H
485 West Milwaukee Avenue
Detroit, Michigan 48202

Work Order No. 01138-070-001

Re: Abandonment of Keck Consulting Services, Inc. Observation Wells
Linden Road Landfill Site

Dear Mr. Peterson:

On behalf of AC Rochester Division of General Motors Corporation (GM), Roy F. Weston, Inc. (WESTON®) has completed the abandonment of 18 observation wells that were installed by Keck Consulting Services, Inc. (Keck) in 1979 and 1980 at the Linden Road Landfill site (LRLF) located in Flint Township, Michigan. This letter presents the background information regarding these wells and describes the procedures followed during their abandonment.

BACKGROUND

Historical records indicated that a total of 19 observation wells were installed during Phase I and Phase II hydrogeological investigations conducted by Keck in 1979 and 1980, respectively. The locations of these wells are shown in Figure 1. Records also indicated that all the wells were constructed of 2-inch diameter, Schedule 40, galvanized pipe with a leading 2-foot, 924-#7 slot stainless steel screen. Soil boring logs and well construction diagrams from Keck's Phase I and Phase II hydrogeological investigation reports indicate that the Keck observation wells consisted of 7 shallow wells and 12 deep wells. The depths of the 19 observation wells, as estimated from well construction diagrams presented in the Phase I and Phase II hydrogeological investigation reports prepared by Keck, are included in Table 1.

Pursuant to a site investigation and interim remedial measures evaluation conducted at the site in 1991 by WESTON on behalf of GM, it was determined that because of the well screen intervals and the construction materials used, the Keck wells could only provide limited data which may not accurately reflect site conditions. Furthermore, additional groundwater monitoring wells were installed by WESTON during the site investigation. These WESTON wells used more appropriate construction materials and more accurately define site conditions. Therefore, it was recommended that the Keck wells be properly abandoned. The findings of the aforementioned site investigation and interim remedial measures evaluation along with recommendations were submitted to the Michigan Department of Natural Resources (MDNR) in a report entitled "Interim Remedial Measures Evaluation and Site Investigation Report, Linden Road Landfill Site, Flint Township, Michigan" (WESTON, March 1992).

OBSERVATION WELL ABANDONMENT

Well abandonment activities were conducted by WESTON's subcontractor, Mateco Drilling Company (Mateco) of Grand Rapids, Michigan. Mateco mobilized a two-man crew with a CME 850 ATV drill rig to the site on 17 November 1993. The drill rig was equipped with 4.25-inch internal diameter (I.D.) hollow stem augers (HSA). The well abandonment work began on 17 November 1993 and was completed on 2 December 1993. A WESTON geologist was present at the site to direct, supervise, and document all field activities throughout this project. The WESTON geologist also served as the Site Health and Safety Coordinator.

During well abandonment activities, field screening was performed using a 10.2 ev HNu photoionization detector (PID). The PID was used to screen all boreholes and cuttings for volatile organic compounds (VOCs). The PID was calibrated daily using factory-approved calibration gases. No readings were detected above background during abandonment at any of the well locations.

WELL ABANDONMENT PROCEDURES

Prior to abandonment, the total depth of each well was measured using an electronic water level indicator. The wells were then overdrilled with the HSA to the approximate depth of each well. On reaching the approximate depth of each well with the augers, the well casing was hoisted from inside the augers with a rig winch. The well casings were disassembled at the connections. The drill cuttings as well as all the removed well materials (well casings and screens) were stockpiled at the respective well locations within the site for appropriate management during the remedial action.

During the overdrilling of Wells OW-1D and OW-7D, the well casings began to sink into the subsurface along with the augers. When this occurred the overdrilling was suspended and the well casings were hoisted without drilling down to the full depth of the wells.

After removing the well materials from the borehole, the HSAs were pressure-grouted with cement/bentonite grout using the tremmie method. The grout mix was prepared using a proportion of 6 bags of portland cement (approximately 100 pounds per bag) to 40 to 50 pounds of bentonite in 100 gallons of water. The cement/bentonite grout was circulated through the grout pump attached to the drill rig to achieve a smooth consistency. The grout was then pumped into the borehole starting at the bottom using a tremmie pipe. After the hole was partially filled, the augers were slowly removed while continuing to add grout using the tremmie pipe as necessary to ensure that a constant head of grout was kept inside the augers. The constant head of grout assured the borehole was completely filled with grout. The volumes of grout pumped into each well were also carefully monitored to confirm that the entire length of the borehole was fully grouted.

The drill rigs, the HSAs, hoses, tremmie pipe, and other associated drilling equipment were steam cleaned between well locations to prevent any potential cross-contamination. The well casing and screens removed were also decontaminated by steam cleaning prior to staging beside each well location.

SUMMARY OF WELL ABANDONMENT ACTIVITIES

Table 1 presents a summary of well abandonment details including well identification numbers, estimated well depths, measured well depths, length of casing removed, depth of overdrilling, and dates of well abandonment. As shown in Table 1, the depths estimated from Keck reports and those measured during abandonment are similar. This comparison indicates that the well depths are reasonably accurate and provides support for proper and complete abandonment of the wells. As also shown in Table 1, the entire lengths of casing and screen material from all the wells except for a 2-foot screen (from well OW-3D) were removed from the subsurface during the abandonment.

Of the total number of 19 observation wells reported to be installed by Keck, 18 wells were located, identified, and abandoned. Well OW-8D, reported in the Keck reports to be a 65-foot deep well installed in the west portion of LRLF approximately 750 feet north of the southwest fence corner of the landfill (Figure 1), could not be located. In addition to a visual search, a backhoe was used to remove surface soils to a depth of 2 to 3 feet in an area of approximately 300 feet by 14 feet (covering the surrounding area of the reported location of the well) to confirm the absence of this well. It is possible that this well may have been abandoned previously by Keck. According to the Keck reports, well OW-8D was sampled during the Phase I investigation but neither the presence of this well nor sampling of this well was documented in Keck's Phase II investigation report.

WESTON
MANAGERS DESIGNERS CONSULTANTS

Mr. Edward Peterson
General Motors Corporation

24 January 1994

If you have any questions or require additional information regarding the well abandonment activities at the Linden Road Landfill site, please call either of the undersigned at (708) 918-4000.

Very truly yours,

ROY F. WESTON, INC.

S. Babusukumar, P.G.
Project Manager

Scott D. Springer
Project Director

SB:SDS/slr
Attachment

Table 1

Keck Observation Well Abandonment Summary
Linden Road Landfill Site
November/December 1993
(All Depths/Lengths in feet)

Well Number	Estimated** Well Depth	Measured Well Depth	Approximate Length of Casing and Screen Removed	Approximate Depth Overdrilled	Date Abandoned
OW-1S	20	22	22	24	11/17/93
OW-1D	75	75	75	55	12/02/93
OW-2S	30	30	30	30	12/02/93
OW-2D	80	75	75	80	11/19/93
OW-3S	25	25	25	25	11/23/93
OW-3D	65	61	59	62	11/18/93
OW-4D	80	74	74	75	11/21/93
OW-5D	80	78	78	78	11/30/93
OW-6D	80	79	79	72	12/01/93
OW-7D	90	85	85	50	12/01/93
OW-8D*	65	NA	NA	NA	NA
OW-9S	38	32	32	33	11/20/93
OW-9D	60	60	60	60	11/20/93
OW-10S	22	22	22	23	11/22/93
OW-10D	55	52	52	55	11/22/93
OW-11S	19	20	20	21	11/21/93
OW-11D	43	40	40	41	11/22/93
OW-12S	24	25	25	25	11/23/93
OW-12D	60	55	55	55	11/30/93

* Well not present.
** Obtained from Keck's Phase I and Phase II hydrogeological investigation reports.
NA - Not applicable.

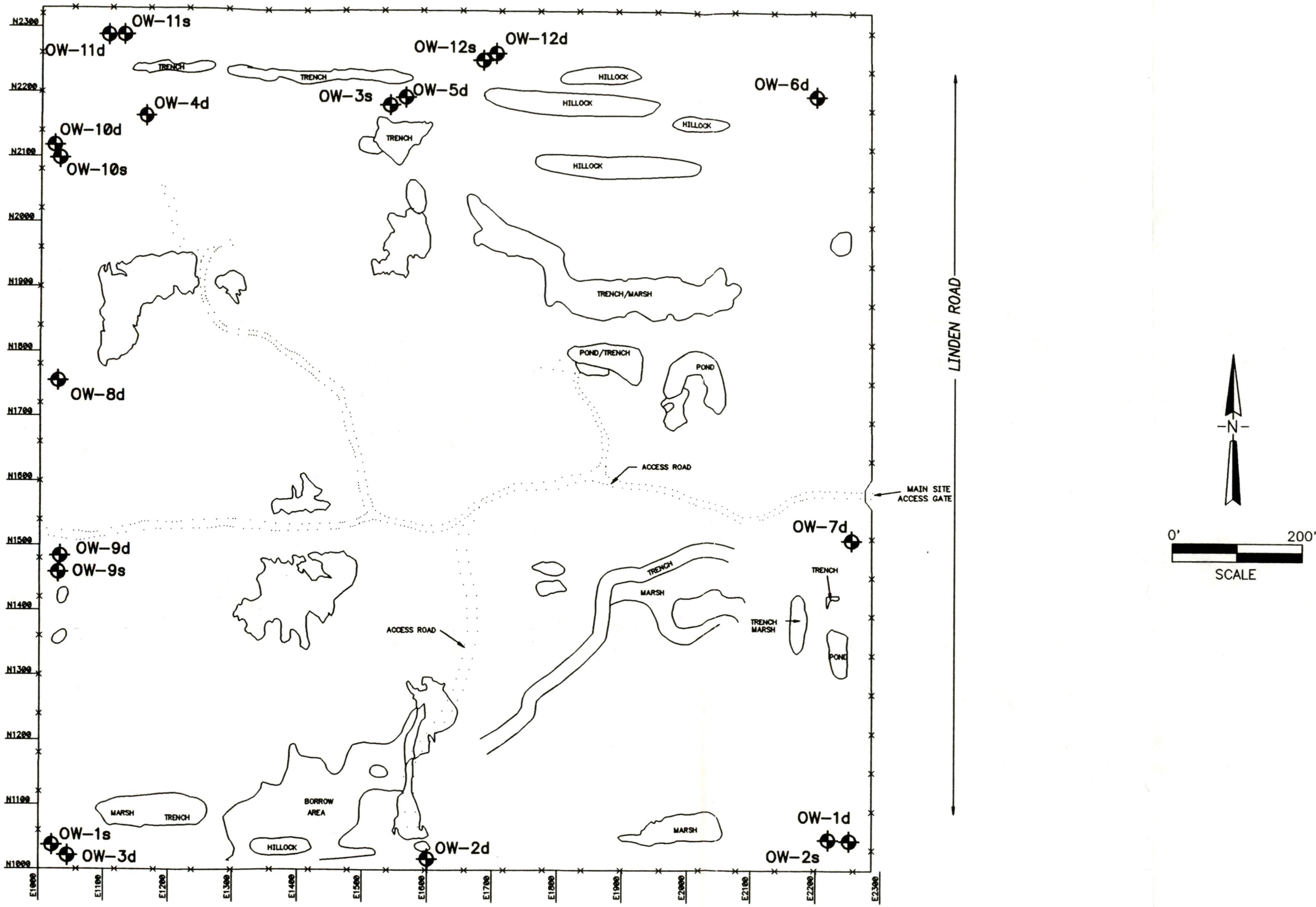

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FIGURE 1

WESTON
MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway
Vernon Hills, Illinois
60061

KECK, INC.
OBSERVATION WELL LOCATIONS
LINDEN ROAD LANDFILL SITE
Flint, Michigan

APPENDIX F

RESULTS OF ADDITIONAL GROUNDWATER INVESTIGATIONS

February 1993 (Round 3) Groundwater Sampling Report

WESTON
MANAGERS DESIGNERS/CONSULTANTS
THREE HAWTHORN PARKWAY, SUITE 40[illegible]
VERNON HILLS, IL 60061-1450
708-918-4000 • FAX: 708-918-4055

FILE COPY

26 February 1993

Mr. Edward Peterson
Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
30400 Mound Road
Warren, Michigan 48090-9015

Work Order No.: 01138-058-002

Re: Groundwater Sampling Results - Round III - December 1992
Linden Road Landfill Site
Flint, Michigan

Dear Mr. Peterson:

As requested by AC Rochester Division of General Motors (GM), Roy F. Weston, Inc. (WESTON®) has completed the third round of groundwater sampling at the Linden Road Landfill site in Flint Township, Michigan. The first two rounds of groundwater samples were collected in June 1991 and September 1991. The results of the first two sampling events were incorporated in a report entitled "Interim Remedial Measures Evaluation and Site Investigation Report, Linden Road Landfill Site, Flint Township, Michigan" submitted to GM and the Michigan Department of Natural Resources (MDNR) in March 1992. This letter presents the results of the third round of groundwater sampling conducted at the Linden Road Landfill site in December 1992.

The third round of groundwater samples was collected on 1 December 1992 concurrent with the interim removal actions implemented at this site. Details of the interim removal actions will be documented separately in a forthcoming report. Groundwater samples were collected from each of the four shallow monitoring wells (MW-01S, MW-02S, MW-03S, and MW-04S), from each of the three deep wells (MW-01D, MW-02D, and MW-03D), and, from each of the two on-site piezometers (PZ-01 and PZ-02). The locations of the monitoring wells and the piezometers are shown in Figure 1. In addition to the above investigative samples, two quality assurance samples including a field duplicate and a trip blank were collected for analysis. The field duplicate was collected from the shallow monitoring well MW-01S.

The well sampling procedures were in accordance with those described in the Site Investigation Work Plan (WESTON, 1990). Prior to sampling the wells, the static water levels were measured to the nearest one-hundredth of a foot. The water levels were used to calculate the volume of water in the respective wells. The wells were then purged using clean bailers. Specific conductance, pH, and temperature measurements were taken of the purged water. Well purging continued until the pH, specific conductance, and temperature readings stabilized, or until a minimum of three well volumes were purged. Following well purging, samples for VOC analyses were collected.

All eleven samples were analyzed for volatile organic compounds (VOCs). Sample analyses were performed by WESTON-Gulf Coast Laboratories, University Park, Illinois using U.S. EPA and MDNR-approved methods consistent with the two previous sampling events. Data validation of the laboratory analyses determined that the results were acceptable. A summary of the analytical data is presented in Table 1. The laboratory data summaries and the data validation summary for this third round of groundwater sampling are included as Attachment A to this letter.

Shallow Monitoring Wells and Piezometers

A total of 6 investigative groundwater samples and a field duplicate (from MW-01S) were analyzed from the 4 shallow monitoring wells and the two piezometers. Three laboratory method blanks were also analyzed along with these samples. Analytical results indicate that a total of 12 VOCs were detected at trace concentrations. Methylene chloride was detected only in PZ-02 at a concentration of 0.061 mg/L. Trace levels of 1,1 Dichloroethene (0.004 mg/L in MW-01S and 0.003 mg/L in MW-01S-Dup) and 1,1 Dichloroethane (0.006 mg/L in both MW-03S and PZ-02) were detected during this round of sampling. These compounds were not detected during the previous sampling events.

Trichloroethene was detected in MW-01S and its duplicate sample MW-01S-Dup at concentrations of 0.210 mg/L and an estimated 0.280 mg/L respectively. These concentrations are lower than those detected in the same monitoring wells during the previous rounds of sampling. Trichloroethene was also detected at an estimated concentration of 0.005 mg/L in MW-03S. This compound was detected in MW-03S during the first round of sampling at a concentration of 0.010 mg/L.

Other compounds detected in the shallow wells and piezometers during the current sampling event include 4-methyl 2-pentanone, toluene, chlorobenzene, ethyl benzene, and xylene. These compounds were detected at estimated concentrations either below the detection limits or slightly above detection limits. The compound 4-methyl-2-pentanone was detected only in MW-03S and PZ-02 at the same estimated concentration of 0.006 mg/L. Toluene was detected only in monitoring wells MW-01S, MW-02S, and MW-03S at concentrations ranging from an estimated 0.004 mg/L to 0.014 mg/L. Chlorobenzene was detected only in PZ-02 at an estimated concentration of 0.003 mg/L. Ethylbenzene and xylenes were detected only in MW-03S. Both ethylbenzene and total xylene concentrations in MW-03S were 0.003 mg/L.

Deep Monitoring Wells

One groundwater sample was collected and analyzed from each of the deep monitoring wells. No VOCs were detected in samples from MW-01D and MW-03D. A single compound, 2-butanone, was detected at an estimated concentration of 0.008 mg/L in MW-02D.

Based upon the results of the current groundwater sampling at the Linden Road Landfill site, there appears to be no significant changes in the quality of shallow or deep groundwater at the site since the previous sampling events in June and September 1991.

If you have any questions or require additional information, please call either of the undersigned at (708) 918-4000.

Very truly yours,

ROY F. WESTON, INC.

S. Babusukumar, P.G.
Project Manager

Scott D. Springer
Project Director

SB:SDS:ebg

cc: R. Eisenman
J. Jaffurs
M. Hester
R. Hubler
T. Carlisle
Project File

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Table 1

Summary of Volatile Organic Compound Analyses
Groundwater Samples - Round III (December 1993)
Site Investigation
Linden Road Landfill
(All Values in mg/L)

Sample No.	MW-01S	MW-01S-DP	MW-01D	MW-02S	MW-02D	MW-03S	MW-03D	MW-04S	PZ-01	PZ-02	Trip Blank	Quantitation Limit (Range)
Date Collected	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92	12/1/92	
Methylene chloride	—	—	—	—	—	—	—	—	—	0.061	—	0.005
1,1-Dichloroethene	0.004 J	0.003 J	—	—	—	—	—	—	—	—	—	0.005
1,1-Dichloroethane	—	—	—	—	—	0.006	—	—	—	0.006	—	0.005
1,2-Dichloroethene (total)	0.035 J	0.029	—	—	—	0.003 J	—	—	—	—	—	0.005
2-Butanone	—	—	—	—	0.008 J	0.022	—	—	—	0.013	—	0.010
1,2-Dichloropropane	—	—	—	—	—	—	—	—	0.009 J	—	—	0.005
Trichloroethene	0.210	0.280 J	—	—	—	0.005 J	—	—	—	—	—	0.005-0.010
4-Methyl-2-pentanone	—	—	—	—	—	0.006 J	—	—	—	0.006 J	—	0.010
Toluene	0.009 J	0.003 J	—	0.004 J	—	0.014	—	—	—	—	—	0.005
Chlorobenzene	—	—	—	—	—	—	—	—	—	0.003 J	—	0.005
Ethylbenzene	—	—	—	—	—	0.003 J	—	—	—	—	—	0.005
Xylenes (total)	—	—	—	—	—	0.003 J	—	—	—	—	—	0.005

— - Compound was analyzed for but not detected.
J - Indicates an estimated value.
DP - Indicates a duplicate sample was collected at that location for QA/QC purposes.
TB - Trip blank.
S - Shallow well.
D - Deep well.

ATTACHMENT A

1. Laboratory Data Summaries
2. Data Validation Summary

April 1995 (Round 4) Groundwater Sampling Report

WESTON
MANAGERS DESIGNERS/CONSULTANTS
Roy F. Weston, Inc.
Suite 400
3 Hawthorn Parkway
Vernon Hills, Illinois 60061-1450
708-918-4000 • Fax 708-918-4055

COPY

21 April 1995

Mr. Robert S. Metcalf, P.E.
Project Manager
Environmental and Energy Staff
General Motors Corporation
CLCD North
902 East Hamilton Avenue
Flint, MI 48550-8504

Work Order No. 01138-079-001

Re: Additional Monitoring Well Installation and Groundwater Sampling
Linden Road Site
Flint, Michigan

Dear Mr. Metcalf:

As requested by General Motors Corporation (GM), Roy F. Weston, Inc. (WESTON®) has completed the additional monitoring well installations and groundwater sampling at the Linden Road site located in Flint Township, Michigan. This well installation and sampling effort was implemented pursuant to a plan submitted to and approved by the Michigan Department of Natural Resources (MDNR). WESTON submitted the above plan on behalf of GM in a letter dated 8 February 1995.

The purpose of installing and sampling new wells, as well as of sampling the existing wells, was to supplement existing information on groundwater quality, particularly along the western boundary of the site.

Details of Well Installation

As proposed in the letter dated 8 February 1995 to MDNR, three additional upgradient shallow monitoring wells (MW-05S, MW-06S, and MW-07S) were installed along the western boundary of the site. The attached Figure 1 shows the locations of both the existing monitoring wells and the newly installed wells.

Drilling and well installation activities were performed by WESTON's subcontractor, Mateco Drilling Company of Grand Rapids, Michigan. These activities were performed between 27 February and 1 March 1995. Monitoring well drilling was performed using 4.25-inch I.D. hollow-stem augers (HSAs). Using ASTM-1586 procedures, soil samples were collected at continuous intervals with standard split-spoon samplers. Well materials consisted of 2-inch diameter stainless steel, flush-jointed riser pipes and stainless steel (Grade 304) screens. The well screens were 10 feet in length with 0.010-inch slotted openings. The screens were positioned to straddle the water table. All well construction and well development methods were consistent with those employed in constructing the previous wells, as described in the "Interim Remedial Measures Evaluation and Site Investigation Report" (March 1992). Attachment A presents the geologic drill logs associated with the well drilling and installation.

A WESTON geologist was present throughout the well drilling and installation, as well as throughout groundwater sampling activities described below. This WESTON geologist also implemented health and safety protocols on site.

Groundwater Sampling and Analysis

Groundwater samples were collected from the newly installed wells (MW-05S, MW-06S, and MW-07S), as well as from the four existing shallow wells (MW-01S, MW-02S, MW-03S, and MW-04S). Sampling was conducted on 1 March 1995.

The well sampling procedures were in accordance with those described in the Site Investigation Plan (WESTON 1990). Prior to sampling the wells, the static water levels were measured to the nearest one-hundredth of a foot. The water levels were used to calculate the volume of water in the respective wells. The wells were then purged using clean bailers. Specific conductance, pH, and temperature measurements were taken of the purged water. Well pumping continued until the pH, specific conductance, and temperature readings stabilized or until a minimum of three well volumes was purged. Following well purging, samples were collected for analysis.

Seven investigative samples, a field duplicate, a field blank, a matrix spike/matrix spike duplicate, and a trip blank sample were collected and analyzed for volatile organic compounds (VOCs). Samples were analyzed by Clayton Environmental Laboratories, located in Novi, Michigan, using U.S. EPA Method DW 846/8260. The analytical detection limits were consistent with MDNR/MERA Operational Memorandum #6, Revision #3 guidelines.

Laboratory Analytical Results

Data validation conducted by WESTON determined that the laboratory results were acceptable. Both the laboratory data summaries and the chain-of-custody documentation related to this sampling effort are included as Attachment B. Analytical results indicate that no VOCs were detected in any of the three newly installed monitoring wells and in two of the existing wells (MW-02S and MW-04S). Trichloroethylene and cis-1,2-Dichloroethylene were detected in Monitoring Well MW-01S, at concentrations of 0.110 mg/L and .010 mg/L, respectively. The concentration of Trichloroethylene in this monitoring well is lower than that detected in the same monitoring well during previous sampling rounds. Four VOCs were detected at trace concentrations in existing Monitoring Well MW-03S. The compounds detected in this well were 1,1-Dichloroethane (0.008 mg/L), cis-1,2-Dichloroethylene (0.002 mg/L), 1,1,1-Trichloroethane (0.003 mg/L), and Trichloroethylene (0.006 mg/L). Several compounds detected during previous sampling rounds in Monitoring Well MW-03S were not detected during this sampling event.

The concentration of Trichloroethylene in Monitoring Well MW-01S has decreased to approximately a third of that of the December 1992 sampling. Further, there has been a significant reduction (more than 50 percent) in the number of compounds detected in Monitoring Well MW-03S. These data indicate that, from a conservative standpoint, there is no deterioration in the quality of shallow groundwater at the site since the previous sampling event in December 1992. The reduction in both the number of compounds detected and the concentrations of the compounds detected could also suggest that the groundwater quality at the site is improving through natural chemical and biological processes.

If you have any questions or require additional samples, please call either of the undersigned at (708) 918-4000.

Very truly yours,

ROY F. WESTON, INC.

S. Babusukumar, P.G.
Project Manager

Scott D. Springer
Project Director

SB/SDS:ebg
Attachments

cc: E. Peterson

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Table F-1

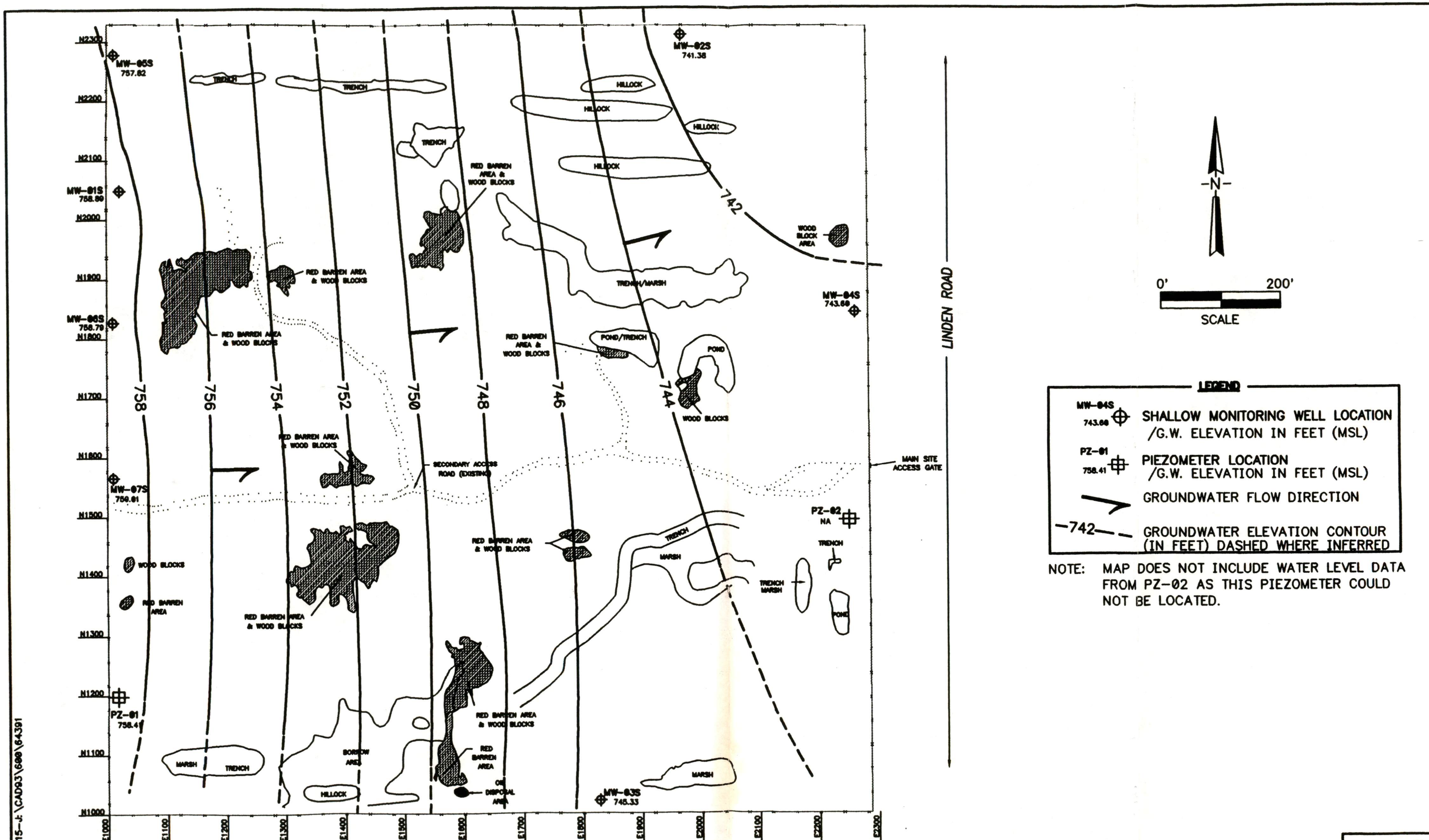
Groundwater Elevation Data (July 1995)
Linden Road Landfill

Well Number	TOC Elevation	July 1995	
		Water Level Depth	Groundwater Elevation
MW-01S	769.90	11.01	758.89
MW-01D	769.44	34.48	734.96
MW-02S	749.94	8.56	741.38
MW-02D	750.83	18.67	732.16
MW-03S	753.16	7.83	745.33
MW-03D	754.29	12.67	741.62
MW-04S	756.76	13.16	743.60
MW-05S	766.10	8.28	757.82
MW-06S	768.66	9.87	758.79
MW-07S	768.45	9.44	759.01
PZ-01	769.61	11.20	758.41
PZ-02	761.20	NA	NA

Notes:

TOC - Top of well casing.
NA - Not applicable.

All depths measured from top of well casing.
All elevations reported in feet referenced to MSL.
PZ-02 could not be located and therefore was not gauged.



NOTE: MAP DOES NOT INCLUDE WATER LEVEL DATA FROM PZ-02 AS THIS PIEZOMETER COULD NOT BE LOCATED.

FIGURE F-1

WESTON
MANAGERS DESIGNERS/CONSULTANTS

Three Hawthorn Parkway
Vernon Hills, Illinois
60061

POTENTIOMETRIC SURFACE CONTOUR MAP
SHALLOW WATER-BEARING ZONE (JULY 1995)

LINDEN ROAD LANDFILL
Flint, Michigan

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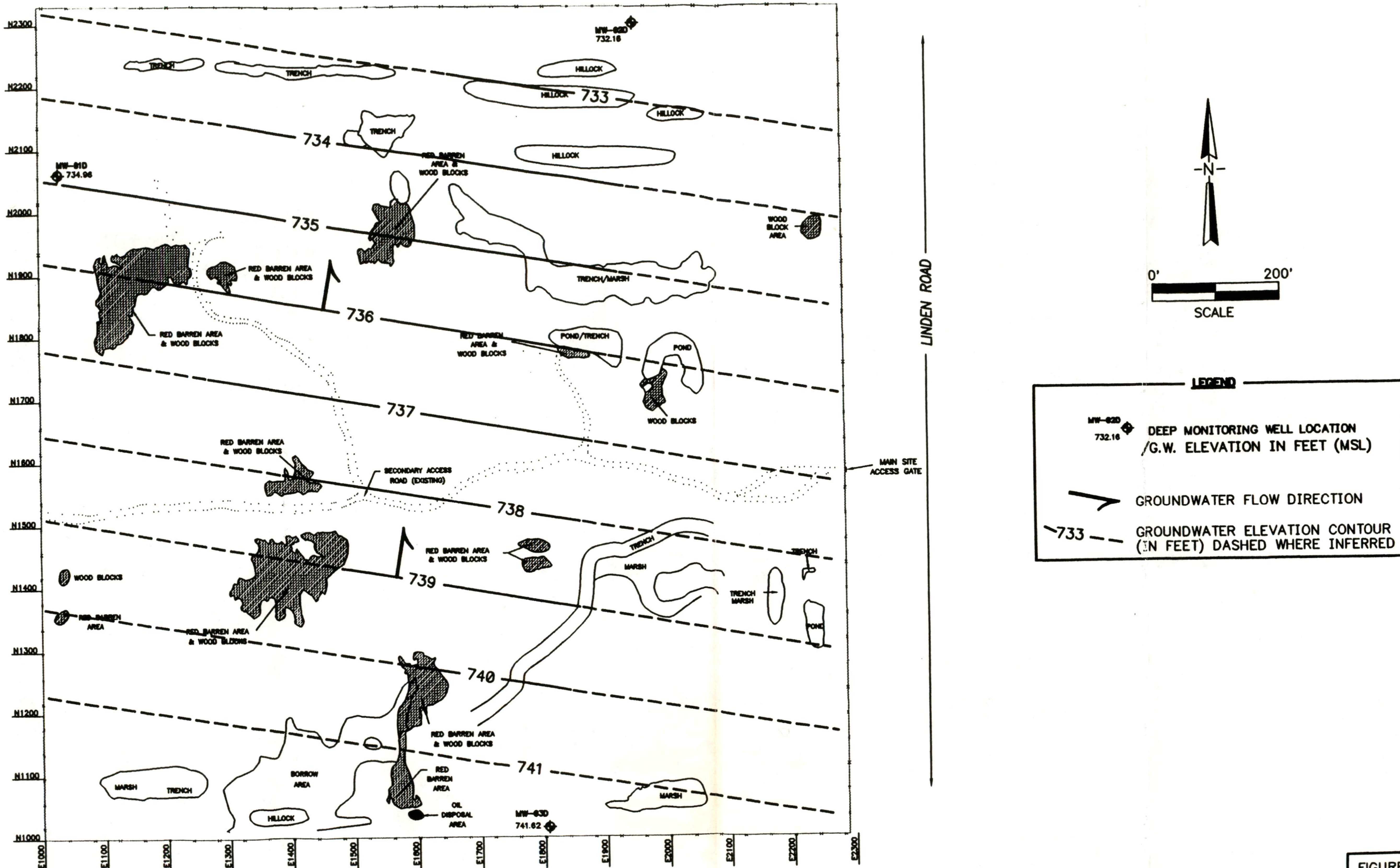

FIGURE F-2

WESTON
MANAGERS DESIGNERS/CONSULTANTS
Three Hawthorn Parkway
Vernon Hills, Illinois
60061

POTENTIOMETRIC SURFACE CONTOUR MAP
DEEP WATER-BEARING ZONE (JULY 1995)
LINDEN ROAD LANDFILL
Flint, Michigan

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