CLASS A-3
RESPONSE ACTION OUTCOME STATEMENT

SUNOCO STATION
88-90 South Maple Street
Westfield, Massachusetts

DUNS: 0374-5593

Release Tracking Numbers 1-15718 and 1-16079

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1.0 INTRODUCTION

On behalf of Sunoco, Inc. (R&M), Corporate Environmental Advisors, Inc. (CEA) has prepared this Class A-3 Response Action Outcome (RAO) Statement for the Sunoco Service Station property located at 88-90 South Maple Street in Westfield, Massachusetts (herein the Site). The property is listed as a disposal site with the Massachusetts Department of Environmental Protection (MADEP) due to the failure of the tank tightness test conducted on the regular unleaded dispenser line associated with the underground storage tank (UST) system on April 12, 2005. Upon repair of the dispenser line, the MADEP was notified of the threat of release condition on April 15, 2005 and release tracking number (RTN) **1-15718** was assigned to the Site. Response actions conducted to address the oil and/or hazardous material (OHM) impacts associated with the release included excavation and removal of petroleum-impacted soils and an extensive program of soil and groundwater monitoring.

On November 17, 2005, sampling of the soil stockpile associated with the petroleum release revealed the presence of polychlorinated biphenyls (PCBs) at 2.31 milligrams per kilogram (mg/kg) which exceeded the Massachusetts Contingency Plan (MCP) RCS-1 reportable concentration of 2 mg/kg. PCBs were also reported at a concentration of 32.05 mg/kg in a composite sample (T1) collected during additional excavation conducted at the Site in November 2005. A Release Notification Form (RNF) was submitted to MADEP on February 8, 2006 and RTN **1-16079** was assigned to the PCB condition.

This Class A-3 RAO has been prepared to address the release conditions associated with RTN **1-15718** and RTN **1-16079**. This RAO describes the assessment and response actions conducted to address the release conditions, summarizes historical and recent soil and groundwater analytical results, and documents that an Activity and Use Limitation (AUL) is required to achieve a condition of No Significant Risk (NSR) to human health, safety, public welfare, safety and the environment for current and unrestricted future site uses. Note that a prior RTN (**1-0489**) was assigned to F.L. Roberts & Company, Inc. (F.L. Roberts) by MADEP in June 1988 due to the detection of total ionizable compound (TIC) readings in excess of 100 parts per million by volume (ppmv) during removal of three 10,000 gallon USTs at the Site. Upon conducting soil and groundwater assessment to assess the release condition, it was concluded that a condition of NSR existed at the Site, and an RAO Statement was submitted to MADEP for RTN **1-0489** on August 2, 1995, by Environmental Compliance Services, Inc. (ECS).

2.0 BACKGROUND

2.1 Site Background

The Sunoco Station (Site) is located in a commercial and residential area of Westfield. The Site operates as retail gasoline service station and a car wash. The property consists of 56,628 square feet and is developed by a 1,728 square foot, one story concrete cinderblock building built in 1988, and consisting of convenience store retail sales floor, offices, storage space, and restrooms. Also located to the rear of the Site is a 3,120-square foot one story, concrete cinderblock building built in 1985 which consists of an automated carwash.

Residential properties abut the Site to the east and across South Maple Street to the north and northeast. A wooded area abuts the Site to the south. Commercial properties are located along South Maple and Mill Street to the west of the Site. Overhead telephone utilities enter the Site from South Maple Street. An underground electric line runs from the street to a transformer on the eastern side of the property then to the convenience store building. The station building is heated with natural gas. Water service and the sewer line enter the Site from South Maple Street. Stormwater runoff is managed through catch basins located on South Maple Street, which discharge to the municipal drain system. Six gasoline dispenser islands exist at the Site which are piped to three 10,000-gallon USTs located in the southern portion of the property behind the convenience store. **Figure 2A (Site Layout)** depicts pertinent Site features.

According to the MADEP **Site Scoring Map (Figure 3)** and the **21E Resource Priority Map (Figure 4)**, the Site is not located within an Interim Wellhead Protection Area (IWPA), Approved Zone 2, Zone A of a Class A Surface Water Body, or within a Potential Drinking Water Source Area. No known private drinking water supply wells are located within 500 feet of the site. The Site and surrounding properties are supplied with municipal water and sewer service provided by the City of Westfield.

The closest surface water body to the Site is Little River which is located approximately 200 feet to the south of the Site. Protected Open Space is located within approximately 1,000 feet to the south, and within approximately a half-mile to the west and east of the Site. The Site is also located within a FEMA 100-year floodplain, to the south and southeast. According to the Natural Heritage and Endangered Species Program (NHESP) Southwick Quad (October 1, 2006), a priority habitat of rare species and estimated habitat of rare wildlife is located within 0.5 miles west of the Site.

2.2 Release/Regulatory History

On June 13, 1988, three 10,000 gallon USTs were removed from the Site. Filed screening of soils encountered in the tank excavation exhibited TIC readings greater than 100 ppmv. On June 21, 1988, MADEP issued a Notice of Responsibility (NOR) to F.L. Roberts which assigned RTN **1-0489** to the Site. On October 25, 1989, MADEP requested a Phase 1 Limited Site Assessment be conducted for the Site by January 25, 1990. A sixty-day extension was subsequently approved by the MADEP.

In 1990, limited assessment activities were conducted at the Site including advancement of soil borings and installation of four overburden monitoring wells (MW-1 through MW-4). Groundwater samples collected from the wells were sampled for benzene, toluene, ethylbenzene, xylenes (BTEX), methyl tert butyl ether (MTBE) and acetone. On April 27, 1990, a Phase I Limited Site Assessment Report was submitted to MADEP which recommended that further assessment be conducted to evaluate the presence of acetone and MTBE in groundwater.

In March 1993, two additional monitoring wells (MW-5 and MW-6) were installed at the Site and groundwater sampling was conducted. On April 28, 1993, a Site Assessment Report was submitted to MADEP which concluded that no spillage of gasoline had occurred at the Site based on the results of the groundwater sampling activities.

On August 2, 1995, a Phase I Completion Report and RAO Statement were submitted to MADEP by ECS, on behalf of F.L. Roberts. The report(s) concluded that a condition of NSR existed at the Site.

On April 12, 2005, a tank tightness test failed on the regular unleaded dispenser line associated with the UST system. On April 15, 2005, the MADEP was notified of the threat of release condition, and RTN **1-15718** was issued to the Site. On April 19, 2005, the MADEP issued a NOR to Sunoco stating that Immediate Response Action (IRA) activities must be completed by April 15, 2006.

On April 14 and 15, 2005, CEA supervised the excavation and repair of the dispenser piping. Soil was excavated from an approximate 9-foot long and 3.5-foot wide trench. On April 27, 2005, the trench was expanded to expose the regular and ultra gasoline dispenser lines, to check for potential leaks and to install cathodic protection. Approximately 5 cubic yards of petroleum-impacted soil was generated between April 15 and 27, 2005. Composite soil samples collected from the limits of the excavation were submitted to Accutest Laboratories of New England (Accutest), a Massachusetts Certified Laboratory for analysis of volatile petroleum hydrocarbons (VPH) via MADEP methods. An IRA Completion Report was submitted to MADEP for RTN **1-15718** on February 7, 2006.

In November 2005, additional soil excavation was conducted at the Site. On November 17, 2005, sampling of the soil stockpile revealed the presence of PCBs at 2.31 mg/kg which exceeded the MCP RCS-1 of 2 mg/kg, which constituted a 120-day reporting condition. PCBs were also reported at a concentration of 32.05 mg/kg in composite sample T1 collected from the excavation area. On February 8, 2006, a RNF was submitted to MADEP for the PCB release condition and RTN **1-16079** was assigned to the Site.

On April 24, 2006, the Phase I Initial Site Investigation and Tier Classification were submitted to MADEP for RTN **1-15718**. The Phase I Report concluded that VPH fractions were present in soils and groundwater above Method 1 S-1 Standards and/or Method 1 GW-2 and/or GW-3 standards, respectively, and that comprehensive response actions were necessary at the Site. The Site was classified as a Tier II disposal site with an NRS score of 288. On February 8, 2007, RTN **1-16079** was linked to the RTN **1-15718**, the primary RTN for the Site. In May, July and October 2007, groundwater sampling was conducted at the Site to assess post-excavation groundwater quality conditions.

3.0 SUMMARY OF MCP RESPONSE ACTIONS

MCP assessment and response actions have been conducted at the Site since 1990 to address the release condition associated with former RTN **1-0489**. MCP assessment and response actions conducted at the Site since 1995 have been conducted to address the petroleum and PCB release conditions associated with current RTNs **1-15718 and 1-16079**. For completeness, a brief summary of all assessment and response actions conducted at the Site since 1990 is provided in the following section. **Figure 2A (Site Layout, April 2005 Excavation)** presents historical soil and groundwater sampling locations and the April 2005 soil excavation locations. **Figure 2B (Excavation Enlargement)** presents the November 2005 soil excavation and sampling locations. **Figure 2C (Site Layout w/Groundwater Contours)** presents current site conditions and groundwater flow contours using October 10, 2007 gauging data. Groundwater appears to flow to the south.

3.1 Phase I Initial Site Investigation, 1990 (RTN 1-0489)

3.1.1 Soil Boring Advancement/Monitoring Well Installation

On March 30, 1990, four soil borings were advanced at the Site and completed as monitoring wells MW-1 through MW-4. MW-1 and MW-2 were installed the west of the pump islands and UST field, respectively. The wells were installed to a depth of 19 feet and 19.5 feet below grade, respectively. MW-3B and MW-4 were installed to the southeast and south of the UST field, respectively. An attempt was made to install MW-3A directly south of the pump island canopy; however, refusal was encountered at 13 feet below surface grade. Therefore, MW-3B was installed to a depth of 11 feet below grade approximately 12 feet south of MW-3A. MW-4 was installed to a depth of 15 feet below grade. Refer to **Figure 2A** for locations of soil borings and monitoring wells.

Each well was completed as a 2-inch diameter PVC monitoring well which included a 10-foot 0.01-slot PVC screen (except MW-3B) set across the water table which was encountered at approximately 7.5 feet below grade. The annular space around the wells was back-filled with no. 2 silica sand to approximately one-foot above the screen interval. A one-foot bentonite seal was placed above the silica sand and the remaining space was back-filled with native material. Soil boring logs and monitoring well completion reports are included in **Appendix A.**

3.1.2 Groundwater Sampling and Analysis

On April 9, 1990, groundwater samples were collected from newly-installed monitoring wells MW-1 through MW-4. Prior to sampling, each well was gauged for depth to water and for the presence of non-aqueous phase liquids (NAPL) using an oil/water interface probe. The wells were then purged of three (3) well volumes to assure that representative groundwater samples were obtained. Groundwater samples were then collected and submitted to a Massachusetts-certified laboratory under chain-of-custody protocol for analysis of volatile organic compounds (VOCs) via EPA Method 8240 and lead.

According to the Phase I Completion Report (ECS, August 1995), MTBE and acetone were detected in the groundwater samples at 38 micrograms per liter (ug/L) and 741 ug/L, respectively, below the MCP RCGW-2 reportable concentrations. Lead was detected in all of the wells at concentrations ranging from 0.017 milligrams per liter (mg/L) in MW-2 to 0.990 mg/L in MW-3, above the RCGW-2 of 0.010 mg/L. No other compounds were detected in any monitoring wells.

3.2 Limited Subsurface Investigation, 1993 to 1995 (RTN 1-0489)

3.2.1 Soil Boring Advancement/Monitoring Well Installation

On March 17, 1993, two soil borings were advanced at the Site and completed as monitoring wells MW-5 and MW-6. Monitoring well MW-5 was installed northwest of the station building, upgradient of the pump islands. Well MW-6 was installed in the southern portion of the Site, downgradient of the station building, pump islands and UST area. Each well was installed to a depth of 22.5 feet below grade and was completed as a 2-inch diameter PVC monitoring well which included a 15-foot 0.01-slot PVC screen set across the water table which was encountered at approximately 12 feet below grade.

The annular space around the wells was back-filled with no. 2 silica sand to approximately one-foot above the screen interval. A one-foot bentonite seal was placed above the silica sand and the remaining space was back-filled with native material. **Figure 2A** presents the locations of the soil borings and monitoring wells. Soil boring logs and monitoring well completion reports are included in **Appendix A.**

3.2.2 Soil Sampling and Analysis

Soil samples were collected from soil borings MW-5 and MW-6 at 5-foot intervals and were field screened for TICs using a photoionization detector (PID) calibrated to an isobutylene standard. No TIC measurements above 0.2 ppmv were recorded in the soil samples collected from MW-5 and MW-6. One soil sample was collected from each boring and submitted to Accutest for analysis of methyl ethyl ketone (MEK) and VOCs via EPA Method 8240, and total petroleum hydrocarbons (TPH) via Method 418.1. According to the Phase I Report (ECS 1995), TPH was reported at 27 mg/kg and 44 mg/kg in soil samples MW-5 (10.5-12.5') and MW-6 (11-13'), respectively. No other compounds were detected in the soil samples.

3.2.3 Groundwater Sampling and Analysis

On March 25, 1993, groundwater samples were collected from monitoring wells MW-1, MW-3, MW-4, MW-5 and MW-6. Prior to sampling, each well was gauged for depth to water and for the presence of NAPL using an oil/water interface probe. The wells were then purged a minimum of three well volumes to assure that representative groundwater samples were obtained. Groundwater samples collected from the wells were submitted to Accutest for analysis of VOCs and MTBE via EPA Method 624. According to the Phase I Completion Report (ECS, August 1995), no VOC compounds were detected in any of the groundwater samples with the exception of a low level of MTBE (13.6 ug/L) in MW-6.

On July 31, 1995, groundwater samples were collected from monitoring wells MW-1, MW-2, MW-4, MW-5 and MW-6 and submitted to Spectrum Analytical, Inc. (Spectrum) for analysis of VOCs via EPA Method 8240 and soluble RCRA 8 Metals. Sampling results revealed concentrations of MTBE, tetrachlorethylene (PCE), barium, chromium and lead, all at concentration below MCP RCGW-2 reportable concentrations.

3.3 Immediate Response Action Activities, April and November 2005 (1-15718)

3.3.1 UST Product Line Excavation and Repair, April 2005

On April 12, 2005, Sunoco removed the unleaded dispenser lines and USTs from service in response to the failed UST line tightness test. On April 14 and 15, 2005, CEA supervised the excavation and repair of the dispenser piping. The location of the line leak was identified through helium tracer testing. Soil was excavated from an approximate 9-foot long and 3.5-foot wide trench (see **Figure 2A**, Excavation Area 1). During the excavation, soil samples were collected from the excavation and field screened using a PID calibrated to an isobutylene standard. Approximately 2-cubic yards of petroleum-impacted soil were temporarily stockpiled on plastic on-site, pending confirmatory laboratory analysis for off-site recycling.

On April 27, 2005, additional excavation was conducted to expose the regular and ultra gasoline dispenser lines, to check for potential leaks and to install cathodic protection (see Excavation Area 2

Field screening of five soil sample locations was conducted using a PID calibrated to an isobutylene standard. On April 28, 2005, the second trench was backfilled with clean material and finished to surface grade with a concrete pad. A total of approximately 5 cubic yards of petroleum impacted soil was generated between April 15 and 27, 2005.

Following repairs, the regular and ultra unleaded lines were tightness tested on April 29, 2005. Leak detectors were also tested. All tests were reported as passing.

3.3.2 Post-Excavation Soil Sampling and Analysis, April 2005

On April 14 and April 27, 2005, four post-excavation composite soil samples obtained from the limits of Excavation Area No. 1 were submitted to Accutest under chain-of-custody protocol for VPH analysis (Samples-1, 2, 3 and 4). **Table 1A** presents the VPH soil analytical results for the Site. As indicated in **Table 1A**, the C5-C8 and C9-C12 aliphatic and C9-C10 aromatic fractions were reported at concentrations well above the Method 1 S-1/GW-2, GW-3 Standard in Sample-3. VPH levels in Samples-1, 2, and 4 were insignificant.

On April 27, 2005, soil represented by Samples-1 and -2 were over-excavated and soil sample '1 S-B-2' was collected. Sample-3 was over-excavated and '2 S-B-2' was collected. Soil samples '4 S-B-2' and '5 S-COMP-2' were also collected. Soil samples collected on April 27, 2005 were submitted to Accutest for analysis of VPH via MADEP methods. Only soil sample '2-S-B 2', collected in the same general area of Excavation Area No. 1 as Sample-3, showed concentrations of VPH fractions above Method 1 S-1 Standards (**Table 1A**). Upon completion of soil excavation and sampling activities, on April 28, 2005 the excavation was backfilled with clean fill material, compacted and restored to grade.

Confirmatory soil sample locations are depicted on **Figure 2A (Site Layout, April 2005 Excavation).** Refer to the IRA Plan dated June 21, 2005 for copies of the soil laboratory analytical reports.

3.3.3 Additional Soil Excavation and Removal, November 2005

Between November 15 and November 18, 2005, the three USTs and dispenser piping were uncovered by Dixon Construction Inc. of Shrewsbury, Massachusetts on behalf of Sunoco to enable UST upgrades, dispenser piping removal and reinstallation. PID screening of soils encountered during the excavation revealed TIC concentrations ranging from 65 ppmv to 85 ppmv at a depth of three feet below grade in the product piping excavation area (i.e., right side of convenience store, vicinity of Excavation Area No. 2).

Field screening of petroleum-impacted soils revealed TIC concentrations ranging from 55 ppmv at a depth of seven feet below grade to 200 ppmv at a depth of four feet below grade in the initial release area product piping excavation (i.e., left side of convenience store, vicinity of Excavation Area No. 1). In the area of the initial release, the excavation was deepened based on soil PID screening results obtained at a depth of four feet. Petroleum-impacted soil was removed and stockpiled on polyethylene sheeting. The excavation in the initial release area was terminated at an approximate depth of seven feet due to the physical constraints of the pump island mat and overhead canopy. Approximately 10 cubic yards of petroleum-impacted soil were segregated and stored on polyethylene plastic on Site.

Groundwater was not encountered in the excavation and dewatering was not necessary. The excavations were backfilled with clean fill and re-paved with concrete.

3.3.4 Post-Excavation Soil Sampling and Analysis, November and December 2005

Upon completion of the UST piping upgrade activities, from November 17 though December 19, 2007, post-excavation soil samples were collected from the tank field of the excavation (composite, Tank field) and the three product piping trenches (composite T1 through T6, RS-2, RS-3, R-3 and R-7).

The 'Tank field' composite was comprised of grab soil samples taken at the four risers on each UST. The 'T1 through T6' composites were comprised of grab soil samples taken roughly every four linear feet along the bottom of the product piping trenches. Soil composite T2 was collected upon over-excavation of soils represented April 2005 soil samples '4 S-B-2' and '5 S-COMP-2'. Soil samples RS-2, RN-2, R-3, R-7 and composite sample T5 were collected upon over-excavation of soils represented April 2005 soil sample '2 S-B-2'. Soil sample composites were also collected from the trenching around the pump islands on the right side of the convenience store (T1-A, T1-B and T1-C). All samples were submitted to Spectrum for analysis of VPH via MADEP methods and/or PCBs. **Tables 1A and 1B** present the VPH and PCB soil results, respectively.

As indicated in **Table 1A**, the C5-C8 aliphatic and C9-C10 aromatic fractions exceeded the Method 1 S-1 GW-2/GW-3 Standards at soil sample location R-7 (7') (i.e., the former location of '2 S-B-2'). No other soil samples revealed significant levels of VPH constituents. One soil sample (T1 composite) revealed a PCB concentration of 32.05 mg/kg which is greater than ten times the Method 1 S-1 Standard. Three additional composite soil samples collected within the T1 composite sampling area (T1-A, T1-B and T1-C) also revealed elevated PCB levels (i.e., 2.97 mg/kg, 3.42 mg/kg, and 8.33 mg/kg respectively) but at lower concentrations than those reported in the T1 composite sample. PCB results in the Tank Field sample and the T2 and T5 composite samples were below the Method 1 S-1 Standard.

3.3.5 Soil Stockpile Sampling and Analysis, June and November 2005

On June 27, 2005 and November 17, 2005, soil samples were collected from the soil stockpile(s) and submitted to Lancaster Laboratories, Inc. and Spectrum Analytical, Inc., respectively, for analysis of typical disposal parameters including; VOCs via EPA Method 8260B, PCBs via Method 8082, total metals via EPA Method 200 and 6000/7000 Series Methods, flashpoint, pH, Reactivity (sulfide and cyanide) and TPH via EPA Method 8100. **Tables 1B and 1C** present the soil analytical results for PCBs and metals.

As indicated in **Table 1B**, PCBs were detected at concentrations of 0.022 mg/kg and 2.31 mg/kg in the June 2005 and November 2005 samples, respectively, the latter exceeding the MCP RCS-1 reportable concentration (2 mg/kg). As indicated in **Table 1C**, all metals were below MCP RCS-1 reportable concentrations, Method 1 S-1 Standards and MADEP background concentrations for "natural soils". All VOC and TPH analytical results were below the applicable MCP RCS-1 reportable concentrations.

3.4 Phase I Initial Site Investigation Activities, August 1995 (RTN 1-15718)

3.4.1 Groundwater Sampling and Analysis

During the Phase I initial site investigation, groundwater sampling of monitoring wells MW-1, MW-2, MW-3B, MW-4, MW-5 and/or MW-6 was conducted on August 1, 2005, February 7, 2006 and March 6, 2006. Prior to each sampling event, each well was gauged for depth to water and for the presence of NAPL using an oil/water interface probe. The wells were then purged a minimum of 3 well volumes to ensure that representative groundwater samples were obtained. On August 1, 2005, depth to water ranged from 11.91 feet below grade in MW-6 to 12.91 feet below grade in MW-5. On February 7, 2006, depth to water ranged from 9.8 feet below grade in MW-6 to 10.44 feet below grade in MW-3B. On March 6, 2006, depth to water in monitoring well MW-3B was measured at 13.25 feet below surface grade. During each event, no NAPL was detected in any wells gauged. Based on the August 1, 2005 gauging data, the apparent groundwater flow direction was estimated to be southwesterly across the Site.

All groundwater samples were placed on ice and transported to Spectrum under chain-of-custody protocol for analysis of VPH via the MADEP method. On August 1, 2005, monitoring wells were also analyzed for EPH via MADEP methods, RCRA Metals, and VOCs via EPA Method 8260B.

Groundwater results from August 1, 2005 revealed no detectable levels of VPH, EPH, VOCs and/or metals in all samples, except for low levels of barium, MTBE and naphthalene (all below the RCGW-2). No EPH compounds were detected in the samples. Groundwater analytical results for samples collected on February 7, 2006, reported all VPH concentrations below laboratory reporting limits (RLs) in monitoring wells MW-1 and MW-5. However, the C5-C8 and C9-C12 aliphatic fractions were reported above the Method 1 GW-2 Standards (in place at the time) in the groundwater sample collected from MW-3B. All other VPH concentrations were below applicable Method 1 GW-2 and GW-3 standards.

The analytical results for groundwater samples collected on March 7, 2006 indicated the C5-C8 aliphatic and C9-C10 aromatic fractions to be above the Method 1 GW-2 Standards in place at the time; however, the reported concentrations were below the MCP Standards promulgated in November 2007. All other VPH compounds were below applicable standards.

3.5 Subsurface Assessment Activities, March and June 2007

3.5.1 Soil Boring Advancement/Monitoring Well Installation

On March 28, 2007, seven soil borings were advanced at the Site using the direct-push drilling method with a rubber-track-mounted Geoprobe. Two soil borings were completed as monitoring wells MW-101 and MW-102. Soil boring SB-103 was originally intended to be an additional monitoring well; however, refusal was encountered when attempting to advance the monitoring well in the boring. Monitoring wells MW-101 and MW-102 were advanced to a depth of 16 feet below grade to the south and to the east of the pump islands, respectively. SB-103 was advanced directly north of the pump islands.

Borings SB-1, SB-2, SB-3 and SB-4 were advanced to the north, west, southwest and south of the pump islands/UST area, respectively, to a depth of 13 feet below grade using the direct push drilling method.

On June 25, 2007, four additional soil borings were advanced at the Site using a rubber-track-mounted drill rig and completed as monitoring wells MW-201 through MW-204. Monitoring well MW-201 was installed directly upgradient and north of the pump islands (northeast of the station building). MW-202 was installed cross-gradient of the pump islands and UST area. MW-203 was installed in the southeast corner of the Site approaching the wooded area (downgradient of the pump islands and UST area). MW-204 was located south and downgradient of the pump islands and UST area. **Figures 2A and 2C** depict the soil boring and monitoring well locations.

MW-201 and MW-202 were advanced to 20 feet below grade and completed as a 2-inch diameter PVC monitoring well which included a 10-foot 0.01-slot PVC screen set across the water table which was encountered at approximately 13 feet below grade. MW-203 and MW-204 were advanced to 12 feet and 17 feet below grade, respectively, and completed as a 2-inch diameter PVC monitoring wells. MW-203 and MW-204 were constructed with 8 foot and 10 foot screens, respectively, set across the water table which was encountered at approximately 11 feet below grade. The annular space around the wells was back-filled with no. 2 silica sand to approximately one-foot above the screen interval. A one-foot bentonite seal was placed above the silica sand and the remaining space was back-filled with native material. Soil boring logs and monitoring well completion reports are included in **Appendix A.**

3.5.2 Soil Sampling and Analysis

Soil samples were collected at 5-foot intervals from all soil borings advanced in 2007. All soil samples collected in March 2007 were field screened for TICs using a PID calibrated to an isobutylene standard. With the exception of MW-103, TIC screening results were generally insignificant (i.e., less than 50 ppmv). However, at MW-103, TIC readings greater than 1,000 ppmv were encountered in the samples collected at depths greater than 15' below grade (i.e., up to 2,357 ppmv). All soil samples collected in June 2007 were field screened for TICs using a MiniRAE PID with a 10.6eV bulb calibrated to an isobutylene standard. With the exception of MW-201, field screening results were insignificant (i.e., less than 10 ppmv). At MW-201, TIC readings greater than 1,000 ppmv were encountered in the soil samples collected from 10-12' (2,159 ppmv) and 12-14' (3,721 ppmv) below grade.

One soil sample was collected from each boring advanced in June 2007 and submitted to Southern Petroleum Laboratories, Inc. (SPL), a Massachusetts-certified laboratory, under chain-of-custody protocol for analysis of VPH via MADEP Method, and for PCBs via EPA Method 8082. With the exception of SB-103 (15') which reported the C9-C10 aromatic fraction at 140 mg/kg, which exceeded the Method 1 S-1 Standard (100 mg/kg), all other VPH and PCBs results were insignificant (well below applicable Method 1 Standards).

One soil sample was collected from each boring advanced in June 2003 and submitted to Lancaster Laboratories, Inc. (Lancaster Labs) for analysis of VPH via MADEP Methods and PCBs. All VPH and PCB analytical results were insignificant (well below applicable Method 1 Standards).

4.0 RECENT ASSESSMENT ACTIVITIES

Recently at the Site, groundwater sampling was conducted on May 8, 2007, July 12, 2007 and October 10, 2007. On May 8, 2007, groundwater samples were collected from monitoring wells MW-1, MW-3B, MW-5, MW-6, MW-101 and MW-102. On July 12, 2007, groundwater samples were collected from monitoring wells MW-1, MW-5, MW-6, MW-101, MW-102, and newly installed monitoring wells MW-201, MW-202 and MW-204. MW-3B and MW-203 were dry, and therefore were not sampled. On October 10, 2007, groundwater samples were collected from monitoring wells MW-1, MW-5, MW-6, MW-101, MW-102, MW-201, MW-202 and MW-204.

Prior to each sampling event, each well was gauged for depth to water and for the presence of NAPL using an oil/water interface probe. The wells were then purged a minimum of three well volumes to assure that representative groundwater samples were obtained. The groundwater samples were placed on ice and transported to SPL Laboratories for analysis of VPH via MADEP Methods.

On October 10, 2007, depth to water as measured in monitoring wells located across the disposal site ranged from 10.95 feet below grade in monitoring well MW-204 to 13.64 feet below grade in monitoring well MW-101. Monitoring wells MW-3B and MW-203 were dry, and therefore were not included in the groundwater flow map. As indicated in **Figure 2C (Site Layout)**, based on the October 10, 2007 gauging results, groundwater flow direction is toward the south across the Site.

Table 2A presents the recent VPH groundwater analytical results for the Site. As indicated in **Table 2A,** low levels of VPH compounds were detected in MW-3B and MW-6 during the May 8, 2007 sampling event, only. With the exception of MTBE, all other VPH compounds were below laboratory RLs during the July 2007 sampling event. All VPH compounds including naphthalene were below laboratory RLs during the October 2007 sampling event. Therefore, there are no current impacts to groundwater.

5.0 NATURE AND EXTENT OF IMPACTS

5.1 Description of Soil Impacts

In April 2005, petroleum-impacted soils were initially encountered at relatively shallow depths in the vicinity of the product dispenser in Excavation Area No. 1 (Figure 2A). Excavation activities conducted in April and November 2005 removed the OHM-impacted soils represented by soil samples Sample-3 and '2 S-B-2'. However, petroleum-impacted soils continued to be encountered in this area, as indicated in the results for soil sample R-7 (7') which was collected in the same general area in November 2005. As indicated in **Table 1A**, the C5-C8 aliphatic and C9-C10 aromatic fractions exceed Method 1 S-1 Standards at soil sample location R-7 (7') (i.e., the former location of '2 S-B-2'). No other soil samples collected at the Site revealed significant levels of VPH constituents.

PCB impacts have been encountered in shallow soils (2-3 feet below grade) located to the right-hand side (west) of the convenience store, as indicated by soil sample T1 composite which revealed PCBs at 32.05 mg/kg. Three additional composite soil samples collected within the T1 composite sampling area (T1-A, T1-B and T1-C) also revealed elevated PCB levels. PCBs were not detected elsewhere at the Site above RCS-1 concentrations.

5.2 Description of Groundwater Impacts

As discussed in Section 4.0 above, there are no current VPH impacts to groundwater. Low levels of VPH compounds were detected in MW-3B and MW-6 during the recent May 8, 2007 sampling event. However, with the exception of naphthalene, all other VPH compounds were below laboratory RLs during the July 2007 sampling event. All VPH compounds including naphthalene were below laboratory RLs during the October 2007 sampling event. Note that the recent 2007 groundwater laboratory reports are included in **Appendix B.**

Assessment activities conducted for RTN 1-0489 has identified relatively low levels of lead in groundwater samples collected at the Site. However, as indicated in **Table 2B**, groundwater samples collected from downgradient monitoring wells MW-4 and MW-6 in August 2005 and analyzed for metals revealed detectable levels of barium, only. Barium was reported at concentrations of 134 ug/L and 109 ug/L in wells MW-4 and MW-6, respectively, well below the Method 1 GW-3 Standard of 50,000 ug/L. No other metals (including lead) were detected in the samples.

5.3 Description of Indoor Air Impacts

Based on the concentrations and location of the VPH impacts to soil and groundwater at the Site, no indoor air impacts due to OHM in soils or groundwater are likely to occur on the property.

5.4 Background Evaluation

As defined in the MCP, background concentrations are those levels of OHMs that would exist in the absence of the disposal site and are:

- ubiquitous and consistently present in the environment at and in the vicinity of the disposal site of concern, and attributable to geologic or ecological conditions, or atmospheric deposition of industrial process or engine emissions;
- attributable to coal ash or wood ash associated with fill material;
- releases to groundwater from a public water supply system; or
- petroleum residues that are incidental to normal operation of motor vehicles.

In accordance with DEP's *Background Levels of Polycyclic Aromatic Hydrocarbons (PAHs) and Metals in Soil-Technical Update* (DEP, 2002e), PAHs and/or metals detected in soil samples are typically compared to MADEP-established background concentrations for "natural soils" to assess whether the occurrence of such compounds are likely to be attributable to background conditions. Due to the nature of the release (i.e., gasoline), metals and PAHs are not considered to be chemicals of concern (COCs) for soil or groundwater at the Site. The COCs at this Site are VPH compounds and PCBs which have been detected in soils in the vicinity of the pump islands and UST area at the Site. Note that barium has recently been detected in groundwater at relatively low levels, and is likely to be a background condition.

For purposes of this RAO, all OHM currently present in soil at the Site, above laboratory reporting limits, are considered to be above site-specific background levels. There are no current impacts to groundwater.

5.5 Disposal Site Boundary

Based on the historical and recent soil and groundwater assessment data collected for the Site, the OHM impacts deemed attributable to releases at or from the Site are generally limited to the immediate vicinity of the convenience store, pumps islands and UST area. Low levels of OHM impacts to groundwater had previously been detected in downgradient well MW-6; however, there are no current impacts to groundwater. Although OHM imacts to soils are generally limited to the convenience store area, the disposal site boundary applicable to this RAO includes the entire 88-90 South Maple Street property. The disposal site boundary is depicted on **Figure 2C, Site Layout w/Groundwater Contours.**

6.0 ELIMINATION OF UNCONTROLLED SOURCES

Pursuant to 310 CMR 40.1003(5), there are no leaking underground or aboveground storage tanks, vessels, drums or other such containers; there are no non-aqueous phase liquids; or other uncontrolled sources that would likely cause an increase in OHM concentrations at the Site. Response actions have been conducted at the Site to remove petroleum-impacted soils, groundwater and NAPL from the Site. There are no other uncontrolled sources of OHM known to exist at the Site.

7.0 SUMMARY OF METHOD 3 RISK CHARACTERIZATION

A Method 3 Risk Characterization (Method 3) was conducted to evaluate the human health risks associated with the occurrence of OHM in soil and groundwater at the 88-90 South Maple Street disposal site property located in Westfield, Massachusetts. The Method 3 evaluated the risks posed to all anticipated current and/or future human receptors at the property including a commercial worker, construction worker, trespasser and resident. For soils, each receptor was evaluated for exposure to the maximum and average OHM levels present in soils from 0-15' below grade, as a worst-case and realistic-case exposure evaluation, respectively.

Groundwater was not deemed a media of concern since there are no current impacts to groundwater on the property. Also, groundwater is not used as a potable water supply and direct exposure to groundwater during future construction activities would be mitigated by dewatering. Based on the location and concentrations of VPH compounds in soil, impacts on indoor air quality of onsite or offsite buildings are not expected to occur.

The Method 3 concluded that under worst-case exposure conditions, the non-cancer and/or excess lifetime cancer risk posed to the commercial worker, construction worker, trespasser and resident exceed the MADEP non-cancer and cancer risk thresholds. Under realistic-case exposure conditions, the non-cancer risk posed to a resident exceeds the MADEP non-cancer risk threshold. Therefore, a condition of No Significant Risk (NSR) of harm to human health does not exist at the disposal site and an Activity and Use Limitation is required to achieve a condition NSR of harm to human health at the Site.

The Method 3 has demonstrated that a condition of NSR of harm to safety, public welfare and the environment does exist at the Site, for current and future site conditions. The Method 3 Risk Characterization is included in **Appendix C.**

8.0 FEASIBILITY OF RESTORATION TO BACKGROUND

Section 40.1020 of the MCP requires that a background feasibility evaluation be conducted consistent with the criteria established in 310 CMR 40.0860 for all sites where a remedial action has been taken to achieve a Class A Response Action Outcome. A background feasibility evaluation is included in this Class A-2 RAO which demonstrates that further response actions are not appropriate for the Site.

The feasibility evaluation has been prepared in accordance with the MCP and DEP's "Guidance for Conducting Feasibility Evaluations under the MCP", Final Policy #WSC-04-160 (DEP, 2004). Pursuant to the MCP and MADEP Policy #WSC-04-160, "background" refers to those levels of OHM that would exist in the absence of the disposal site, which are either:

- Ubiquitous and consistently present in the environment at and in the vicinity of the disposal site of concern, and attributable to geologic or ecological conditions, or atmospheric deposition or industrial process or engine emissions;
- Attributable to coal ash or wood ash associated with fill material;
- A release to groundwater from a public water supply system; or
- Petroleum residues that are incidental to the normal operation of motor vehicles."

As discussed in Section 5.0, low-to-moderate levels of VPH continue to be present in soils in the vicinity of the product dispenser area (i.e., left of convenience store, vicinity of Excavation Area No. 1). Elevated levels of PCBs continue to be present in shallow soils located to the right of the convenience store (i.e., vicinity of Excavation Area No. 2). The Method 3 has demonstrated that an AUL is required to achieve a condition of NSR of harm to health for current and future site conditions. However, a condition of NSR of harm to the safety, public welfare and the environment exists at the Site.

The MADEP Final Policy #WSC-04-160 establishes a series of criterion for determining the conditions when further efforts to reduce OHM are warranted bases on an evaluation of benefit versus cost, as indicated below:

- Section 2.0(b) states that response actions to achieve background are warranted unless the costs of conducting the remedial action, or risk resulting from these actions, would not be justified by the benefits, considering such factors as potential damage to the environment, health, costs of environmental restoration, long-term operation and maintenance costs and nonpecuniary value.
- Section 3.0(a) states the incremental cost of conducting the remedial action alternative is substantial and disproportionate to the incremental benefit of risk reduction, environmental restoration, and monetary and non-pecuniary values.
- Section 9.3.2.3 states that achieving or approaching background can be deemed infeasible for degradable/non-persistent contaminants regardless of media, except for small quantities of petroleum-impacted soil considered accessible.

It is noted that the residual VPH and PCB-impacted soils are located beneath pavement, in close proximity to a currently operating convenience store, gasoline dispenser pump islands and gasoline UST area, and underground utilities are extensive in the area.

As stated in Section 9.3.2.1 of MADEP Policy #WSC-04-160, any portion of remedial work required to achieve background that requires excavation under the foundation of a building or other permanent structure, such that the integrity of the structure would be impaired, may be considered infeasible. Thus, further excavation to remove PCB-impacted soils in the vicinity of the pump island would be infeasible.

Due to the non-persistent nature of the gasoline-related (VPH) impacts at the Site (petroleum-based), pursuant to Section 9.3.2.3 of MADEP Policy #WSC-04-160, "the benefits of additional remedial actions to achieve or approach background for these degradable/non-persistent contaminants would be insufficient to justify the costs of those actions".

In summary, further response actions designed to achieve background conditions at the 88-90 South Maple Street Site located in Westfield, Massachusetts are categorically infeasible.

9.0 DATA QUALITY EVALUATION

Section 40.1056(2)(k) of the MCP requires that a Representativeness Evaluation and a Data Usability Assessment be provided in the documentation that supports a Class A, B or C RAO. According to the MCP, the Representativeness Evaluation shall document the adequacy of the spatial and temporal data sets used to support the RAO. The Data Usability Assessment must document that the data relied upon is scientifically valid and defensible, and is of a sufficient level of precision, accuracy and completeness to support the RAO. The Representativeness Evaluation and Data Usability Assessment presented herein has been prepared in accordance with draft MADEP Policy #WSC-07-350.

9.1 Representativeness Evaluation

According to Section 6.0 of draft MADEP Policy #WSC-07-350, the Representativeness Evaluation determines whether the data set in total sufficiently characterizes conditions at the Disposal Site and supports a coherent Conceptual Site Model. The Representativeness Evaluation determines whether there is enough information from the right locations, both spatially and temporally, to support the RAO. The Representativeness Evaluation should:

- Demonstrate the adequacy of cumulative data to characterize the nature and extent of contamination at the Disposal Site, the risk to health, safety, public welfare and the environment and the elimination/control of OHM sources; and
- Identify inconsistent and incomplete information and sources of uncertainty, and justify why such inconsistent information, data gaps, or uncertainty are not sufficient to undermine the RAO opinion.

9.1.1 Conceptual Site Model

The Conceptual Site Model (CSM) for the Site is discussed below:

- Petroleum impacts at the Site were generally limited to shallow soils present in the in the vicinity of the pump islands and service station building (Sample 3 (2'), 1-S-B-2 (2')) with the exception of one area of limited subsurface impact encountered at sample R-7 (7'). The likely source of these petroleum impacts were releases from the product dispenser(s) and/or the associated piping located in the northern portion of the Site. The majority of the petroleum-impacted soils were excavated and removed from the Site.
- PCB impacts were encountered in shallow soils (2-3 feet below grade) located to the right-hand side (west) of the convenience store, as indicated by soil sample T1 composite. Three additional composite soil samples collected within the T1 composite sampling area (T1-A, T1-B and T1-C) also revealed elevated PCB levels. The actual source of the PCBs is unknown but likely due to spills and/or releases from the building.

9.1.2 Use of Field/Screening Data

Field screening data collected from the Disposal Site was used in the response action decision making process in the following manner:

- Field screening data was used extensively during the assessment activities conducted to assess the horizontal and vertical distribution of petroleum impacts extending beyond the immediate vicinity of the release area, as evidence by the PID field screening results available from soil borings MW-101, MW-102, MW-103, SB-1, SB-2, SB-3, SB-4, MW-202, MW-203 and MW-203. The PID results were used to guide soil sampling depths and locations for sample submittal to the laboratory.

9.1.3 Sampling Rationale

Soil samples T-1 (3') through T-6 (3'), R-7 (7'), R-3 (3'), RS-2 (2') and RN-2 (2') were collected subsequent to the soil excavation activities to characterize residual petroleum impacts in the immediate vicinity of the pump islands. Soil borings MW-101, MW-102, MW-103, SB-1, SB-2, SB-3, SB-4, MW-202, MW-203 and MW-203 which include field screening and subsurface soil sampling at depths ranging from 10-15 feet below grade were used to characterize OHM released away from the pump island area to outer portions of the Site. The monitoring wells currently present at the Site (MW-101, MW-102, MW-201 through MW-204, MW-1, MW-3B, MW-5, MW-5 and MW-6) are adequately situated to monitor impacts to groundwater as they exist in the immediate vicinity of the release area and/or at locations downgradient, upgradient and/or cross-gradient of the release area.

9.1.4 Number, Spatial Distribution and Handling of Samples

For petroleum-related OHM, the number(s) and spatial distribution of soil and groundwater sampling stations were designed to characterize the nature of the release at the source (i.e. dispenser islands) as well as the horizontal and vertical extent of the release as it extended away for the source. For PCBs, composite sampling locations were chosen to determine locations where PCBs are present in soils above reportable concentrations, as needed to assess the feasibility of conducting further remediation to remove the PCBs, to assess risk, and to evaluate the need for an Activity and Use Limitation at the Site.

Soil samples were collected as grab samples in containers provided by the laboratory containing the appropriate preservatives, placed on ice and transported to the Massachusetts-Certified laboratory under chain-of-custody protocol. Groundwater samples were collected from the monitoring wells only after purging the wells to assure representative samples were obtained. The samples were then collected using dedicated, disposable equipment, and were placed in clean glassware provided by the testing laboratory. Samples were placed in coolers, preserved with ice, and transported to the testing laboratory under chain-of-custody protocol.

9.1.5 Temporal Distribution of Samples

Following completion of soil excavation activities at the Site, groundwater samples were collected on five (5) occasions from MW-1, MW-5 and MW-6; on three (3) occasions from MW-3B, MW-101 and MW-102; and on two (2) occasions from MW-201, MW-202 and MW-203. As indicated in **Table 2A,** groundwater sampling results for VPH showed little variability throughout these events indicating that groundwater quality conditions are stable and/or trending downward. Further sampling of groundwater was deemed unnecessary.

9.1.6 Critical Samples

Critical samples are defined as samples for which usable results are necessary to support a conclusion that the response action objectives have been met. For this RAO Statement, all soil and groundwater samples are considered to be critical to the assessment of soil and groundwater quality at the Site.

9.1.7 Completeness

No data gaps in sampling or analytical information used to support this RAO have been identified

9.1.8 Inconsistency and Uncertainty

No inconsistent or uncertain information was identified or disregarded when rendering the RAO Opinion for this disposal site.

9.1.9 Information Considered Unrepresentative

No inconsistent or uncertain information was identified or disregarded when rendering the RAO Opinion for this disposal site.

9.2 Data Usability Assessment

According to Section 7.0 of draft MADEP Policy #WSC-07-350, a Data Usability Assessment has an analytical component and a field component. An Analytical Data Usability Assessment is used to evaluate whether analytical data points are scientifically valid and defensible, and of a sufficient level of precision, accuracy and sensitivity to support the RAO. The Field Data Usability Assessment evaluates whether the sampling procedure ensures that the sample collected and delivered to the laboratory is representative of the sampling point.

9.2.1 Evaluation for CAM Compliant Data

The final version of the MADEP's "Compendium of Analytical Methods", or CAM, (MADEP Policy #WSC-02-320) was published on June 18, 2003. The CAM requires that all response action submittals provide details on any known conditions or findings which may affect the validity of analytical data, including unsatisfactory analytical results received on QA/QC blank, duplicate, surrogate or spiked samples. CAM Compliant data is defined as data with "Presumptive Certainty". Refer to Section 3.2 of the CAM for the definition of "Presumptive Certainty".

All soil and groundwater samples collected subsequent to the publication of the above-stated CAM document were collected and analyzed in accordance with the CAM requirements. Thus, all data used in completing the RAO and Method 3 were collected in accordance with these methods. Therefore, Presumptive Certainty Status exists for the data.

9.2.2 Evaluation for CAM Non-Compliant, Non-CAM and Pre-CAM Data

Appendix I of MADEP Policy WSC-07-350 defines "pre-CAM data" as an analytical result determined using an analytical method conducted prior to August 1, 2003 for methods included in the CAM. No CAM non-compliant, Non-CAM, or Pre-CAM samples were utilized in preparation of this RAO Statement.

9.2.3 Data Evaluation Criteria

Laboratory analytical data has been evaluated and determined to be usable for the purpose of supporting this RAO Statement. No limitations and/or significant qualifications (see below) on the use of the laboratory data used to support this RAO Statement exist. Method reporting limits for the analytical data have been evaluated and determined to be at or below the applicable Method 1 standards and/or critical risk-based concentration limits.

9.2.4 Evaluation of Precision and Accuracy

Precision pertains to the reproducibility of analytical results. Accuracy pertains to the degree of agreement of a sample measurement with a known reference value, and is usually indicated by acceptability of surrogate recoveries. Compliance with CAM requirements is used to assess whether Presumptive Certainty is likely to have been achieved for the data.

A qualitative review of the soil and groundwater sampling results for precision indicates that there are no instances where the analytical data present a data result which does not conform with the conceptual model for the Site (i.e., anomaly). Thus, there is no evidence of erroneous results being reported by the laboratory. In referring to the groundwater results, a qualitative evaluation of precision indicates that the multiple sampling events conducted from February 2006 through October 2007 demonstrate a high degree of reproducibility and consistency of measurements over time. Thus, a high degree of precision has been achieved for the soil and groundwater assessment programs.

In reviewing the soil and groundwater analytical results for accuracy, although there were a number of instances where individual surrogate recoveries in the data sets were outside or below QC control limits,

in no cases did the laboratory reject the data nor were deficiencies encountered in the groundwater data that would alter RAO findings. No deficiencies were noted in the indoor air laboratory reports.

9.2.5 Field Data Usability Assessment

The purpose of the field data usability assessment is to ensure that the sample delivered to the laboratory for analysis is actually representative of field conditions. Table 3 of Draft Policy #WSC-07-350 provides the following summary of field quality control elements to be considered when evaluating the quality of analytical results:

- Sampling Procedure –all groundwater samples were collected as grab samples. Indoor air samples were collected as composite samples (i.e., time-weighted). Groundwater samples were collected using dedicated, disposable equipment, and were placed in clean glassware provided by the testing laboratory. Samples were placed in coolers, preserved with ice, and transported to the testing laboratory under chain-of-custody protocol. Indoor air samples were collected in stainless steel canisters supplied by the laboratory and also transported to the testing laboratory under chain-of-custody protocol.
- Sample Containers/Preservation – Sample containers and required preservatives were provided by the testing laboratories and were in accordance with the specifications outlined in Appendix VII of MADEP Policy #WSC-02-320;
- Holding Times – All samples were transported to the testing laboratory within the applicable holding times;

Field Duplicates - The contaminants of concern for the release subject to this RAO Statement VPH compounds. As indicated in Table VII A-1 of MADEP Policy # WSC-02-320, field duplicates of aqueous samples are not mandatory for these analytes. Consequently, none were collected;

- Matrix Spikes/Matrix Spike Duplicates - The contaminants of concern for the release subject to this RAO Statement are VPH compounds. As indicated in Table VII A-1 of MADEP Policy # WSC-02-320, matrix spike samples of soil or aqueous media are not mandatory for these analytes; and,
- Equipment Blank/Trip Blank - The contaminants of concern for the release subject to this RAO Statement are VPH compounds. As indicated in Table VII A-1 of MADEP Policy # WSC-02-320, trip blanks are not mandatory for soil or aqueous samples for these analytes. Consequently, none were collected.

9.2.6 Rejection of Analytical Data as the Result of Gross Failure

None of the analytical data meets the definition of rejected data as defined in Appendix IV of Policy #WSC-07-350.

9.3 Conclusions

The Data Usability Assessment has documented that the data relied upon is scientifically valid and defensible, and is of a sufficient level of precision, accuracy and completeness to support the RAO. In addition, the Representativeness Evaluation has documented the adequacy of the spatial and temporal data sets used to support the RAO.

10.0 MANAGEMENT OF REMEDIATION WASTE

Remediation wastes generated during the MCP response actions were managed in accordance with all MADEP policies and guidance, as described in prior MADEP submittals. A brief summary of remedial waste management activities is provided below:

- On January 9, 2006, approximately 10 cubic yards of petroleum-impacted soil generated during the IRA activities conducted for RTN **1-15718** were transported to Environmental Soil Management Inc. (ESMI) of Loudon, New Hampshire for thermal treatment, under a MADEP Bill of Lading (BOL). The BOL documentation was forwarded to MADEP under a prior submittal.
- Pursuant to Section 310 CMR 40.0045(7) of the MCP, water generated during groundwater sampling activities was discharged at the point of withdrawal.

No other remedial wastes have been generated during the response actions completed at the Site.

11.0 RESPONSE ACTION OUTCOME STATEMENT

The following conclusions have been reached for the disposal site identified as the 88-90 South Maple Street property located in Westfield, Massachusetts:

1) A condition of No Significant Risk of harm to safety, public welfare, and the environment exists for all current and future site conditions based on the performance of a Method 3 Risk Characterization. However, an Activity and Use Limitation is required to achieve a condition of No Significant Risk of harm to health by restricting certain site activities and uses.
2) OHM levels in soil exceed site-specific background levels for petroleum compounds and PCBs; however, it is infeasible from a technical or categorical standpoint to reduce such OHM levels to background conditions.
3) This RAO addresses RTNs **1-15718 & 1-16079**. No other outstanding RTNs are present at the Site.
4) A Class A-3 RAO Statement is appropriate for this site since a Permanent Solution has been achieved, OHM levels exceed site-specific background levels and an AUL is required to achieve a condition of NSR of harm to human health.
5) The disposal site boundary is shown on **Figure 2C, Site Layout w/Groundwater Contours.**

Future activities conducted at this disposal site must comply with the MCP provisions established in 310 CMR 40.0032(3), which state:

> Soils containing oil or waste oil at concentrations less than a release notification threshold specified in 310 CMR 40.0300 and 40.1600, and that are not otherwise a hazardous waste, and soils that contain one or more hazardous materials at concentrations less than a release notification threshold, and that are not a hazardous waste may be transported from a disposal site without notification to or approval from the Department under the provisions of this Contingency Plan, provided that such soils:
>
> a) are not disposed or reused at locations where the concentrations of oil or hazardous materials in the soil would be in excess of a release notification threshold applicable at the receiving site, as delineated in 310 CMR 40.0300 and 40.1600; and
>
> b) are not disposed or reused at locations where existing concentrations of oil and/or hazardous materials at the receiving site are significantly lower than the levels of those oil or hazardous materials present in the soil being disposed or reused.

Note that residual OHM impacts are present at this Site both above and below MCP reportable concentrations. Thus, future actions at this Site must be consistent with the actions assessed and deemed appropriate for this Site.

12.0 PUBLIC INVOLVEMENT

Copies of the letters that were sent to the Town of Westfield Chief Municipal Officer (CMO) and Board of Health (BOH) informing them of the availability of this Class A-3 RAO are included in **Appendix D.**

13.0 REFERENCES

CEA, 2006. Immediate Response Action Completion Report for RTN **1-15718.** 88-90 South Maple Street, Westfield, MA. Corporate Environmental Advisors, Inc., February 7, 2006.

CEA, 2006. Phase I Initial Site Investigation Report and Tier Classification for RTN **1-15718.** 88-90 South Maple Street, Westfield, MA. Corporate Environmental Advisors, Inc., April 24, 2006.

ECS, 1995. Phase I Completion Report, 88-90 South Maple Street, Westfield, MA. August 1995.

MADEP, 2004. Guidance for Conducting Feasibility Evaluations under the MCP, Final Policy #WSC 04-160. Massachusetts Department of Environmental Protection, 2004.

MADEP, 2002. Implementation of the VPH/EPH Approach, Final Policy. Massachusetts Department of Environmental Protection. October 2002.

MADEP, 2006. Massachusetts Contingency Plan, 310 CMR 40.0000. Massachusetts Department of Environmental Protection. April 2006.

MADEP, 1995. Guidance for Disposal Site Risk Characterization, In Support of the MCP. Massachusetts Department of Environmental Protection. July 1995.

MADEP, 2006. Documentation for the Development of the MCP Numerical Standards. Massachusetts Department of Environmental Protection. January 2006.

TABLES

Table 1A
Soil Analytical Results - VPH
88-90 South Maple Street
Westfield, MA

Sample ID	Date	Depth (feet)	C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics	Benzene	Toluene	Ethyl benzene	Total Xylenes	MtBE	Naph thalene	Total VOCs
MW-5*	3/17/1993	10.5'-12.5'	NA	NA	NA	<5.8	<5.8	<5.8	<5.8	NA	NA	ND
MW-6*	3/17/1993	11'-13'	NA	NA	NA	<5.5	<5.5	<5.5	<5.5	NA	NA	ND
Sample 1 **	04/14/05	2'	4.9	<2.4	<2.4	<0.12	0.64	0.12	0.48	3.79	<0.12	NA
Sample 2 **	04/12/05	2'	9.7	4.3	8.4	<0.11	0.90	0.30	1.63	2.89	<0.11	NA
Sample 3 **	04/13/05	2'	**3,410**	**1,300**	**1,040**	28.6	545	124	421	205	19.9	NA
Sample 4 ***	04/14/05	2'	4.5	2.4	<2.1	<0.11	0.38	<0.11	0.39	0.62	<0.11	NA
1 S-B-2' ***	4/27/2005	2'	9.63	<3.1	<3.1	<0.15	0.20	<0.15	0.17	7.35	0.17	NA
2 S-B-2' ***	4/27/2005	2'	**4,790**	**2,190**	**2,380**	30.3	**1,050**	416	**1,454**	204	**40.1**	NA
4 S-B-2' ***	4/27/2005	2'	8.2	<3.0	<3.0	<0.15	0.8	0.15	0.64	3.1	0.17	NA
5 S-COMP-2' ***	4/27/2005	2'	4.75	<3.6	<3.6	<0.18	<0.18	<0.18	0.18	0.21	<0.18	NA
Tank Field	11/16/2005	1' - 5'	41.7	26.6	70.6	0.16	7.52	4.19	21.2	10.5	3.62	NA
R-7'	11/18/2005	7'	**1,870**	935	**1,650**	5.76	291	132	539	23.8	32.9	NA
T1	11/17/2005	3'	8.95	3.45	9.89	0.23	0.75	0.34	1.71	0.27	0.72	NA
T2	11/17/2005	3'	3.2	0.61	0.98	0.071	0.24	0.074	0.26	<0.64	0.1	NA
T3	11/18/2005	3'	1.23	<0.31	0.48	<0.06	0.134	<0.06	0.16	<0.06	<0.06	NA
T4	11/18/2005	3'	2.9	0.96	<0.82	<0.16	<0.16	<0.16	<0.49	<0.16	<0.16	NA
T5	11/18/2005	3'	30.1	24.6	58.2	<0.11	3.47	1.92	14.36	0.53	1.83	NA
T6	11/18/2005	3'	21.7	27.7	52.9	<0.17	1.24	1.1	8.2	<0.17	1.05	NA
R-3'	12/19/2005	3'	36.9	64.4	77.9	<0.161	1.71	0.37	8.34	<0.161	2.6	NA
RS-2'	12/19/2005	2'	<1.38	0.65	0.77	0.094	0.13	<0.092	<0.28	0.12	<0.092	NA
RN-2'	12/19/2005	2'	1.58	1.48	1.16	<0.07	0.1	<0.07	<0.22	<0.07	<0.07	NA
MW-101 (15')	3/28/2007	15'	<4.7	<2.3	<0.7	0.07	0.19	<0.023	0.058	<0.19	<0.23	NA
MW-102 (15')	3/28/2007	15'	<5.6	<2.8	<0.84	<0.028	<0.028	<0.028	<0.084	<0.22	<0.28	NA
SB-103 (15')	3/28/2007	15'	72	170	**140**	0.061	0.22	0.88	2.8	<0.2	2.8	NA
SB-1 (14')	3/28/2007	14'	<5.2	2.8	1.3	0.047	0.15	0.034	0.135	<0.21	<0.26	NA
SB-2 (14')	3/28/2007	14'	<4.6	<2.3	<0.69	<0.023	0.046	<0.023	<0.069	<0.18	<0.23	NA
SB-3 (13')	3/28/2007	13'	<4.9	<2.5	<0.74	0.038	0.12	<0.025	<0.074	<0.2	<0.25	NA
SB-4 (13')	3/28/2007	13'	<5.1	<2.6	<0.77	0.026	0.079	<0.026	<0.077	<0.21	<0.26	NA
MW-201	6/25/2007	12-14'	4.95	97.2	54.4	<0.04	<0.04	0.5	0.5	<0.04	1.59	NA
MW-202	6/25/2007	12-14'	<1.56	<1.56	<1.56	<0.03	<0.03	<0.03	<0.06	<0.03	0.05	NA
MW-203	6/25/2007	10-12'	<1.39	<1.39	<1.39	<0.03	<0.03	<0.03	<0.06	<0.03	<0.03	NA
MW-204	6/25/2007	10-12'	<1.75	<1.75	<1.75	<0.04	<0.04	<0.04	<0.08	<0.04	<0.04	NA
Method 1 Standards[1]	S-1/GW-2, GW-3		100	1000	100	30	500	500	300/500	100	40/500	NA
	S-2/GW-2, GW-3		500	3000	500	200	1000	1000	300/1000	100/500	40/1000	NA
	S-3//GW-2, GW-3		500	5000	500	700/900	2000/3000	1000/3000	300/3000	100/500	40/3000	NA
MCP Upper Conc Limits (UCL)[1]			5000	20000	5000	9000	10000	10000	10000	5000	10000	NA

Notes:

All concentrations are in milligrams per kilogam (mg/kg)

Bold - concentration exceeds Method 1 Standards

< - compound was below the laboratory reporting limit

VPH - Volatile Petroleum Hydrocarbons

*Samples were analyzed for VOCs, MEK and TPH; only TPH was detected at 27 mg/kg (MW-5) and 44 mg/kg (MW-6)

** Soil samples taken on 4-14-2005 were excavated on 4-27-2005

*** Soil samples taken on 4-14-2005 and 4-27-2005 were excavated on 11-18-2005

Ref[1] 310 CMR 40 (November 2007)

MTBE - Methyl tert-butyl ether

Table 1B
Soil Analytical Results - PCBs
88-90 South Maple Street
Westfield, MA

Sample ID	Sample Date	Sample Depth (feet)	Total PCBs	PCB 1016 (mg/kg)	PCB 1221 (mg/kg)	PCB 1232 (mg/kg)	PCB 1242 (mg/kg)	PCB 1248 (mg/kg)	PCB 1254 (mg/kg)	PCB 1260 (mg/kg)	PCB 1262 (mg/kg)	PCB 1268 (mg/kg)
StockPile	11/17/2005	--	**2.31**	<0.031	<0.031	<0.031	<0.031	**2.31**	<0.031	<0.031	<0.031	<0.031
Tank Field	11/16/2005	3' - 5'	1.37	<0.028	<0.028	<0.028	<0.028	1.32	<0.028	0.046	<0.028	<0.028
T1	11/17/2005	3'	**32.05**	<0.61	<0.61	<0.61	<0.61	**31.7**	<0.61	0.35	<0.03	<0.03
T2	11/17/2005	3'	0.21	<0.031	<0.031	<0.031	<0.031	0.098	<0.031	0.11	<0.031	<0.031
T5	11/18/2005	3'	0.14	<0.03	<0.03	<0.03	<0.03	0.07	<0.03	0.065	<0.03	<0.03
T1-A	12/19/2005	2'	**2.97**	<0.03	<0.03	<0.03	<0.03	**2.97**	<0.03	<0.03	<0.03	<0.03
TI-B	12/19/2005	2'	**3.42**	<0.03	<0.03	<0.03	<0.03	**3.42**	<0.03	<0.03	<0.03	<0.03
T1-C	12/19/2005	2'	**8.33**	<0.15	<0.15	<0.15	<0.15	**8.33**	<0.03	<0.03	<0.03	<0.03
MW-101 (15')	3/28/2007	15'	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	--	--
MW-102 (15')	3/28/2007	15'	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	--	--
SB-103 (15')	3/28/2007	15'	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	--	--
SB-1 (14')	3/28/2007	14'	0.33	<0.035	<0.035	<0.035	<0.035	0.33	<0.035	<0.035	--	--
SB-2 (14')	3/28/2007	14'	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	--	--
SB-3 (13')	3/28/2007	13'	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	--	--
SB-4 (13')	3/28/2007	13'	0.19	<0.036	<0.036	<0.036	<0.036	0.19	<0.036	<0.036	--	--
MW-201	6/25/2007	12-14'	<0.0056	<0.0036	<0.0056	<0.0036	<0.0036	<0.0036	<0.0036	<0.0036	--	--
MW-202	6/25/2007	12-14'	<0.0036	<0.0036	<0.0057	<0.0036	<0.0036	<0.0036	<0.0036	<0.0036	--	--
MW-203	6/25/2007	10-12'	<0.0034	<0.0034	<0.0053	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	--	--
MW-204	6/25/2007	10-12'	0.0096	<0.0036	<0.0057	<0.0036	<0.0036	<0.0036	0.0096 J	<0.0036	--	--
Disposal	6/25/2007	NA	0.022	<0.0036	<0.0057	<0.0036	<0.0036	<0.0036	0.022	<0.0036	--	--
Method 1 Standards[1]	S-1/GW-2, GW-3		2	2	2	2	2	2	2	2	2	2
	S-2/GW-2, GW-3		3	3	3	3	3	3	3	3	3	3
	S-3//GW-2, GW-3		3	3	3	3	3	3	3	3	3	3
MCP Upper Conc Limits (UCL)[1]			100	100	100	100	100	100	100	100	100	100

Notes:
All concentrations are in milligrams per kilogam (mg/kg)
Bold - concentration exceeds Method 1 Standards
< - compound was below the laboratory reporting limit

Ref[1] 310 CMR 40 (November 2007)
PCBs - Polychlorinated Biphenyls

Table 1C
Soil Analytical Results - Metals
88-90 South Maple Street
Westfield, MA

Sample ID	Date	Depth (feet)	Arsenic (mg/kg)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)
StockPile	6/27/2005	NA	1.97 J	38.5	<0.071	15	13.1	0.016 J	<1.07	<0.186
StockPile	11/17/2005	NA	<1.62	37.3	<0.27	8.21	8.78	NA	<1.62	<1.08
Method 1 Standards[1]	S-1/GW-2, GW-3		20	1000	2	30	300	20	400	100
	S-2/GW-2, GW-3		20	3000	30	200	300	30	800	200
	S-3//GW-2, GW-3		20	5000	30	200	300	30	800	200
MCP Upper Conc Limits (UCL)[1]			200	10000	300	2000	3000	300	8000	2000
MADEP Background Conc, Natural Soils			20	50	2	30	100	0.3	0.5	0.6

Notes:
All concentrations are in milligrams per kilogam (mg/kg)
J - approximate value
< - compound was below the laboratory reporting limit
Ref[2]. DEP's "Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil" (May 2002)

Table 2A
Groundwater Analytical Results - VPH
88-90 South Maple Street
Westfield, MA

Method 1 Standards[1]	C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics	Benzene	Toluene	Ethyl benzene	Total Xylenes	Naph thalene	MtBE
GW-2	3,000	5,000	7,000	2,000	50,000	20,000	9,000	1,000	50,000
GW-3	50,000	50,000	50,000	10,000	40,000	5,000	5,000	20,000	50,000
MCP UCLs[1]	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

Well ID	Sample Date	C5-C8 Aliphatics (ug/L)	C9-C12 Aliphatics (ug/L)	C9-C10 Aromatics (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl benzene (ug/L)	Total Xylenes (ug/L)	Naph thalene (ug/L)	MTBE (ug/L)
MW-1	08/01/05	<75	<25	<25	<5	<5	<5	<15	5	<5
	02/07/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	08/22/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	05/08/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-3B	02/07/06	2,920	1,070	2,520	252	2,060	676	2,238	95.4	2,320
	03/06/06	2,100	478	4,880	77.2	536	585	1,166	103	637
	05/08/07	616	2,012	2,000	9.5	6.5	32.0	256	68	18
MW-4	08/01/05	<75	<25	<25	<5	<5	<5	<15	<5	1,690 *
MW-5	08/01/05	<75	<25	<25	<5	<5	<5	<15	<5	<5
	02/07/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	08/22/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	05/08/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-6	08/01/05	<150	<50	<50	<10	<5	<5	<15	<5	1,570
	02/07/06	<50	<50	<50	446	12.3	<2	9.5	6.7	22,900
	08/22/06	<250	<250	<250	41	<10	<10	<10	<15	7,890
	05/08/07	3,095	<100	<30	3.2	1.4	<1	<3	<10	2,700
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	1800
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8

Table 2A
Groundwater Analytical Results - VPH
88-90 South Maple Street
Westfield, MA

Method 1 Standards[1]	C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics	Benzene	Toluene	Ethyl benzene	Total Xylenes	Naph thalene	MtBE
GW-2	3,000	5,000	7,000	2,000	50,000	20,000	9,000	1,000	50,000
GW-3	50,000	50,000	50,000	10,000	40,000	5,000	5,000	20,000	50,000
MCP UCLs[1]	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

Well ID	Sample Date	C5-C8 Aliphatics (ug/L)	C9-C12 Aliphatics (ug/L)	C9-C10 Aromatics (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl benzene (ug/L)	Total Xylenes (ug/L)	Naph thalene (ug/L)	MTBE (ug/L)
MW-101	05/08/07	<200	<100	<30	<1	<1	1.2	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-102	05/08/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-201	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-202	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-204	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8

Notes

All concentrations are in micrograms per liter (ug/L)
< indicates compound was below the laboratory reporting limit
*MW-4 & MW-6 were analyzed for VOCs & EPH on 8/1/05. No EPH were detected.
*MTBE was the only VOC detected (1,690 ug/L). The VPH result for MTBE was <5.

Ref[1] 310 CMR 40 (Nov 2007)
VPH - Volatile Petroleum Hydrocarbons
MTBE - Methyl tert-butyl ether

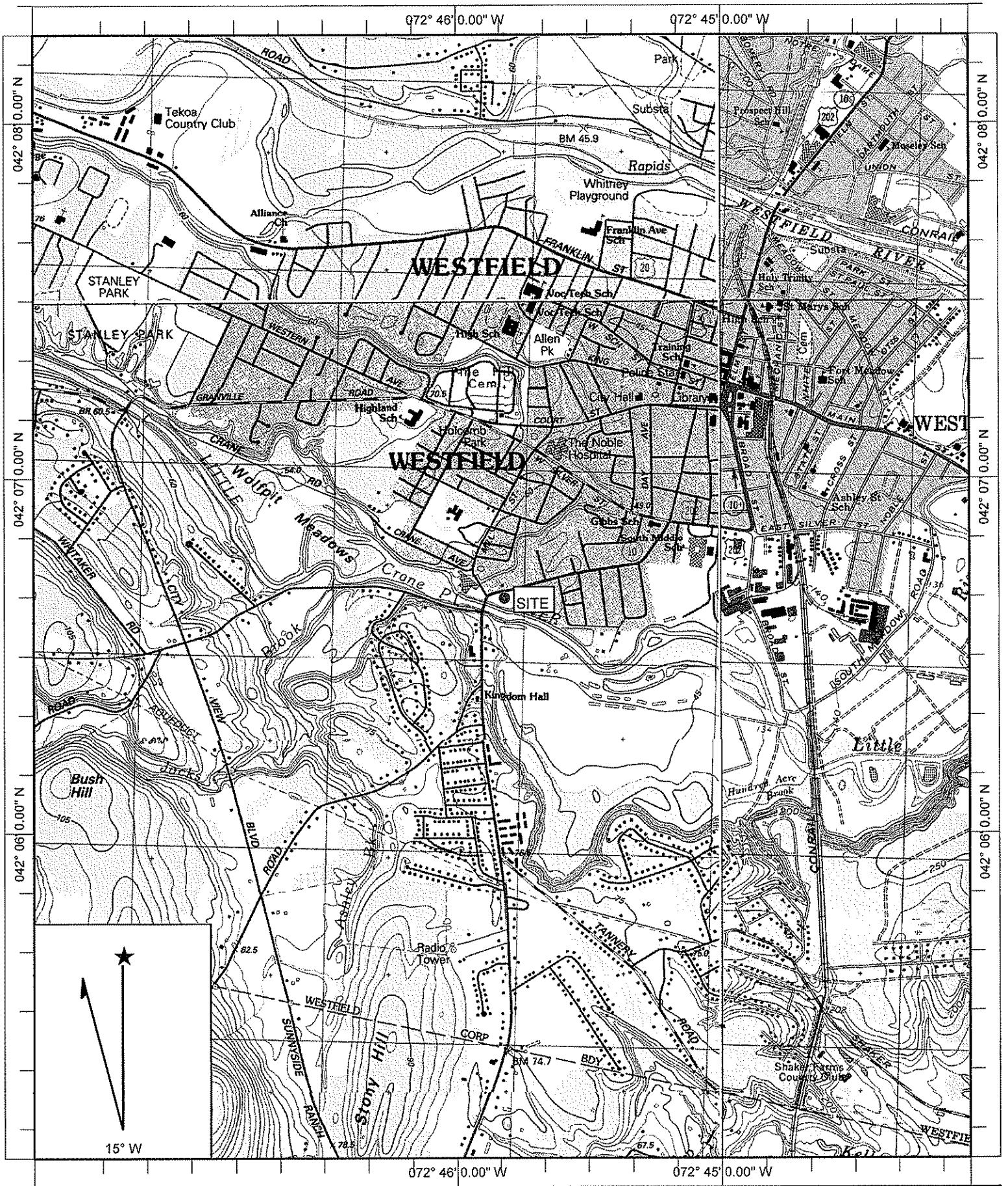
Table 2B
Groundwater Analytical Results - Metals
88-90 South Maple Street
Westfield, MA

Method 1 Standards	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
GW-2	NA	NA	NA	NA	NA	NA	NA	NA
GW-3	900	50,000	4	300	10	20	100	7
MCP UCLs	9,000	100,000	50	3,000	150	200	1,000	1,000

Sample ID	Sample Date	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
MW-4	8/1/2005	<4	134	<1.2	<2.5	<3.8	<0.2	<7.5	<5
MW-6	8/1/2005	<4	109	<1.2	<2.5	<3.8	<0.2	<7.5	<5

Notes
All concentrations are in micrograms per liter (ug/L)
< indicates compound was below the laboratory reporting limit
Ref[1] 310 CMR 40 (Nov 2007)

FIGURES



Name: SOUTHWICK
Date: 6/17/2005
Scale: 1 inch equals 2000 feet

Location: 042° 06' 40.0" N 072° 45' 49.7" W
Caption: Site Locus
Westfield Sunono
88-90 South Maple Street, Westfield, MA 01085

LITTLE RIVER

WOODED AREA

TREE LINE

APPROX. PROPERTY BOUNDARY

MW-203

MW-6

PAVED AREA

EDGE OF PAVEMENT

MW-204

GRASSY AREA

(3) EXISTING 10,000 GAL. USTs

(3) VENT PIPES

MW-4

SB-4

MW-2 (former)

GRASSY AREA

DISPOSAL SITE BOUNDARY

EXCAVATION AREA

SB-3

MW-3B

MW-1

SB-2

TRANSFORMER

EXCAVATION AREA

MW-101

EXISTING BUILDING

MW-5

CAR WASH BLDG.

PUMP PAD / CANOPY

SB-1

SEE EXCAVATION ENLARGEMENT NO. 2

UE

MW-102

MW-201

PUMP ISLAND (TYPICAL)

SB-103

SEE EXCAVATION ENLARGEMENT NO. 1

UNDERGROUND UTILITY CORRIDOR CONTAINING TELEPHONE, SEWER, WATER AND GAS LINES

PAVED AREA

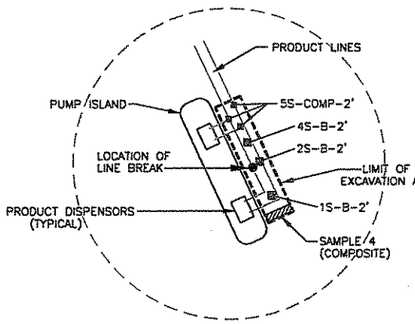
PRODUCT DISPENSOR (TYPICAL)

MW-202

STREET

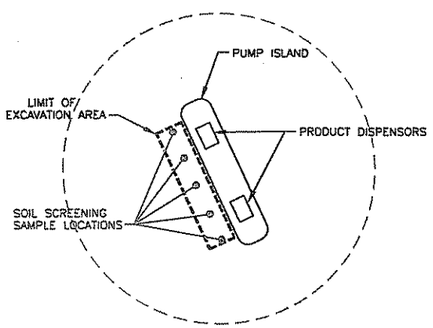
MAPLE

SOUTH



EXCAVATION AREA NO. 1

NOT TO SCALE



EXCAVATION AREA NO. 2

NOT TO SCALE

SCALE

0 20 40 60 80 FEET

(APPROX.)

LEGEND

- SOIL BORING
- EXISTING GROUNDWATER MONITORING WELL
- UE — UNDERGROUND ELECTRIC

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Assessments – Remediation – Emergency Response

127 HARTWELL ST. W.BOYLSTON, MA.

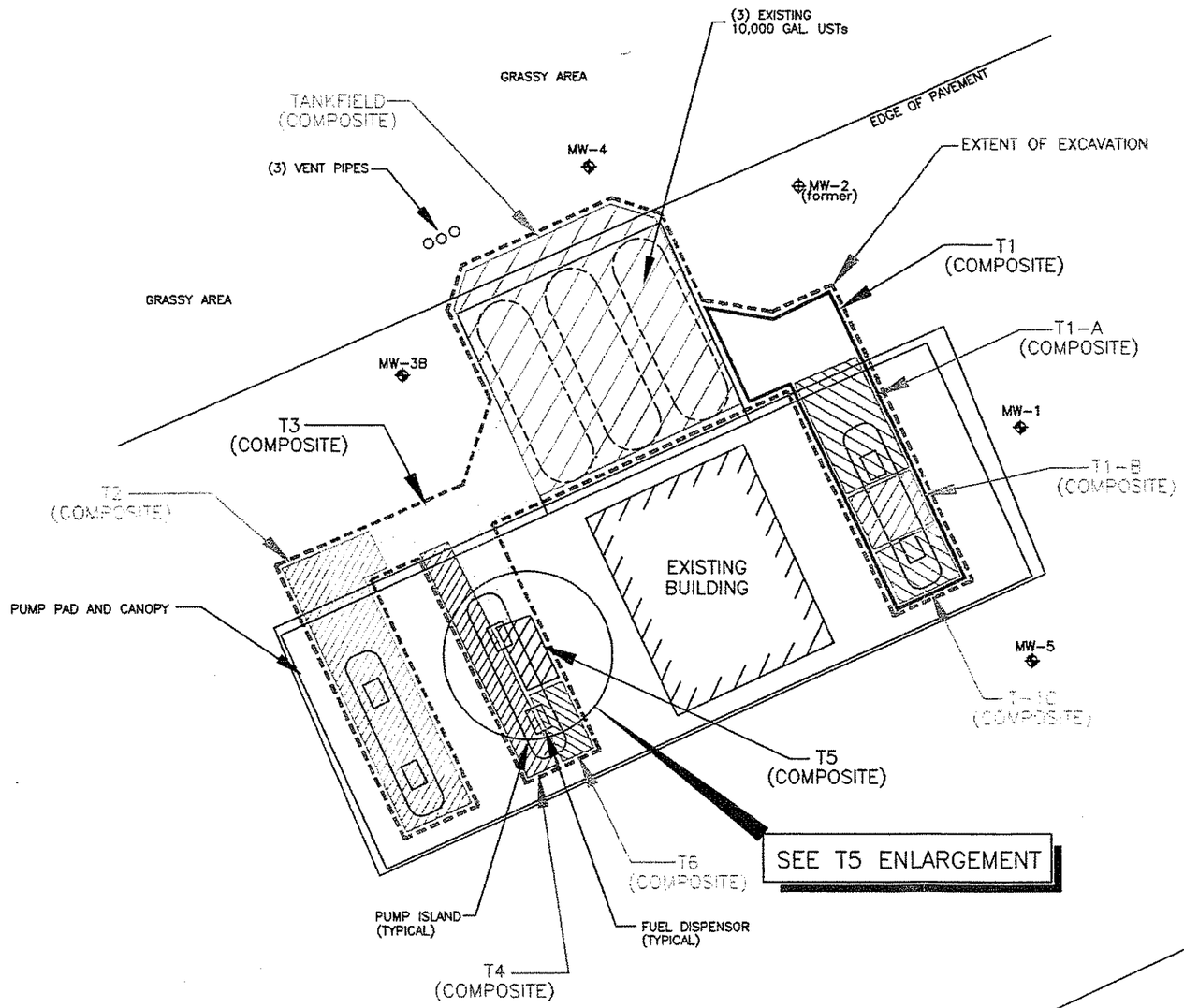
SCALE: AS SHOWN		DR. BY: K. HAZEL
DATE: 12/19/07	APP. BY: SEV	JOB NO.: 5795-05

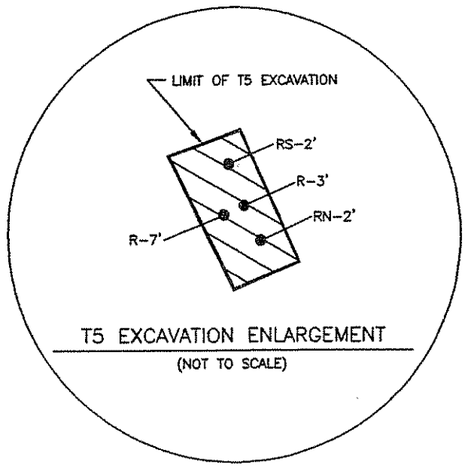
SITE LAYOUT
(APRIL 2005 EXCAVATION)

SUNOCO, INC.

88 SOUTH MAPLE ST. WESTFIELD, MA.

FIGURE-2A





T5 EXCAVATION ENLARGEMENT

(NOT TO SCALE)

SCALE

0 5 10 20 40 FT.

(APPROX.)

SOUTH MAPLE STREET

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Assessments – Remediation – Emergency Response

127 HARTWELL ST W.BOYLSTON, MA

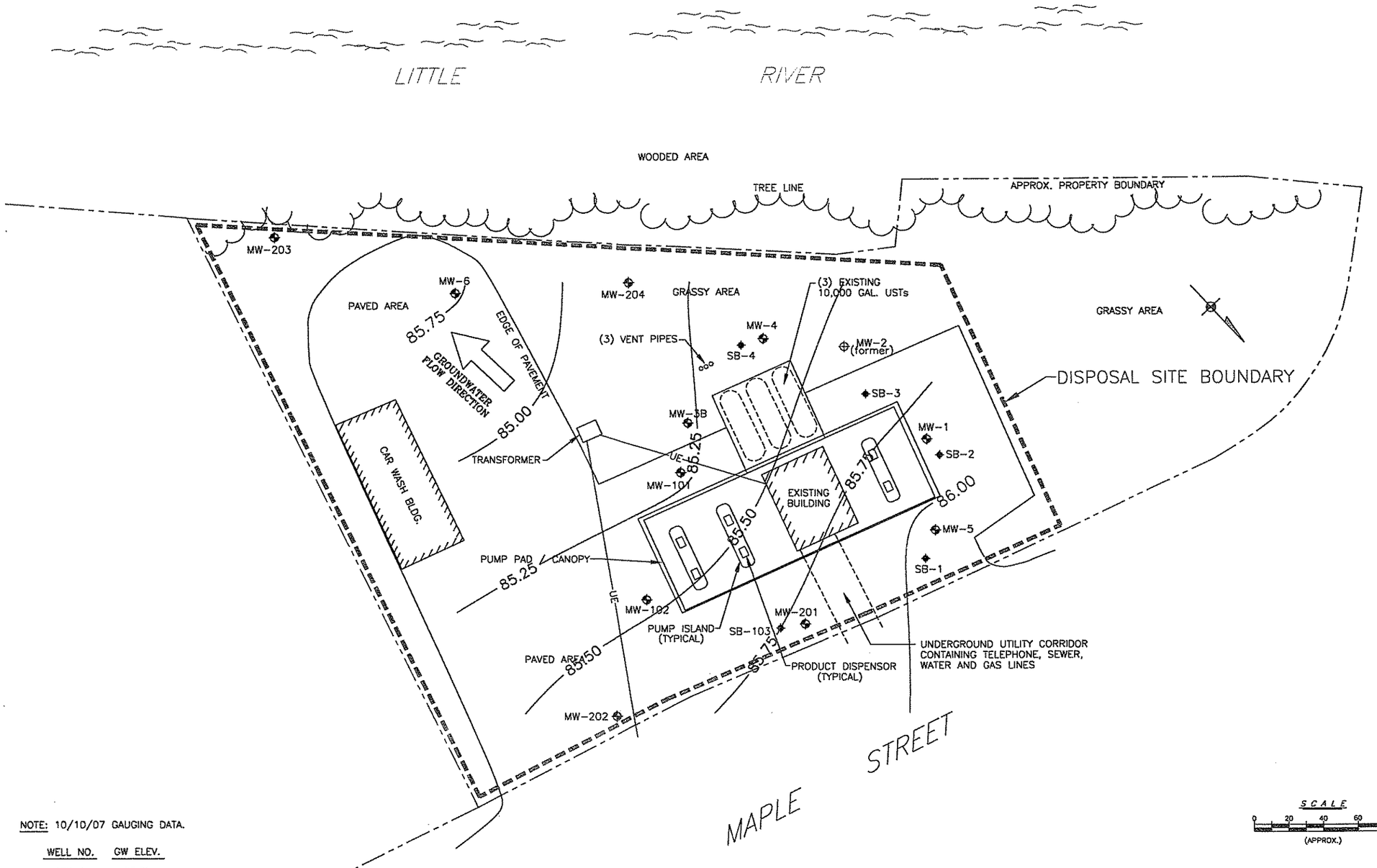
SCALE: AS SHOWN		DR. BY: K. HAZEL
DATE: 1/10/06	APP. BY: SEV	JOB NO.: 5795-05

EXCAVATION ENLARGEMENT
(11-12/2005 EXCAVATION)

SUNOCO, INC.

88 SOUTH MAPLE ST. WESTFIELD, MA.

FIGURE-2B



NOTE: 10/10/07 GAUGING DATA.

WELL NO.	GW ELEV.
MW-1	85.82
MW-3B	DRY
MW-5	86.07
MW-6	84.74
MW-101	85.20
MW-102	85.45
MW-201	85.79
MW-202	85.67
MW-203	DRY
MW-204	85.17

LEGEND

- ◆ – SOIL BORING
- ◆ – EXISTING GROUNDWATER MONITORING WELL
- ----UE---- – UNDERGROUND ELECTRIC

SCALE

0 20 40 60 80 FEET

(APPROX.)

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Assessments – Remediation – Emergency Response

127 HARTWELL ST. W.BOYLSTON, MA.

SCALE: AS SHOWN		DR. BY: K. HAZEL
DATE: 12/18/07	APP. BY: SEV	JOB NO.: 5795-05

SITE LAYOUT W/GROUNDWATER CONTOURS

SUNOCO, INC.

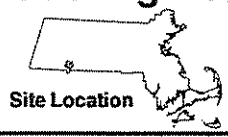
88 SOUTH MAPLE ST. WESTFIELD, MA.

FIGURE-2C

MA DEP - Bureau of Waste Site Cleanup

Site Scoring Map: 500 feet & 0.5 Mile Radii

SITE NAME:
Westfield Sunoco
88 South Maple Street
WESTFIELD, MA 01085
420640n 724548ew



The information shown on this map is the best available at the date of printing. Please refer to the data source descriptions document.

MASSGIS — Massachusetts Geographic Information System
Massachusetts Executive Office of Environmental Affairs - 2005

Roads: Limited Access, Divided, Major Road, Connector, Street, Track, Trail
Boundaries: Town, County, DEP Region; Train; Powerline; Pipeline; Aqueduct
Basins: Major, Sub; Streams: Perennial, Intermittent, Man Made Shore, Dams
Potentially Productive Aquifers: Medium,High Yield
Non-Potential Drinking Water Source Area: Medium,High Yield

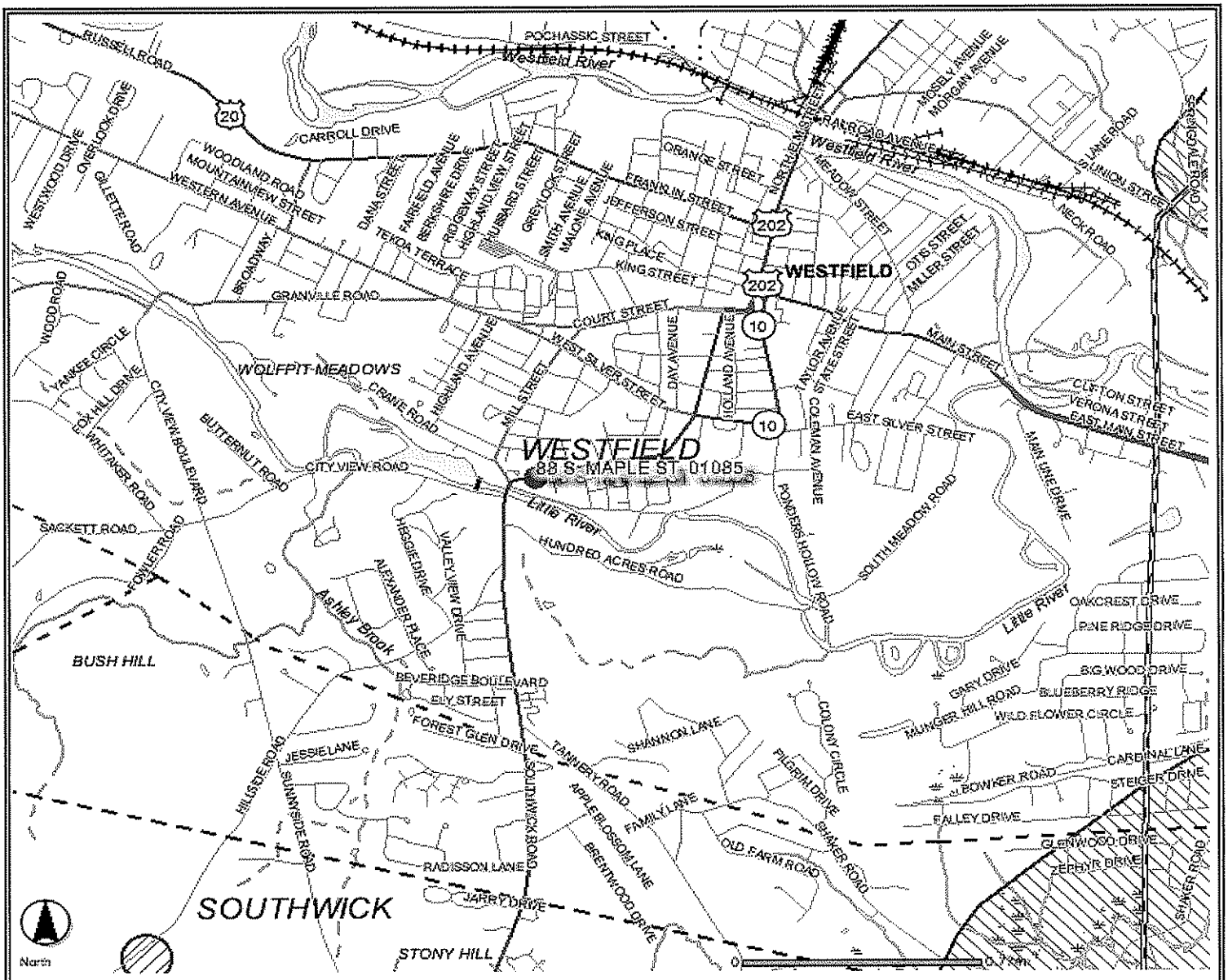
EPA Sole Source Aquifer; FEMA 100-year floodplain
Public Water Supplies: Ground,Surface,Non Community
Approved Zone2; IWPA; Surface Water Supply Zone A
Hydrography: Water Features,Public Surface Water Supply
Wetlands: Fresh,Salt,NHESP Wetlands Habitat
Protected Open Space; ACEC
DEP Permitted Solid Waste Facilities; Certified Vernal Pools

N W E S

SCALE 1:15000

0 1/2 MILES
0 1/2 KILOMETERS

August 01, 2005



- Zone IIs
- IWPAs
- Zone A
- Sole Source Aquifers
- Solid Waste Sites
- Protected Openspace
- ACECs
- NHESP Estimated Habitat of Rare Wildlife in Wetland Areas
- Certified Vernal Pools 2003 NHESP
- Subbasins
- Mass Major Basins
- DEP Region

Aquifers, By Yield
- HIGH YIELD
- MEDIUM YIELD

Non Potential Drinking Water Source Area
- HIGH YIELD
- MEDIUM YIELD

FEMA Floodplains
- 100 YEAR FLOODPLAIN

Hydrography
- WATER
- RESERVOIR
- WETLANDS
- SALTWATER WETLANDS
- FLATS,SHOALS

Rivers and Streams
- PERENNIAL
- INTERMITTENT
- SHORELINE
- MAN MADE SHORE
- DAM
- AQUEDUCT

EOT-OTP Roads
- LIMITED ACCESS HIGHWAY
- MULTILANE HWY, NOT LIMITED ACCESS
- OTHER NUMBERED HWY
- MAJOR ROAD / COLLECTOR
- MINOR STREET OR ROAD, RAMP

Tracks and Trails MHD
- TRACK
- TRAIL

Transmission Lines
- PIPELINE
- POWERLINE
- TRAIN

21E Resource Priority Map Sunoco Station 88-90 South Maple Street Westfield, MA	**Date:** March 12, 2007 **CEA Project No.: 5795-05**	CORPORATE ENVIRONMENTAL ADVISORS, INC. **Figure 4**

APPENDIX A

COLD SPRING ENVIRONMENTAL CONSULTANTS

CLIENT F. L. Roberts & Co, Inc.
PROJECT NAME Phase I
LOCATION 38 Maple St., Westfield

BORING NUMBER MW-1
SHEET No. 1 of 1

BORING/WELL LOG

DRILLER Seaboard Env.
INSPECTOR A. Weiss
DATE START 3-30-90
DATE FINISH 3-30-90

	Casing	Sampler	Core Barrel
TYPE	HSA	SS	
SIZE I D	3 1/4	1 3/8	
HAMMER WT		140 lb	
HAMMER FALL		30 in.	

FILE NO
SITE LOCUS
25' E of canopy

FEET	SAMPLE NO	DEPTH RANGE	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	REC	COL A	STRATA CHANGE	FIELD CLASSIFICATION AND REMARKS
	S-1	0" - 12"					1	Fill	Dark brown, coarse sand and gravel fill.
5	S-2	5'-6.5'	1	4	3	12"	1	Med. Sand	Light Brown, well-graded medium sand. Some fine sand. No odor. Dry and loose.
10	S-3	10'-11.5'	16	26	19	11"	1		Nested cobbles with coarse sand and gravel. Dry, no odor.
								▼	
15	S-4	15'-16.5'	1	5	8	13"	1	Med Sand	Light brown, fine to medium sand. Wet, loose. No odor. Water at 13'.
								19' EOB	
19							1		Red, clayey till with some coarse sand.

19' EOB
Well Point at 19'
10' of 2" I.D. Screen to 9'.
#2 Jersey Gravel to 7'
Bentonite Pellets to 6'
Native fill to roadbox at surface.
Concrete apron from 1.5' to surface.

MW

SAMPLE IDENTIFICATION
S — SPLIT SPOON
T — THIN WALL TUBE
U — UNDISTURBED PISTON
O — OPEN END ROD
W — WASH SAMPLE
A — AUGER SAMPLE

PENETRATION RESISTANCE
140 lb. Wt. falling 30" on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency	
0-4	Very Loose	0-2	Very Soft
5-9	Loose	3-4	Soft
10-29	Med Dense	5-8	Med. Stiff
30-49	Dense	9-15	Stiff
50 +	Very Dense	16-30	Very Stiff
		31 +	Hard

PROPORTIONS USED

trace	0-10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

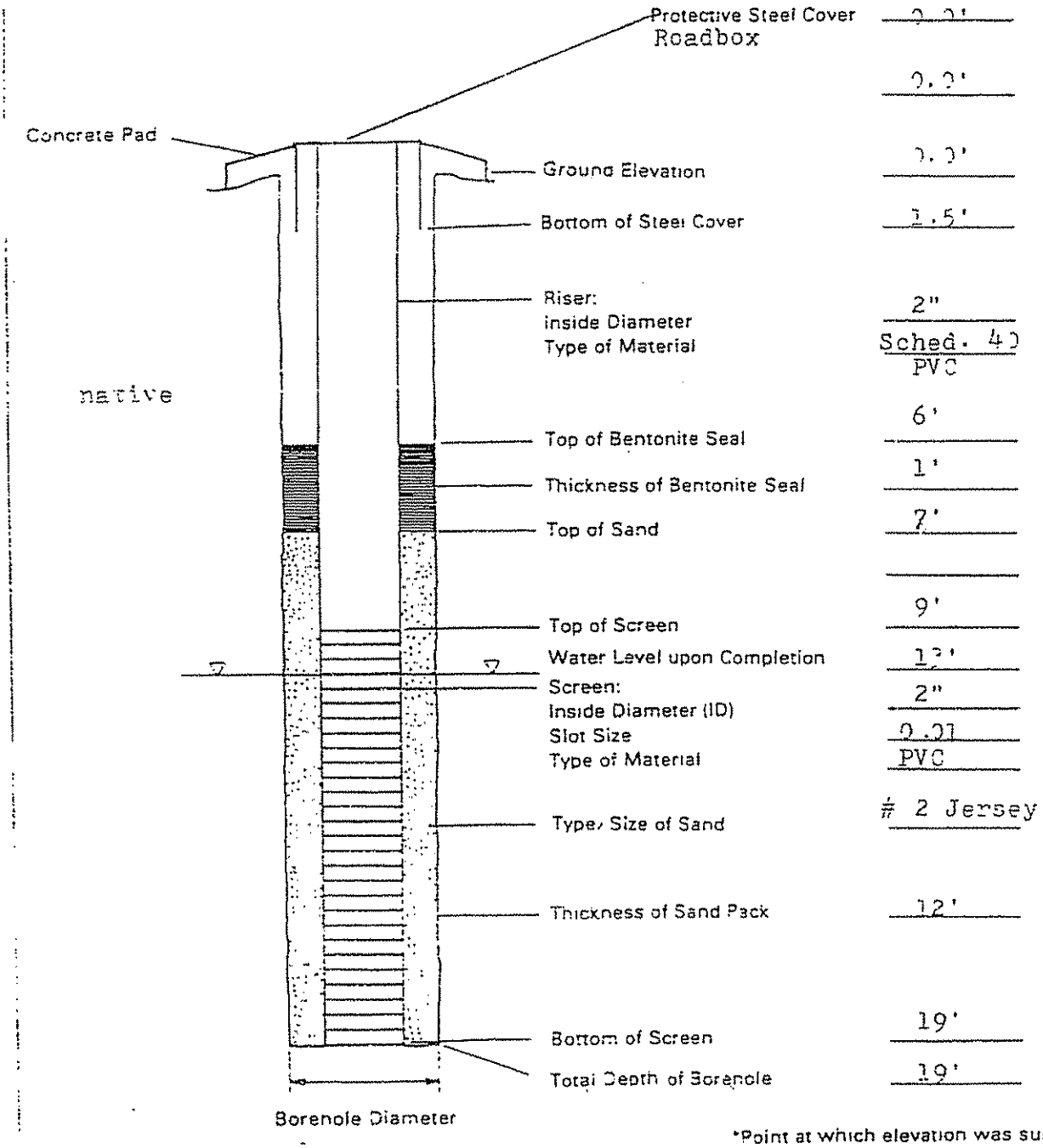
REMARKS:
Col. A HNU-ppm

Project No 93-12 Project Name F.J. Roberts, Westfield BORING MONITOR WELL NO MW-1

Installed by Seaboard Date Started/Completed 3-31-93 Project Location 88 S. Maple

Method Hallow stem Total Depth 19' Inspected by A. Weiss Logged By A Weiss

GROUND WATER MONITOR WELL DETAIL



Protective Steel Cover Roadbox	0.0'
	0.0'
Ground Elevation	0.0'
Bottom of Steel Cover	2.5'
Riser: inside Diameter	2"
Type of Material	Sched. 40 PVC
Top of Bentonite Seal	6'
Thickness of Bentonite Seal	1'
Top of Sand	7'
Top of Screen	9'
Water Level upon Completion	12'
Screen: Inside Diameter (ID)	2"
Slot Size	0.01
Type of Material	PVC
Type/ Size of Sand	# 2 Jersey
Thickness of Sand Pack	12'
Bottom of Screen	19'
Total Depth of Borehole	19'

*Point at which elevation was surveyed

▽ Point from which water level was measured

COLD SPRING ENVIRONMENTAL CONSULTANTS

CLIENT F.L. Roberts & Co., Inc.
PROJECT NAME Phase I
LOCATION 88 Maple St., Westfield

BORING NUMBER MW-2
SHEET No 1 of 1

BORING/WELL LOG

DRILLER Seaboard Env.
INSPECTOR A. Weiss
DATE START 3/30/90
DATE FINISH 3/30/90

	Casing	Sampler	Core Barrel
TYPE	HSA	SS	
SIZE I.D	3 1/4	1 3/8	
HAMMER WT		140 lb.	
HAMMER FALL		30 in	

FILE NO
SITE LOCUS

DEPTH	SAMPLE NO	SAMPLE DEPTH RANGE	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	REC.	COL. A	STRATA CHANGE	FIELD CLASSIFICATION AND REMARKS
	S-1	1'-1.5'					2?	Fill	Dark brown, coarse sand and gravel fill. Dry, No odor.
5	S-2	5'-6.5'	6	6	6	12"	<1	Fine to Med sand	Light brown, well sorted fine to medium sand. Loose, dry, no odor.
10	S-3	10'-11.5'	5	6	6	11"	<1	Coarse Sand ▽	Dark brown to rust brown coarse sand and gravel, some cobbles. Slightly moist, no odor.
15	S-4	15'-16 5'	3	5	5	14"	<1	Fine Sand	Grey to brown fine sand mixed with some silt and gravel. Wet, no odor.
20								EOB 20'	Red clayey till with coarse sand and gravel.

Water table at 13.5'
Well point at 19 5'
10' Well Screen to 9.5'
#2 Jersey sand to 7'
Bentonite seal to 6'
Native sand pack to 1.5'
Cement collar and road box at surface.

MW

SAMPLE IDENTIFICATION
S — SPLIT SPOON
T — THIN WALL TUBE
U — UNDISTURBED PISTON
O — OPEN END ROD
W — WASH SAMPLE
A — AUGER SAMPLE

PENETRATION RESISTANCE
140 lb Wt. falling 30" on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency	
0-4	Very Loose	0-2	Very Soft
5-9	Loose	3-4	Soft
10-29	Med Dense	5-8	Med Stiff
30-49	Dense	9-15	Stiff
50 –	Very Dense	16-30	Very Stiff
		31 –	Hard

PROPORTIONS USED

trace	0-10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

REMARKS:

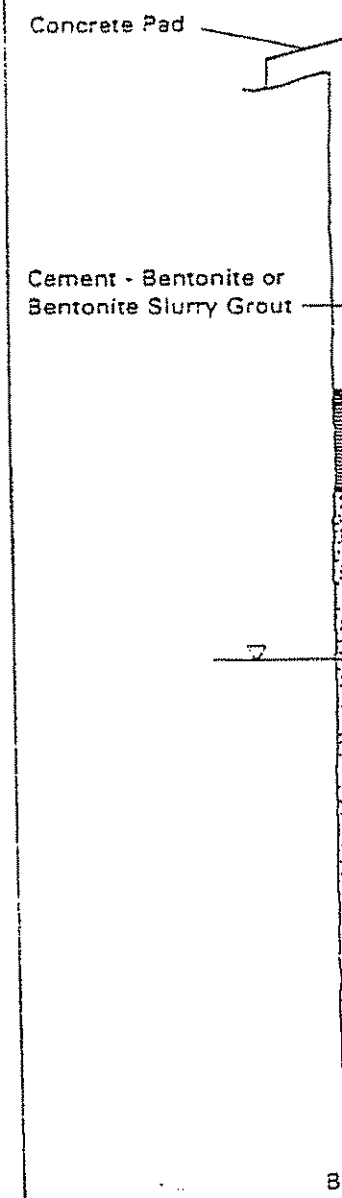
Col. A HNU-ppm

Project No 90-12 Project Name F L Roberts, Westfield BORING MONITOR WELL NO MW-2

Installed by Seaboard Date Started, Completed 3-30-90 Project Location 88 Maple St.

Method Hallow Stem Total Depth 19 5 Inspected by A. Weiss Logged By A. Weiss

GROUND WATER MONITOR WELL DETAIL



Protective Steel Cover roadbox	2.2
Ground Elevation	2.0
Bottom of Steel Cover	1.5
Riser:	2"
Inside Diameter	
Type of Material	Sced.40 PVC
Top of Bentonite Seal	6'
Thickness of Bentonite Seal	1'
Top of Sand	7'
Top of Screen	9.5'
Water Level upon Completion	14'
Screen:	2"
Inside Diameter (ID)	
Slot Size	0.01
Type of Material	PVC
Type/Size of Sand	# 2 Jersey
Thickness of Sand Pack	12.5'
Bottom of Screen	19.5'
Total Depth of Borehole	20.0'

*Point at which elevation was surveyed

▽ Point from which water level was measured

COLD SPRING ENVIRONMENTAL CONSULTANTS

CLIENT F.L. Roberts & Co., Inc
PROJECT NAME Phase I
LOCATION 88 Maple St., Westfield

BORING NUMBER B-3A
SHEET No 1 of 1

BORING/WELL LOG

FILE NO
SITE LOCUS

DRILLER Seaboard Env.
INSPECTOR A. Weiss
DATE START 3-30-90
DATE FINISH 3-30-90

	Casing	Sampler	Core Barrel
TYPE	HSA	SS	
SIZE I.D	3 1/4	1 3/8	
HAMMER WT		140 lb.	
HAMMER FALL		30 in.	

DEPTH	SAMPLE NO.	SAMPLE DEPTH RANGE	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	REC.	COL. A	STRATA CHANGE	FIELD CLASSIFICATION AND REMARKS
	S-1	1'-1.5'					<1	Fill	Brown, coarse sand and gravel fill. No odor.
5	S-2	5'-6.5'	2	2	5	12"	<1	Fine to Med Sand	Light brown, fine to medium sand, well graded. Loose, dry, no odor.
10	S-3	10'-11.5'	4	5	7	14"	<1		Grey to brown fine to medium well-sorted sand. Loose, dry, no odor.
								EOB 13'	Refusal at 13' in B-3A Moved hole 12' south to other side of fence.

MW

SAMPLE IDENTIFICATION
S — SPLIT SPOON
T — THIN WALL TUBE
U — UNDISTURBED PISTON
O — OPEN END ROD
W — WASH SAMPLE
A — AUGER SAMPLE

PENETRATION RESISTANCE
140 lb. Wt. falling 30" on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency	
0-4	Very Loose	0-2	Very Soft
5-9	Loose	3-4	Soft
10-29	Med. Dense	5-8	Med. Stiff
30-49	Dense	9-15	Stiff
50 +	Very Dense	16-30	Very Stiff
		31 +	Hard

PROPORTIONS USED

trace	0-10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

REMARKS:

Col. A HNU-ppm

COLD SPRING ENVIRONMENTAL CONSULTANTS

CLIENT F.L. Roberts & Co., Inc.
PROJECT NAME Phase I
LOCATION 88 Maple St., Westfield

BORING NUMBER MW-3B
SHEET No 1 of 1

BORING/WELL LOG

FILE NO SITE LOCUS

DRILLER Seaboard Env.
INSPECTOR A. Weiss
DATE START 3/30/90
DATE FINISH 3/30/90

	Casing	Sampler	Core Barrel
TYPE	HSA	SS	
SIZE I.D	3 1/4	1 3/8	
HAMMER WT		140 lb	
HAMMER FALL		30 in.	

DEPTH	SAMPLE NO	DEPTH RANGE	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	REC	COL. A	STRATA CHANGE	FIELD CLASSIFICATION AND REMARKS
	S-1	1'-1.5'					1	Fill	Brown, coarse sand and gravel fill.
5	S-2	5'-6.5'	3	3	5	12"	1	Fine to Med Sand ▽	Light brown, fine to medium sand, well graded Loose, dry, no odor
10	S-3	10'-11.5'	23	20	33	12"	1	11' EOB	Red to grey coarse sand and gravel, some silt, trace clay. Wet, no odor.
15									

Water at 8.5'
EOB/Refusal at 11.0'
8' of 2" Well Screen to 3'.
#2 Jersey sand pack to 2'.
Bentonite pellets to 1'
2' Standpipe cemented at surface.

SAMPLE IDENTIFICATION
S — SPLIT SPOON
T — THIN WALL TUBE
U — UNDISTURBED PISTON
O — OPEN END ROD
W — WASH SAMPLE
A — AUGER SAMPLE

PENETRATION RESISTANCE
140 lb. Wt. falling 30" on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency	
0-4	Very Loose	0-2	Very Soft
5-9	Loose	3-4	Soft
10-29	Med. Dense	5-8	Med Stiff
30-49	Dense	9-15	Stiff
50+	Very Dense	16-30	Very Stiff
		31+	Hard

PROPORTIONS USED

trace	0-10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

REMARKS:

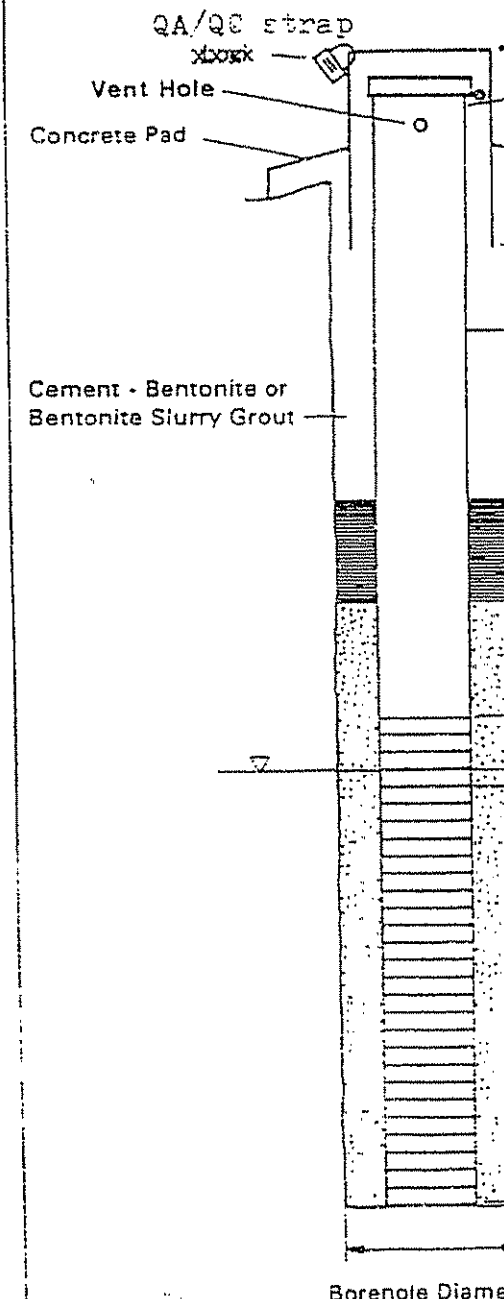
Col. A HNU-ppm

Project No. 90-12 Project Name E.L. Roberts, Westfield BORING/MONITOR WELL NO MW-3b

Installed by Seaboard Date Started/Completed 3-30-90 Project Location 88 S. Maple St

Method Hallow Stem Total Depth 11' Inspected by A Weiss Logged By A Weiss

GROUND WATER MONITOR WELL DETAIL



Stick-up of Protective Steel Cover	2.0
Stick-up of Riser	2.0
Ground Elevation	0.0
Bottom of Steel Cover	2.0
Riser: Inside Diameter	2"
Type of Material	Sched 40, PVC
Top of Bentonite Seal	1'
Thickness of Bentonite Seal	1'
Top of Sand	2'
Top of Screen	3'
Water Level upon Completion	7.5'
Screen: Inside Diameter (ID)	2"
Slot Size	0.01
Type of Material	PVC
Type/Size of Sand	#2 Jersey
Thickness of Sand Pack	
Bottom of Screen	11'
Total Depth of Borenole	11'

*Point at which elevation was surveyed

▽ Point from which water level was measured

COLD SPRING ENVIRONMENTAL CONSULTANTS

CLIENT F.L. Roberts & Co., Inc.
PROJECT NAME Phase I
LOCATION 88 Maple St., Westfield

BORING NUMBER MW-4
SHEET No 1 of 1

BORING/WELL LOG

DRILLER Seaboard Env.
INSPECTOR A. Weiss
DATE START 3/30/90
DATE FINISH 3/30/90

	Casing	Sampler	Core Barrel
TYPE	HSA	SS	
SIZE I.D	3 1/4	1 3/8	
HAMMER WT		140 lb	
HAMMER FALL		30 in	

FILE NO.
SITE LOCUS

DEPTH	SAMPLE NO	DEPTH RANGE	BLOWS PER 6" ON SAMPLER 0-6	6-12	12-18	REC.	COL. A	STRATA CHANGE	FIELD CLASSIFICATION AND REMARKS
	S-1	1'-1.5'					<1	Sand	Brown Loamy sand, loose, moist.
5	S-2	5'-6.5'	5	3	3	14"	<1	Sand	Grey-brown fine to medium sand, well sorted, moist, no odor
10	S-3	10'-11.5'	26	20	20	16"	<1		Same as S-2, wet.
15								EOB 15'	EOB at 15' 10' of well screen to 5'. #2 Jersey sand pack to 3'. Bentonite pellets to 2' Cemented standpipe to surface, 2' stick-up Water table at 7.5'

MW

SAMPLE IDENTIFICATION
S — SPLIT SPOON
T — THIN WALL TUBE
U — UNDISTURBED PISTON
O — OPEN END ROD
W — WASH SAMPLE
A — AUGER SAMPLE

PENETRATION RESISTANCE
140 lb. Wt. falling 30" on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency	
3-4	Very Loose	0-2	Very Soft
5-9	Loose	3-4	Soft
10-29	Med Dense	5-8	Med Stiff
30-49	Dense	9-15	Stiff
50+	Very Dense	16-30	Very Stiff
		31+	Hard

PROPORTIONS USED

trace	0-10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

REMARKS:

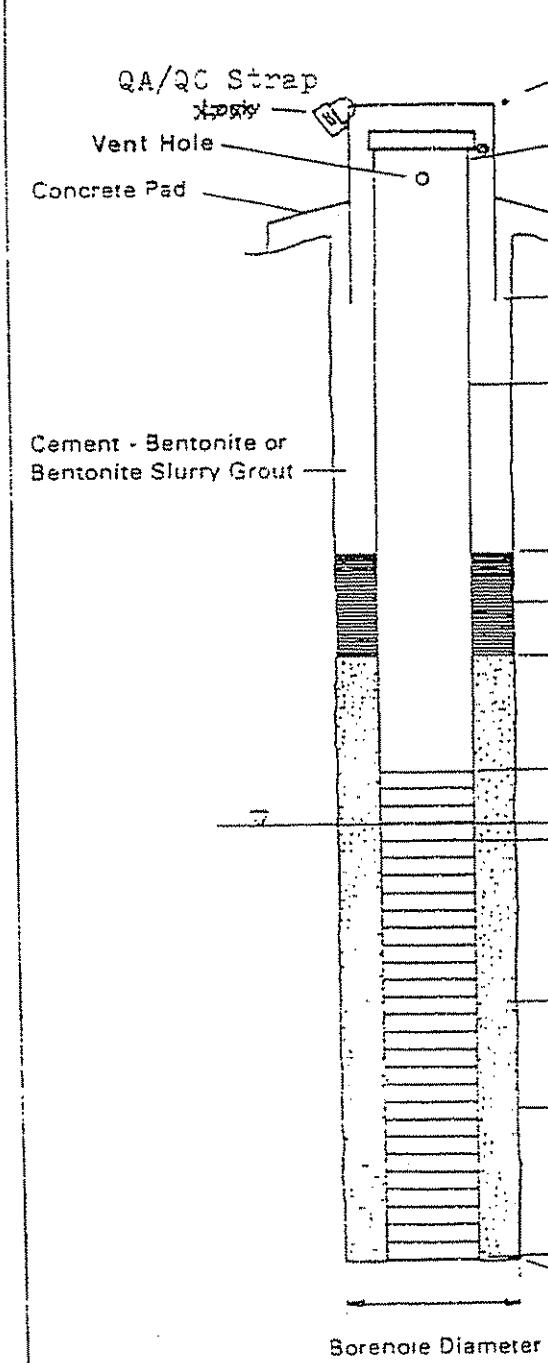
Col. A HNU-ppm

Project No 93-12 Project Name E. L. Roberts, Westfield BORING, MONITOR WELL NO MW-4

Installed by Seaboard Date Started/Completed 3-30-93 Project Location 88 S. Maple St

Method Hallow Stem Total Depth 15' Inspected by A. Weiss Logged By A. Weiss

GROUND WATER MONITOR WELL DETAIL



Stick-up of Protective Steel Cover	2.0
Stick-up of Riser	2.0
Ground Elevation	0.0
Bottom of Steel Cover	2.0
Riser: Inside Diameter	2"
Type of Material	Sched. 40 PVC
Top of Bentonite Seal	2'
Thickness of Bentonite Seal	1'
Top of Sand	3'
Top of Screen	5'
Water Level upon Completion	7.5'
Screen: Inside Diameter (ID)	2"
Slot Size	0.01
Type of Material	PVC
Type/Size of Sand	#2 Jersey
Thickness of Sand Pack	12'
Bottom of Screen	15'
Total Depth of Borehole	15'

*Point at which elevation was surveyed

▽ Point from which water level was measured

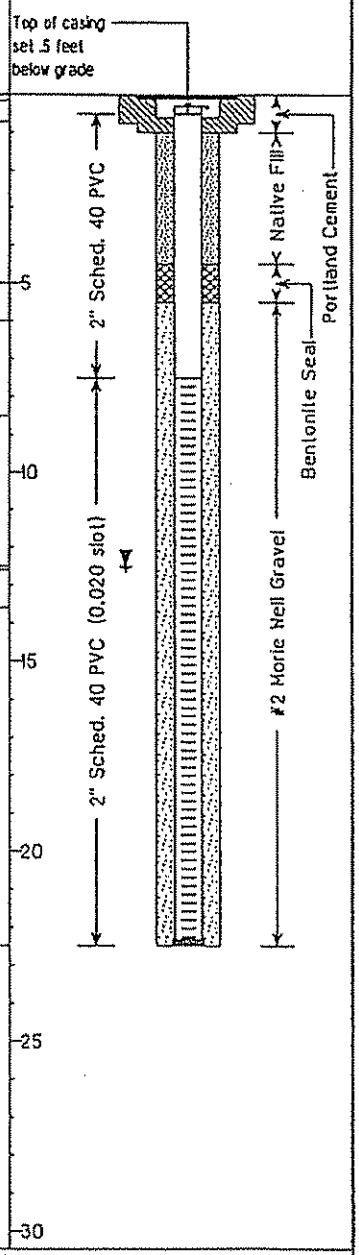
Handex of New England

WELL LOG: MW-5

Permit #: *N/A*	Drill Date: *3/17/93*	Use: *Monitoring*
Location: *88-90 S. Maple St., Westfield, MA*		Owner Loc #: *N/A*
Owner: *Sun Company, Inc.*		Handex Loc #: *105041*
Owner Address: *Philadelphia, PA*	BORING - Depth: *22.5 ft.*	Diameter: *8 in.*
Drilling Method: *Hollow Stem Auger*	CASING - Length: *7 ft.*	Diameter: *2 in.*
Sampling Method: *Split Spoon*	SCREEN - Length: *15 ft.*	Diameter: *2 in.*
Static Water Level: *12 ft. (3/17/93)*	WELL - Depth: *22.5 ft.*	

Depth (ft.)	Sample ID	Sample Depth	Blows/6 in.	HNu	Graphic Log	Geologic Description
0						ASPHALT
						Tan fine to coarse SAND, little fine to coarse Gravel.
						Brown very fine to fine SAND, trace Silt.
5	SS-1		2,1,2,2	ND		Light Brown fine to medium SAND.
						Light Brown very fine to fine SAND, trace Silt.
10	SS-2		15,11,9,9	.2		Tan medium to coarse SAND, some fine to coarse Gravel.
						Red Brown Silty CLAY.
15	SS-3		4,7,5,5			BOULDER
						Red Brown very fine to coarse SAND, little (+) fine to medium Gravel, trace (+) Silty Clay.
20						
25						
30						

Well Diagram



Geologist: Jeff Lantiegne

Driller: Paul Schimke

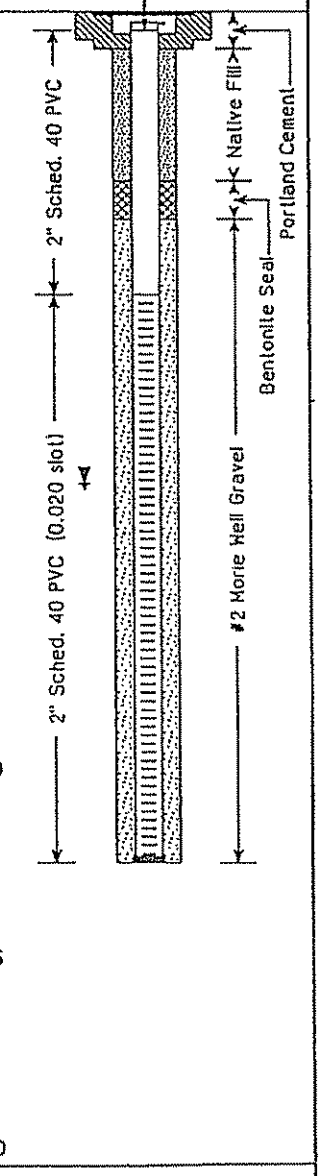
Handex of New England

WELL LOG: MW-6

Permit #: *N/A*	Drill Date: *3/17/93*	Use: *Monitoring*
Location: *88-90 S. Maple St., Westfield, MA*		Owner Loc #: *N/A*
Owner: *Sun Company, Inc.*		Handex Loc #: *105041*
Owner Address: *Philadelphia, PA*	BORING - Depth: *22.5 ft.*	Diameter: *8 in.*
Drilling Method: *Hollow Stem Auger*	CASING - Length: *7 ft.*	Diameter: *2 in.*
Sampling Method: *Split Spoon*	SCREEN - Length: *15 ft.*	Diameter: *2 in.*
Static Water Level: *12 ft. (3/17/93)*	WELL - Depth: *22.5 ft.*	

Depth (ft.)	Sample ID	Sample Depth	Blows/6 in.	HNu	Graphic Log	Geologic Description
0						ASPHALT
5	SS-1		2,2,2,3	ND		Brown very fine to fine SAND, trace (-) medium to coarse Sand.
						Brown fine SAND, Cobbles present.
10	SS-2		2,8,16,20	ND		Brown fine to coarse SAND, little (-) fine Gravel.
15	SS-3		5,4,5,8			Brown very fine to fine SAND.
20						
25						
30						

Well Diagram



Geologist: Jeff Lantinaga

Driller: Paul Schimko

Site:	Sunoco							**Boring/Well# MW-101**		Page 1 of 1
	88 South Maple Street		Construction	Feet BSG				**Construction Material**		**Symbol**
	Westfield, Ma		Riser	6	to	Gr		2" diameter schedule 40 PVC		
Date:	3/28/2007		Screen	16	to	6		2" diameter schedule 40 PVC, 10-slot		
Client:	Sunoco		Sandpack	16	to	5		No. 2 Silica Sand		
Driller:	CEA		Seal	5	to	4		Bentonite		
Inspector:	Matt Dowling		Backfill	4	to	Gr		Native		
Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**				**Soil Description** (color, consistency, moisture, structure)		**PID (ppm)**
ground level										
								Precleared 0-5'		
5'										0.0
										0.0
								Very Well Sorted Dry to Moist		
10'			5					Fine Sand, Light Brown		0.1
								1' Very Well Sorted Dry to Moist		
								Fine Sand, Light Brown		0.0
								1' Grey to Brown Coarse Sand		
								3' Orange to Brown Poorly Sorted Coarse		
15'	MW-101		5					Sand and Gravel. Bottom 2" are Grey		6.0
								Refusal 16'		

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 14.0'		And	35	to	50	Sampler Size: 5'
Drilling Method:	Direct Push	Some	20	to	35	
Drill Rig Model	GeoProbe	Little	10	to	20	

TOTAL DEPTH OF WELL: 16 Feet

Site:	Sunoco 88 South Maple Street Westfield, Ma	Construction	Feet BSG			Boring/Well# MW-102	Page 1 of 1
						Construction Material	**Symbol**
		Riser	9	to	Gr	2" diameter schedule 40 PVC	
Date:	3/28/2007	Screen	19	to	9	2" diameter schedule 40 PVC, 10-slot	
Client:	Sunoco	Sandpack	19	to	8	No. 2 Silica Sand	
Driller:	CEA	Seal	8	to	7	Bentonite	
Inspector:	Matt Dowling	Backfill	7	to	Gr	Native	

Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**	**Soil Description (color, consistency, moisture, structure)**	**PID (ppm)**
ground level						
					Precleared 0-5'	
5'						
					5'-10' Well Sorted Dry to Moist	
10'			4		Fine Sand, Light Brown	0.6
					10'-12' Well Sorted Moist	
					Fine Sand some Gravel, Light Brown	0.1
					12'-14' Medium to Poorly Sorted Coarse Sand	
					to Gravel, Light Brown to Orange and Grey	35.7
15'	MW-102		4			
					Saturated, Poorly Sorted, Brown	
20'			4		Medium to Coarse Sand and Gravel	31.4

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 14.0'		And	35	to	50	Sampler Size: 5'
Drilling Method:	Direct Push	Some	20	to	35	
Drill Rig Model	GeoProbe	Little	10	to	20	

TOTAL DEPTH OF WELL: 19 Feet

Site:	I Sunoco 88 South Maple Street Westfield, Ma
Date:	3/28/2007
Client:	Sunoco
Driller:	CEA
Inspector:	Matt Dowling

Construction	Feet BSG		
Riser	6	to	Gr
Screen	16	to	6
Sandpack	16	to	5
Seal	5	to	4
Backfill	4	to	Gr

Boring/Well# MW-103 Page 1 of 1

Construction Material	Symbol
2" diameter schedule 40 PVC	
2" diameter schedule 40 PVC, 10-slot	
No. 2 Silica Sand	
Bentonite	
Native	

Depth (feet)	Sample	Blow Counts per 6"	Recovery (feet)	Detail	Soil Description (color, consistency, moisture, structure)	PID (ppm)
ground level						
					Precleared 0-5'	
5'						
					3' Well Sorted	
					Fine Sand	0.0
					2' Poorly Sorted	
10'			5		Sand and Gravel	0.8
					4' Poorly Sorted	
					Sand and Gravel	10.9
					1' Poorly Sorted	
15'	MW-103		5		Sand and Gravel, Very Grey	2,357
					2' Orange to Brown to Grey, Saturated	
					Poorly Sorted Sand and Gravel	2,003
					1' Grey, Saturated	
20'			3		Well Sorted Silt	15.4

SOIL BORING ONLY - REFUSAL FOR WELL PLACEMENT

* Indicates laboratory sample

Miscellaneous Data		Portion	Percent			Sampling Protocol
Depth to Water (ft): approx. 14.0'		And	35	to	50	Sampler Size: 5'
Drilling Method:	Direct Push	Some	20	to	35	
Drill Rig Model	GeoProbe	Little	10	to	20	

TOTAL DEPTH OF WELL:

Site:	Sunoco							**Boring/Well# SB-1**		Page 1 of 1
	88 South Maple Street		Construction	Feet BSG				**Construction Material**		**Symbol**
	Westfield, Ma		Riser		to			2" diameter schedule 40 PVC		
Date:	3/28/2007		Screen		to			2" diameter schedule 40 PVC, 10-slot		
Client:	Sunoco		Sandpack		to			No. 2 Silica Sand		
Driller:	CEA		Seal		to			Bentonite		
Inspector:	Matt Dowling		Backfill		to			Native		
Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**				**Soil Description** (color, consistency, moisture, structure)		**PID (ppm)**
ground level										
								Precleared 0-5'		
5'										
								5-7' Well Sorted Medium to Fine Sand		
								Light Brown		0.0
								7-10' Well Sorted Medium to Fine Sand		
10'			5					Light Brown		3.6
								10-12' Fine Sand		2.8
	SB-1							12-14' Very Poorly Sorted		3.4
								Sand and Gravel and Cobble		
15'			4							

SOIL BORING ONLY

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 13.0'		And	35	to	50	Sampler Size: 5'
Drilling Method:	Direct Push	Some	20	to	35	
Drill Rig Model	GeoProbe	Little	10	to	20	

TOTAL DEPTH OF WELL:

Site:	Sunoco							**Boring/Well# SB-2**		Page 1 of 1
	88 South Maple Street		Construction	Feet BSG				**Construction Material**		**Symbol**
	Westfield, Ma		Riser		to			2" diameter schedule 40 PVC		
Date:	3/28/2007		Screen		to			2" diameter schedule 40 PVC, 10-slot		
Client:	Sunoco		Sandpack		to			No. 2 Silica Sand		
Driller:	CEA		Seal		to			Bentonite		
Inspector:	Matt Dowling		Backfill		to			Native		
Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**				**Soil Description** (color, consistency, moisture, structure)		**PID (ppm)**
ground level										
								Precleared 0-5'		
5'										
								5-8.5' Very Well Sorted Fine Sand		0.0
								8.5-10' Poorly Sorted Fine to Coarse Sand		
10'			5					and Gravel and Cobbles		0.6
								Poorly Sorted Fine to Coarse Sand		
	SB-2							and Gravel and Cobbles, Bottom 2" Grey		2.4
			4					Refusal 14'		
15'										

SOIL BORING ONLY

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 13.0'		And	35	to	50	Sampler Size: 5'
Drilling Method:	Direct Push	Some	20	to	35	
Drill Rig Model	GeoProbe	Little	10	to	20	

TOTAL DEPTH OF WELL:

Site:	Sunoco 88 South Maple Street Westfield, Ma	Construction	Feet BSG			Boring/Well# SB-3	Page 1 of 1
						Construction Material	**Symbol**
		Riser		to		2" diameter schedule 40 PVC	
Date:	3/28/2007	Screen		to		2" diameter schedule 40 PVC, 10-slot	
Client:	Sunoco	Sandpack		to		No. 2 Silica Sand	
Driller:	CEA	Seal		to		Bentonite	
Inspector:	Matt Dowling	Backfill		to		Native	

Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**	**Soil Description** (color, consistency, moisture, structure)	**PID (ppm)**
ground level						
					Precleared 0-5'	
5'						
					Poorly Sorted Sand and Gravel and Cobbles	
10'			4		Dry	1.3
					Poorly Sorted Sand and Gravel and Cobbles	
					Dry	2.0
	SB-3 (13')					
					0.5' Well Sorted Very Coarse	
15'					Saturated	2.0
					2.5' Very Well Sorted Coarse Sand	
					Light Brown to Orange	
					0.5' Grey Well Sorted Fine to Medium Sand	0.4
20'			5		2.0' Very Well Sorted Red Silt	0.0

SOIL BORING ONLY

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 13.0'		And	35	to	50	Sampler Size: 5'
Drilling Method:	Direct Push	Some	20	to	35	
Drill Rig Model	GeoProbe	Little	10	to	20	

TOTAL DEPTH OF WELL:

Site:	Sunoco 88 South Maple Street Westfield, Ma	Construction	Feet BSG	Boring/Well# SB-4	Page 1 of 1
				Construction Material	**Symbol**
		Riser	to	2" diameter schedule 40 PVC	
Date:	3/28/2007	Screen	to	2" diameter schedule 40 PVC, 10-slot	
Client:	Sunoco	Sandpack	to	No. 2 Silica Sand	
Driller:	CEA	Seal	to	Bentonite	
Inspector:	Matt Dowling	Backfill	to	Native	

Depth (feet)	Sample	Blow Counts per 6"	Recovery (feet)	Detail	Soil Description (color, consistency, moisture, structure)	PID (ppm)
ground level						
					Precleared 0-5'	
5'						
					Poorly Sorted Sand and Gravel and Cobbles	
10'			4		Dry to Moist	0.3
					2' Dry to Moist	
	SB-4 (13')				Poorly Sorted Sand and Gravel and Cobbles	1.4
					2' Medium Sorted Coarse to Medium Sand	
15'					Saturated	2.0
					2' Saturated, Very Coarse Sand and Pebbles	
					Well Sorted	6.4
					Refusal 17'	

SOIL BORING ONLY

*** Indicates laboratory sample**

Miscellaneous Data		Portion	Percent			Sampling Protocol
Depth to Water (ft): approx. 13.0'		And	35	to	50	Sampler Size: 5'
Drilling Method:	Direct Push	Some	20	to	35	
Drill Rig Model	GeoProbe	Little	10	to	20	

TOTAL DEPTH OF WELL:

Site:	Sunoco							Boring/Well# MW-201	Page 1 of 1
	88 South Maple Street		Construction	Feet BSG				**Construction Material**	**Symbol**
	Westfield, Ma		Riser	10	to	Gr		2" diameter schedule 40 PVC	
Date:	6/25/2007		Screen	20	to	10		2" diameter schedule 40 PVC, 10-slot	
Client:	Sunoco		Sandpack	20	to	9		No. 2 Silica Sand	
Driller:	CEA		Seal	9	to	8		Bentonite	
Inspector:	Adam Guaraldi		Backfill	8	to	Gr		Native	

Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**	**Soil Description (color, consistency, moisture, structure)**	**PID (ppm)**
ground level						
5'						
10'						
					Poorly Sorted Gravel and Sand and Rock	
	(10-12')	41,33,27,29	1.5'		Brown to Grey, Unsaturated	2159
	MW-201				Poorly Sorted Sand and Gravel and Rock	
	(12-14')	23,27,18,19	1		Saturated, Brown to Grey	3721
15'						
20'						

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 13.0'		And	35	to	50	Sampler Size: 2'
Drilling Method:	Spin Auger	Some	20	to	35	
Drill Rig Model	CME-55	Little	10	to	20	

TOTAL DEPTH OF WELL: 20 Feet

Site:	Sunoco 88 South Maple Street Westfield, Ma	Construction	Feet BSG			Boring/Well# MW-202	Page 1 of 1
						Construction Material	**Symbol**
		Riser	10	to	Gr	2" diameter schedule 40 PVC	
Date:	6/25/2007	Screen	20	to	10	2" diameter schedule 40 PVC, 10-slot	
Client:	Sunoco	Sandpack	20	to	9	No. 2 Silica Sand	
Driller:	CEA	Seal	9	to	8	Bentonite	
Inspector:	Adam Guaraldi	Backfill	8	to	Gr	Native	

Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**	**Soil Description** (color, consistency, moisture, structure)	**PID (ppm)**
ground level						
5'						
10'						
					Coarse Sand to Medium Gravel	
	(10-12')	17,18,23,24	1'		Brown, Unsaturated	0.5
	MW-202				Poorly Sorted Sand and Gravel	
	(12-14')	8,7,7,5	0.5'		Saturated, Brown	2.8
15'						
20'						

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 13.0'		And	35	to	50	Sampler Size: 2'
Drilling Method:	Spin Auger	Some	20	to	35	
Drill Rig Model	CME-55	Little	10	to	20	

TOTAL DEPTH OF WELL: 20 Feet

Site:	Sunoco 88 South Maple Street Westfield, Ma								**Boring/Well# MW-203**		Page 1 of 1
			Construction	Feet BSG					**Construction Material**		**Symbol**
			Riser	4	to	Gr			2" diameter schedule 40 PVC		
Date:	6/25/2007		Screen	12	to	4			2" diameter schedule 40 PVC, 10-slot		
Client:	Sunoco		Sandpack	12	to	3			No. 2 Silica Sand		
Driller:	CEA		Seal	3	to	2			Bentonite		
Inspector:	Adam Guaraldi		Backfill	2	to	Gr			Native		
Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**					**Soil Description** (color, consistency, moisture, structure)		**PID (ppm)**
ground level											
5'											
10'	(8-10')	18,25,36,46	1'						White to Tan, Fine to Medium Sand and Gravel and Crushed Rock		0.2
	MW-203 (10-12')	67,73,48,29	2'						White to Brown, Fine to Coarse Sand and Medium Gravel and Rock, Little Brick, Saturated		0.4
									Refusal 12'		
15'											

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 11.0'		And	35	to	50	Sampler Size: 2'
Drilling Method:	Spin Auger	Some	20	to	35	
Drill Rig Model	CME-55	Little	10	to	20	

TOTAL DEPTH OF WELL: 12 Feet

Site:	Sunoco							Boring/Well# MW-204	Page 1 of 1
	88 South Maple Street		Construction	Feet BSG				**Construction Material**	**Symbol**
	Westfield, Ma		Riser	7	to	Gr		2" diameter schedule 40 PVC	
Date:	6/25/2007		Screen	17	to	7		2" diameter schedule 40 PVC, 10-slot	
Client:	Sunoco		Sandpack	17	to	6		No. 2 Silica Sand	
Driller:	CEA		Seal	6	to	5		Bentonite	
Inspector:	Adam Guaraldi		Backfill	5	to	Gr		Native	

Depth (feet)	**Sample**	**Blow Counts per 6"**	**Recovery (feet)**	**Detail**	**Soil Description** (color, consistency, moisture, structure)	**PID (ppm)**
ground level						
5'						
10'	(8-10')	5,8,13,30	1'		Light Brown to Grey, Medium Sand to Gravel Some Crushed Rock, Unsaturated	0.5
	MW-204 (10-12')	16,14,10,11	1'		Light Brown to Grey, Medium Sand to Gravel Saturated	4
15'						
20'						

*** Indicates laboratory sample**

Miscellaneous Data		**Portion**	**Percent**			**Sampling Protocol**
Depth to Water (ft): approx. 11.0'		And	35	to	50	Sampler Size: 2'
Drilling Method:	Spin Auger	Some	20	to	35	
Drill Rig Model	CME-55	Little	10	to	20	

TOTAL DEPTH OF WELL: 17 Feet

APPENDIX B

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Case Narrative for:

SUNOCO, INC

Certificate of Analysis Number:

07050432

Report To:		Project Name:	88-90 SOUTH MAPLE ST.
CORPORATE ENVIRONMENTAL ADVISORS, INC.		Site:	SUNOCO WESTFIELD - DUNS#0374-5
ADAM GUARALDI		Site Address:	
127 HARTWELL ST.			
WEST BOYLESTON		PO Number:	
MA		State:	Massachusetts
01583-		State Cert. No.:	M-LA013
ph: (508) 835-8822	fax:	Date Reported:	5/16/2007

Matrix spike (MS) and matrix spike duplicate (MSD) samples are chosen and tested at random from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data for those samples spiked by the laboratory and may be applicable to other samples of similar matrix from the site. Since the MS and MSD are chosen at random from an analytical batch, the sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group.

The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The Laboratory Control Sample (LCS) and the Method Blank (MB) are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process. If insufficient sample is supplied for MS/MSD, a Laboratory Control Sample (LCS) and a Laboratory Control Sample Duplicate (LCSD) are reported with the analytical batch and serve as the batch quality control (QC).

Results are reported on a Wet Weight Basis unless otherwise noted in the sample unit field as -dry.

The collection of samples using encores, terracores or other field collection devices may result in inconsistent initial sample weights for the parent sample and MS/MSD samples.

The MS/MSD recovery and precision data are calculated based on detected spike concentrations that are adjusted for initial sample weights. As a result of the variability between initial sample weights, the calculated RPD may have increased bias.

Any other exceptions associated with this report will be footnoted in the analytical result page(s) or the quality control summary page(s).

Please do not hesitate to contact us if you have any questions or comments pertaining to this data report. Please reference the above Certificate of Analysis Number.

SPL, Inc. is pleased to be of service to you. We anticipate working with you in fulfilling all your current and future analytical needs.

TOTAL NUMBER OF PAGES IN THIS REPORT: _____ PAGES

5/16/2007

Alberto E. Granados
Project Manager

Date

Test results meet all requirements of NELAC, unless specified in the narrative.

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

SUNOCO, INC

Certificate of Analysis Number:

07050432

Report To: CORPORATE ENVIRONMENTAL ADVISORS, INC.
ADAM GUARALDI
127 HARTWELL ST.

WEST BOYLESTON
MA
01583-
ph: (508) 835-8822 fax:

Fax To:

Project Name: 88-90 SOUTH MAPLE ST.
Site: SUNOCO WESTFIELD - DUNS#0374-5
Site Address:

PO Number:
State: Massachusetts
State Cert. No.: M-LA013
Date Reported: 5/16/2007

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
MW-1	07050432-01	Water	5/8/2007 11:10:00 AM	5/9/2007 10:04:20 AM		☐
MW-3B	07050432-02	Water	5/8/2007 10:00:00 AM	5/9/2007 10:04:20 AM		☐
MW-5	07050432-03	Water	5/8/2007 12:00:00 PM	5/9/2007 10:04:20 AM		☐
MW-6	07050432-04	Water	5/8/2007 9:30:00 AM	5/9/2007 10:04:20 AM		☐
MW-101	07050432-05	Water	5/8/2007 10:30:00 AM	5/9/2007 10:04:20 AM		☐
MW-102	07050432-06	Water	5/8/2007 9:00:00 AM	5/9/2007 10:04:20 AM		☐

5/16/2007

Alberto E. Granados
Project Manager

Date

Ron Benjamin
Laboratory Director

Tristan Davis
Quality Assurance Officer

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-1 **Collected:** 05/08/2007 11:10 **SPL Sample ID:** 07050432-01

Site: SUNOCO WESTFIELD - DUNS#0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				**MCL _VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND			1	1	05/12/07 13:28	RRH	2216089
Toluene	ND			1	1	05/12/07 13:28	RRH	2216089
Ethylbenzene	ND			1	1	05/12/07 13:28	RRH	2216089
m,p-Xylene	ND			2	1	05/12/07 13:28	RRH	2216089
o-Xylene	ND			1	1	05/12/07 13:28	RRH	2216089
Methyl tert-butyl ether	ND			8	1	05/12/07 13:28	RRH	2216089
Naphthalene	ND			10	1	05/12/07 13:28	RRH	2216089
C5-C8 Aliphatics (Unadjusted)	ND			200	1	05/12/07 13:28	RRH	2216090
C9-C12 Aliphatics (Unadjusted)	ND			100	1	05/12/07 13:28	RRH	2216090
C9-C10 Aromatics	ND			30	1	05/12/07 13:28	RRH	2216089
C5-C8 Aliphatics (Adjusted)	ND			200	1	05/12/07 13:28	RRH	2216089
C9-C12 Aliphatics (Adjusted)	ND			100	1	05/12/07 13:28	RRH	2216089
Surr: 2,5-Dibromotoluene	88.9		%	70-130	1	05/12/07 13:28	RRH	2216089
Surr: 2,5-Dibromotoluene	86.9		%	70-130	1	05/12/07 13:28	RRH	2216090

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-3B **Collected:** 05/08/2007 10:00 **SPL Sample ID:** 07050432-02

Site: SUNOCO WESTFIELD - DUNS#0374-5593

Analyses/Method	Result	QUAL	Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)			**MCL _VPH_EPH_ALL**		**Units: ug/L**		
Benzene	9.5		1	1	05/12/07 13:57	RRH	2216091
Toluene	6.5		1	1	05/12/07 13:57	RRH	2216091
Ethylbenzene	32		1	1	05/12/07 13:57	RRH	2216091
m,p-Xylene	46		2	1	05/12/07 13:57	RRH	2216091
o-Xylene	210		1	1	05/12/07 13:57	RRH	2216091
Methyl tert-butyl ether	18		8	1	05/12/07 13:57	RRH	2216091
Naphthalene	68		10	1	05/12/07 13:57	RRH	2216091
C5-C8 Aliphatics (Unadjusted)	650		200	1	05/12/07 13:57	RRH	2216092
C9-C12 Aliphatics (Unadjusted)	2300		100	1	05/12/07 13:57	RRH	2216092
C9-C10 Aromatics	2000		150	5	05/15/07 0:55	RRH	2218636
C5-C8 Aliphatics (Adjusted)	616		200	1	05/12/07 13:57	RRH	2216091
C9-C12 Aliphatics (Adjusted)	2012		100	1	05/12/07 13:57	RRH	2216091
Surr: 2,5-Dibromotoluene	100		% 70-130	5	05/15/07 0:55	RRH	2218636
Surr: 2,5-Dibromotoluene	106		% 70-130	1	05/12/07 13:57	RRH	2216091
Surr: 2,5-Dibromotoluene	97.8		% 70-130	1	05/12/07 13:57	RRH	2216092

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-5 **Collected:** 05/08/2007 12:00 **SPL Sample ID:** 07050432-03

Site: SUNOCO WESTFIELD - DUNS#0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				**MCL_VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND			1	1	05/12/07 14:26	RRH	2216093
Toluene	ND			1	1	05/12/07 14:26	RRH	2216093
Ethylbenzene	ND			1	1	05/12/07 14:26	RRH	2216093
m,p-Xylene	ND			2	1	05/12/07 14:26	RRH	2216093
o-Xylene	ND			1	1	05/12/07 14:26	RRH	2216093
Methyl tert-butyl ether	ND			8	1	05/12/07 14:26	RRH	2216093
Naphthalene	ND			10	1	05/12/07 14:26	RRH	2216093
C5-C8 Aliphatics (Unadjusted)	ND			200	1	05/12/07 14:26	RRH	2216094
C9-C12 Aliphatics (Unadjusted)	ND			100	1	05/12/07 14:26	RRH	2216094
C9-C10 Aromatics	ND			30	1	05/12/07 14:26	RRH	2216093
C5-C8 Aliphatics (Adjusted)	ND			200	1	05/12/07 14:26	RRH	2216093
C9-C12 Aliphatics (Adjusted)	ND			100	1	05/12/07 14:26	RRH	2216093
Surr: 2,5-Dibromotoluene	100		%	70-130	1	05/12/07 14:26	RRH	2216093
Surr: 2,5-Dibromotoluene	99.8		%	70-130	1	05/12/07 14:26	RRH	2216094

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
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Client Sample ID MW-6 **Collected:** 05/08/2007 9:30 **SPL Sample ID:** 07050432-04

Site: SUNOCO WESTFIELD - DUNS#0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				**MCL _VPH_EPH_ALL**		**Units: ug/L**		
Benzene	3.2			1	1	05/12/07 14:55	RRH	2216095
Toluene	1.4			1	1	05/12/07 14:55	RRH	2216095
Ethylbenzene	ND			1	1	05/12/07 14:55	RRH	2216095
m,p-Xylene	ND			2	1	05/12/07 14:55	RRH	2216095
o-Xylene	ND			1	1	05/12/07 14:55	RRH	2216095
Methyl tert-butyl ether	2700			40	5	05/15/07 1:23	RRH	2218638
Naphthalene	ND			10	1	05/12/07 14:55	RRH	2216095
C5-C8 Aliphatics (Unadjusted)	3100			200	1	05/12/07 14:55	RRH	2216096
C9-C12 Aliphatics (Unadjusted)	ND			100	1	05/12/07 14:55	RRH	2216096
C9-C10 Aromatics	ND			30	1	05/12/07 14:55	RRH	2216095
C5-C8 Aliphatics (Adjusted)	3095.4			200	1	05/12/07 14:55	RRH	2216095
C9-C12 Aliphatics (Adjusted)	ND			100	1	05/12/07 14:55	RRH	2216095
Surr: 2,5-Dibromotoluene	95.2		%	70-130	5	05/15/07 1:23	RRH	2218638
Surr: 2,5-Dibromotoluene	106		%	70-130	1	05/12/07 14:55	RRH	2216095
Surr: 2,5-Dibromotoluene	101		%	70-130	1	05/12/07 14:55	RRH	2216096

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-101 **Collected:** 05/08/2007 10:30 **SPL Sample ID:** 07050432-05

Site: SUNOCO WESTFIELD - DUNS#0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				**MCL _VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND			1	1	05/12/07 15:24	RRH	2216097
Toluene	ND			1	1	05/12/07 15:24	RRH	2216097
Ethylbenzene	1.2			1	1	05/12/07 15:24	RRH	2216097
m,p-Xylene	ND			2	1	05/12/07 15:24	RRH	2216097
o-Xylene	ND			1	1	05/12/07 15:24	RRH	2216097
Methyl tert-butyl ether	ND			8	1	05/12/07 15:24	RRH	2216097
Naphthalene	ND			10	1	05/12/07 15:24	RRH	2216097
C5-C8 Aliphatics (Unadjusted)	ND			200	1	05/12/07 15:24	RRH	2216098
C9-C12 Aliphatics (Unadjusted)	ND			100	1	05/12/07 15:24	RRH	2216098
C9-C10 Aromatics	ND			30	1	05/12/07 15:24	RRH	2216097
C5-C8 Aliphatics (Adjusted)	ND			200	1	05/12/07 15:24	RRH	2216097
C9-C12 Aliphatics (Adjusted)	ND			100	1	05/12/07 15:24	RRH	2216097
Surr: 2,5-Dibromotoluene	106		%	70-130	1	05/12/07 15:24	RRH	2216097
Surr: 2,5-Dibromotoluene	98.7		%	70-130	1	05/12/07 15:24	RRH	2216098

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-102 **Collected:** 05/08/2007 9:00 **SPL Sample ID:** 07050432-06

Site: SUNOCO WESTFIELD - DUNS#0374-5593

Analyses/Method	Result	QUAL	Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)			**MCL _VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND		1	1	05/12/07 15:53	RRH	2216099
Toluene	ND		1	1	05/12/07 15:53	RRH	2216099
Ethylbenzene	ND		1	1	05/12/07 15:53	RRH	2216099
m,p-Xylene	ND		2	1	05/12/07 15:53	RRH	2216099
o-Xylene	ND		1	1	05/12/07 15:53	RRH	2216099
Methyl tert-butyl ether	ND		8	1	05/12/07 15:53	RRH	2216099
Naphthalene	ND		10	1	05/12/07 15:53	RRH	2216099
C5-C8 Aliphatics (Unadjusted)	ND		200	1	05/12/07 15:53	RRH	2216100
C9-C12 Aliphatics (Unadjusted)	ND		100	1	05/12/07 15:53	RRH	2216100
C9-C10 Aromatics	ND		30	1	05/12/07 15:53	RRH	2216099
C5-C8 Aliphatics (Adjusted)	ND		200	1	05/12/07 15:53	RRH	2216099
C9-C12 Aliphatics (Adjusted)	ND		100	1	05/12/07 15:53	RRH	2216099
Surr: 2,5-Dibromotoluene	104	%	70-130	1	05/12/07 15:53	RRH	2216099
Surr: 2,5-Dibromotoluene	98.5	%	70-130	1	05/12/07 15:53	RRH	2216100

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

Quality Control Documentation

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Quality Control Report

SUNOCO, INC

88-90 SOUTH MAPLE ST.

Analysis: Volatile Petroleum Hydrocarbons (water) **WorkOrder:** 07050432
Method: MA_VPH_EPH_ALL **Lab Batch ID:** R152328

Method Blank

RunID: HPDD_070511E-2216086 Units: ug/L
Analysis Date: 05/12/2007 7:13 Analyst: RRH

Analyte	Result	Rep Limit
C5-C8 Aliphatics (Unadjusted)	ND	200
C9-C12 Aliphatics (Unadjusted)	ND	100
Surr: 2,5-Dibromotoluene	98.3	70-130

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
07050432-01A	MW-1
07050432-02A	MW-3B
07050432-03A	MW-5
07050432-04A	MW-6
07050432-05A	MW-101
07050432-06A	MW-102

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

RunID: HPDD_070511E-2216082 Units: ug/L
Analysis Date: 05/12/2007 5:47 Analyst: RRH

Analyte	LCS Spike Added	LCS Result	LCS Percent Recovery	LCSD Spike Added	LCSD Result	LCSD Percent Recovery	RPD	RPD Limit	Lower Limit	Upper Limit
C5-C8 Aliphatics (Unadjusted)	300	296	98.8	300	296	98.6	0.2	20	70	130
C9-C12 Aliphatics (Unadjusted)	220	251	114	220	247	112	1.4	20	70	130
Surr: 2,5-Dibromotoluene	100	99.3	99.3	100	103	103	3.4	30	70	130

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Quality Control Report

SUNOCO, INC

88-90 SOUTH MAPLE ST.

Analysis: Volatile Petroleum Hydrocarbons (water) **WorkOrder:** 07050432
Method: MA_VPH_EPH_ALL **Lab Batch ID:** R152328

Method Blank

RunID: HPDD_070511E-2216085 Units: ug/L
Analysis Date: 05/12/2007 7:13 Analyst: RRH

Analyte	Result	Rep Limit
Benzene	ND	1.0
C5-C8 Aliphatics (Adjusted)	ND	200
C9-C10 Aromatics	ND	30
C9-C12 Aliphatics (Adjusted)	ND	100
Ethylbenzene	ND	1.0
m,p-Xylene	ND	2.0
Methyl tert-butyl ether	ND	8.0
Naphthalene	ND	10
o-Xylene	ND	1.0
Toluene	ND	1.0
Surr: 2,5-Dibromotoluene	100.3	70-130

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
07050432-01A	MW-1
07050432-02A	MW-3B
07050432-03A	MW-5
07050432-04A	MW-6
07050432-05A	MW-101
07050432-06A	MW-102

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

RunID: HPDD_070511E-2216081 Units: ug/L
Analysis Date: 05/12/2007 5:47 Analyst: RRH

Analyte	LCS Spike Added	LCS Result	LCS Percent Recovery	LCSD Spike Added	LCSD Result	LCSD Percent Recovery	RPD	RPD Limit	Lower Limit	Upper Limit
Benzene	25.0	21.0	84.1	25.0	21.2	84.7	0.7	19	70	130
C9-C10 Aromatics	40.0	45.9	115	40.0	46.9	117	2.1	20	70	130
Ethylbenzene	25.0	22.4	89.6	25.0	22.7	90.7	1.3	17.6	70	130
m,p-Xylene	100	95.3	95.3	100	97.0	97.0	1.8	17.4	70	130
Methyl tert-butyl ether	75.0	59.5	79.3	75.0	61.1	81.4	2.6	25.8	70	130
Naphthalene	50.0	44.5	88.9	50.0	46.4	92.8	4.3	27.4	70	130
o-Xylene	50.0	45.8	91.6	50.0	46.7	93.4	2.0	17.9	70	130
Toluene	75.0	66.7	89.0	75.0	67.6	90.2	1.4	17.5	70	130
Surr: 2,5-Dibromotoluene	100	102	102	100	107	107	5.5	30	70	130

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Quality Control Report

SUNOCO, INC
88-90 SOUTH MAPLE ST.

Analysis: Volatile Petroleum Hydrocarbons (water) **WorkOrder:** 07050432
Method: MA_VPH_EPH_ALL **Lab Batch ID:** R152456

Method Blank

RunID: HPDD_070514G-2218634 Units: ug/L
Analysis Date: 05/14/2007 21:33 Analyst: RRH

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
07050432-02A	MW-3B
07050432-04A	MW-6

Analyte	Result	Rep Limit
C9-C10 Aromatics	ND	30
Methyl tert-butyl ether	ND	8.0
Surr: 2,5-Dibromotoluene	97.8	70-130

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

RunID: HPDD_070514G-2218630 Units: ug/L
Analysis Date: 05/14/2007 20:07 Analyst: RRH

Analyte	LCS Spike Added	LCS Result	LCS Percent Recovery	LCSD Spike Added	LCSD Result	LCSD Percent Recovery	RPD	RPD Limit	Lower Limit	Upper Limit
C9-C10 Aromatics	40.0	49.6	124	40.0	50.4	126	1.6	20	70	130
Methyl tert-butyl ether	75.0	56.0	74.7	75.0	57.7	77.0	3.0	25.8	70	130
Surr: 2,5-Dibromotoluene	100	89.3	89.3	100	105	105	16.0	30	70	130

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

Sample Receipt Checklist

And

Chain of Custody

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Sample Receipt Checklist

Workorder:	**07050432**	Received By:	**CCP**
Date and Time Received:	**5/9/2007 10:04:20 AM**	Carrier name:	**FedEx-Std 1 Day PM**
Temperature:	**3.0°C**	Chilled by:	**Water Ice**

1. **Shipping container/cooler in good condition?**	Yes ☑	No ☐	Not Present ☐	
2. **Custody seals intact on shippping container/cooler?**	Yes ☑	No ☐	Not Present ☐	
3. **Custody seals intact on sample bottles?**	Yes ☐	No ☐	Not Present ☑	
4. **Chain of custody present?**	Yes ☑	No ☐		
5. **Chain of custody signed when relinquished and received?**	Yes ☑	No ☐		
6. **Chain of custody agrees with sample labels?**	Yes ☑	No ☐		
7. **Samples in proper container/bottle?**	Yes ☑	No ☐		
8. **Sample containers intact?**	Yes ☑	No ☐		
9. **Sufficient sample volume for indicated test?**	Yes ☑	No ☐		
10. **All samples received within holding time?**	Yes ☑	No ☐		
11. **Container/Temp Blank temperature in compliance?**	Yes ☑	No ☐		
12. **Water - VOA vials have zero headspace?**	Yes ☑	No ☐	VOA Vials Not Present ☐	
13. **Water - Preservation checked upon receipt (except VOA*)?**	Yes ☐	No ☐	Not Applicable ☑	

***VOA Preservation Checked After Sample Analysis**

SPL Representative: _____ **Contact Date & Time:** _____

Client Name Contacted: _____

Non Conformance Issues: _____

Client Instructions: _____

Chain of Custody Record

On-site Time:	Temp:
Off-site Time:	Temp:
Sky Conditions:	
Meteorological Events:	
Wind Speed:	Direc

Sunoco DUNS #: 0374-5593 07050437
Region:
State or Lead Regulatory Agency: MADEP
Requested Due Date (mm/dd/yy):
COC Tracking Number:

Lab Name:	Southern Petroleum Laboratories	Facility Address:	88-90 South Maple Street	Consultant/Contractor:	CEA
Address:	500 Ambassador Caffery Parkway	Facility City, State:	Westfield MA	Address:	127 Hartwell Street
	Scott, LA 70583	Site Lat/Long:			W. Boylston, MA 01583
Lab PM:		Sunoco PM Contact:	Bill Brochu	Consultant/Contractor Project No.:	4776-01
Tele: 717-656-2300	Fax: 717-656-2(681	Address:	4 Bellows Rd, PO Box 1262,	Consultant/Contractor PM:	Scott VanderSea
Report Type & QC Level:	USEPA Region 5 EDMAN no QC	Westborough, MA 01581		Tele/Fax:	(508) 835-8822
E-mail EDD To:	SunocoENFOS@deltaenv.com	Tele/Fax:	(800) 777-6444 x1357 (866) 257-9205	Invoice to:	

Lab Bottle Order No:

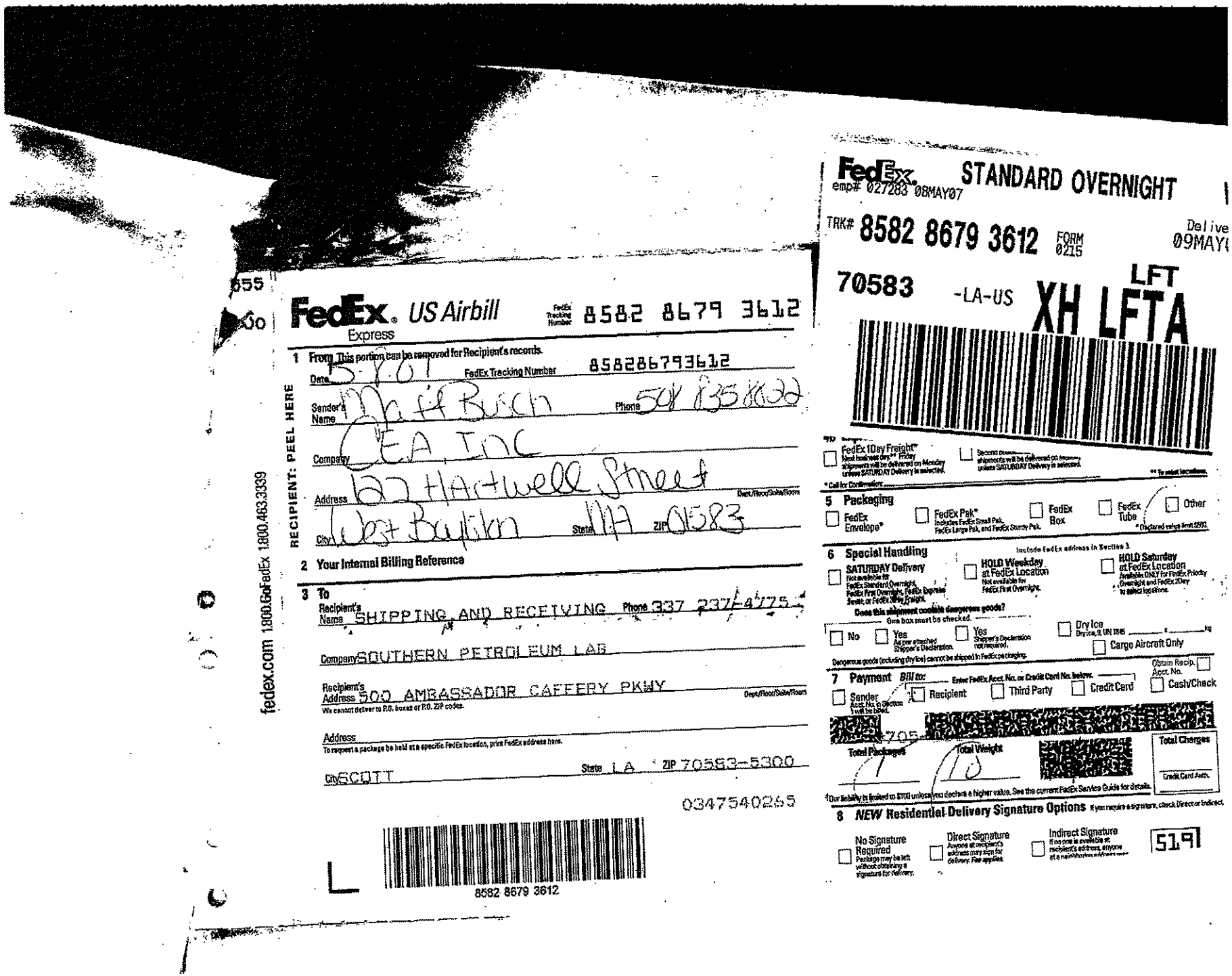
Item No.	Sample Description	Time	Date	Matrix: Liquid	Matrix: Soil	Laboratory No.	No. of Containers	Preservative: MeOH	Preservative: None	Preservative: HCl	Requested Analysis: VPH	Sample Point Lat/Long and Comments
1	MW-1	11:10	5-8-07	X			3			X	X	3 CSO on cooler
2	MW-3B	10:05		X			3			X	X	3 (BL-138 W1)
~~3~~	~~MW-4~~			~~X~~							~~X~~ MB 5-8-07	
4	MW-5	12:00		X			3			X	X	3
5	MW-6	9:30		X			3			X	X	3 Temp
6	MW-101	10:30		X			3			X	X	3 3.0
7	MW-102	9:00		X			3			X	X	3
8												
9												
10												
11												
12												

Sampler's Name:	Busch + Zoltay	Relinquished By / Affiliation	Date	Time	Accepted By / Affiliation	Date	Time
Sampler's Company:	CEA		5-8-07	2:30	Fedex		
Shipment Date:	5-8-07	Fedex					
Shipment Method:	Air		5/9/07	9:00	Paulette Connie	5/9	10:00
Shipment Tracking No:	8582 8679 3612						

Special Instructions:

Must meet MADEP GW-1 Groundwater Standards, Email laboratory analytical report to mdowling@cea-inc.com

Custody Seals In Place Yes No Temp Blank Yes No Cooler Temperature on Receipt OF/C Trip Blank Yes No



FedEx. US Airbill
Express
FedEx Tracking Number 8582 8679 3612

RECIPIENT: PEEL HERE

1 From This portion can be removed for Recipient's records.
Date 5-7-07 FedEx Tracking Number 858286793612
Sender's Name Matt Busch Phone 504 835 8622
Company CEA, Inc
Address 622 Hartwell Street Dept/Floor/Suite/Room
City West Baton Rouge State LA ZIP 70583

2 Your Internal Billing Reference

3 To
Recipient's Name SHIPPING AND RECEIVING Phone 337 237-4775
Company SOUTHERN PETROLEUM LAB
Recipient's Address 500 AMBASSADOR CAFFERY PKWY Dept/Floor/Suite/Room
We cannot deliver to P.O. boxes or P.O. ZIP codes.
Address
To request a package be held at a specific FedEx location, print FedEx address here.
City SCOTT State LA ZIP 70583-5300

0347540265

8582 8679 3612

fedex.com 1.800.GoFedEx 1.800.463.3339

FedEx. STANDARD OVERNIGHT
emp# 027283 08MAY07
TRK# 8582 8679 3612 FORM 0215
Delive 09MAY(
70583 -LA-US XH LFTA LFT

FedEx 1Day Freight* Next business day.** Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
Second business day.** Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
** To most locations.
* Call for Confirmation:

5 Packaging
FedEx Envelope* FedEx Pak* Includes FedEx Small Pak, FedEx Large Pak, and FedEx Sturdy Pak. FedEx Box FedEx Tube Other
* Declared value limit $500.

6 Special Handling
Include FedEx address in Section 3
SATURDAY Delivery Not available for FedEx Standard Overnight, FedEx First Overnight, FedEx Express Saver, or FedEx 3Day Freight.
HOLD Weekday at FedEx Location Not available for FedEx First Overnight.
HOLD Saturday at FedEx Location Available ONLY for FedEx Priority Overnight and FedEx 2Day to select locations.
Does this shipment contain dangerous goods?
One box must be checked.
No Yes As per attached Shipper's Declaration. Yes Shipper's Declaration not required. Dry Ice Dry Ice, 9, UN 1845 ____ x ____ kg Cargo Aircraft Only
Dangerous goods (including dry ice) cannot be shipped in FedEx packaging.

7 Payment Bill to: Enter FedEx Acct. No. or Credit Card No. below.
Sender Acct. No. in Section 1 will be billed. Recipient Third Party Credit Card Cash/Check
Obtain Recip. Acct. No.
705
Total Packages 1 Total Weight 10 Total Charges
Credit Card Auth.
Our liability is limited to $100 unless you declare a higher value. See the current FedEx Service Guide for details.

8 NEW Residential Delivery Signature Options If you require a signature, check Direct or Indirect.
No Signature Required Package may be left without obtaining a signature for delivery.
Direct Signature Anyone at recipient's address may sign for delivery. Fee applies.
Indirect Signature If no one is available at recipient's address, anyone at a neighboring address may...

519

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Case Narrative for:

SUNOCO, INC

Certificate of Analysis Number:

07100405

Report To:		**Project Name:**	5795-05
CORPORATE ENVIRONMENTAL ADVISORS, INC.		**Site:**	SUNOCO DUNS #0374-5593
SCOTT VARDERSEA		**Site Address:**	88-90 SOUTH MAPLE STREET
127 HARTWELL ST.			WESTFIELD MA
		PO Number:	
WEST BOYLESTON		**State:**	Massachusetts
MA		**State Cert. No.:**	M-LA013
01583-		**Date Reported:**	10/24/2007
ph: (508) 835-8822	fax:		

Matrix spike (MS) and matrix spike duplicate (MSD) samples are chosen and tested at random from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data for those samples spiked by the laboratory and may be applicable to other samples of similar matrix from the site. Since the MS and MSD are chosen at random from an analytical batch, the sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group.

The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The Laboratory Control Sample (LCS) and the Method Blank (MB) are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process. If insufficient sample is supplied for MS/MSD, a Laboratory Control Sample (LCS) and a Laboratory Control Sample Duplicate (LCSD) are reported with the analytical batch and serve as the batch quality control (QC).

Results are reported on a Wet Weight Basis unless otherwise noted in the sample unit field as -dry.

The collection of samples using encores, terracores or other field collection devices may result in inconsistent initial sample weights for the parent sample and MS/MSD samples.

The MS/MSD recovery and precision data are calculated based on detected spike concentrations that are adjusted for initial sample weights. As a result of the variability between initial sample weights, the calculated RPD may have increased bias.

Any other exceptions associated with this report will be footnoted in the analytical result page(s) or the quality control summary page(s).

Please do not hesitate to contact us if you have any questions or comments pertaining to this data report. Please reference the above Certificate of Analysis Number.

This report shall not be reproduced except in full, without the written approval of the laboratory. The reported results are only representative of the samples submitted for testing.

SPL, Inc. is pleased to be of service to you. We anticipate working with you in fulfilling all your current and future analytical needs.

TOTAL NUMBER OF PAGES IN THIS REPORT: 26 PAGES

10/24/2007
Date

Alberto E. Granados
Project Manager

Test results meet all requirements of NELAC, unless specified in the narrative.

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

SUNOCO, INC

Certificate of Analysis Number:

07100405

Report To: CORPORATE ENVIRONMENTAL ADVISORS, INC.
SCOTT VARDERSEA
127 HARTWELL ST.

WEST BOYLESTON
MA
01583-
ph: (508) 835-8822 fax:

Fax To:

Project Name: 5795-05
Site: SUNOCO DUNS #0374-5593
Site Address: 88-90 SOUTH MAPLE STREET
WESTFIELD MA
PO Number:
State: Massachusetts
State Cert. No.: M-LA013
Date Reported: 10/24/2007

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
MW-1	07100405-01	Water	10/10/2007 8:30:00 AM	10/11/2007 9:30:00 AM		☐
MW-101	07100405-02	Water	10/10/2007 10:45:00 AM	10/11/2007 9:30:00 AM		☐
MW-102	07100405-03	Water	10/10/2007 12:30:00 PM	10/11/2007 9:30:00 AM		☐
MW-201	07100405-04	Water	10/10/2007 11:30:00 AM	10/11/2007 9:30:00 AM		☐
MW-202	07100405-05	Water	10/10/2007 9:00:00 AM	10/11/2007 9:30:00 AM		☐
TRIP BLANK	07100405-06	Water	10/10/2007	10/11/2007 9:30:00 AM		☐
MW-204	07100405-07	Water	10/10/2007 1:30:00 PM	10/11/2007 9:30:00 AM		☐
MW-5	07100405-08	Water	10/10/2007 9:30:00 AM	10/11/2007 9:30:00 AM		☐
MW-6	07100405-09	Water	10/10/2007 10:00:00 AM	10/11/2007 9:30:00 AM		☐

10/24/2007
Date

Alberto E. Granados
Project Manager

Ron Benjamin
Laboratory Director

Tristan Davis
Quality Assurance Officer

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-1 **Collected:** 10/10/2007 8:30 **SPL Sample ID:** 07100405-01

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL	Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)			MCL_VPH_EPH_ALL		Units: ug/L		
Benzene	ND <		1	1	10/17/07 12:38	JAP	2399277
Toluene	ND <		1	1	10/17/07 12:38	JAP	2399277
Ethylbenzene	ND <		1	1	10/17/07 12:38	JAP	2399277
m,p-Xylene	ND <		2	1	10/17/07 12:38	JAP	2399277
o-Xylene	ND <		1	1	10/17/07 12:38	JAP	2399277
Methyl tert-butyl ether	ND <		8	1	10/17/07 12:38	JAP	2399277
Naphthalene	ND <		10	1	10/17/07 12:38	JAP	2399277
C5-C8 Aliphatics (Unadjusted)	ND <		200	1	10/17/07 12:38	JAP	2399278
C9-C12 Aliphatics (Unadjusted)	ND <		100	1	10/17/07 12:38	JAP	2399278
C9-C10 Aromatics	ND <		30	1	10/17/07 12:38	JAP	2399277
C5-C8 Aliphatics (Adjusted)	ND <		200	1	10/17/07 12:38	JAP	2399277
C9-C12 Aliphatics (Adjusted)	ND <		100	1	10/17/07 12:38	JAP	2399277
Surr: 2,5-Dibromotoluene	108	%	70-130	1	10/17/07 12:38	JAP	2399278
Surr: 2,5-Dibromotoluene	102	%	70-130	1	10/17/07 12:38	JAP	2399277

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-101 **Collected:** 10/10/2007 10:45 **SPL Sample ID:** 07100405-02

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL	Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)			MCL _VPH_EPH_ALL		Units: ug/L		
Benzene	ND <		1	1	10/17/07 13:08	JAP	2399280
Toluene	ND <		1	1	10/17/07 13:08	JAP	2399280
Ethylbenzene	ND <		1	1	10/17/07 13:08	JAP	2399280
m,p-Xylene	ND <		2	1	10/17/07 13:08	JAP	2399280
o-Xylene	ND <		1	1	10/17/07 13:08	JAP	2399280
Methyl tert-butyl ether	ND <		8	1	10/17/07 13:08	JAP	2399280
Naphthalene	ND <		10	1	10/17/07 13:08	JAP	2399280
C5-C8 Aliphatics (Unadjusted)	ND <		200	1	10/17/07 13:08	JAP	2399279
C9-C12 Aliphatics (Unadjusted)	ND <		100	1	10/17/07 13:08	JAP	2399279
C9-C10 Aromatics	ND <		30	1	10/17/07 13:08	JAP	2399280
C5-C8 Aliphatics (Adjusted)	ND <		200	1	10/17/07 13:08	JAP	2399280
C9-C12 Aliphatics (Adjusted)	ND <		100	1	10/17/07 13:08	JAP	2399280
Surr: 2,5-Dibromotoluene	115	%	70-130	1	10/17/07 13:08	JAP	2399279
Surr: 2,5-Dibromotoluene	108	%	70-130	1	10/17/07 13:08	JAP	2399280

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-102 **Collected:** 10/10/2007 12:30 **SPL Sample ID:** 07100405-03

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				MCL _VPH_EPH_ALL		Units: ug/L		
Benzene	ND <			1	1	10/17/07 13:38	JAP	2399282
Toluene	ND <			1	1	10/17/07 13:38	JAP	2399282
Ethylbenzene	ND <			1	1	10/17/07 13:38	JAP	2399282
m,p-Xylene	ND <			2	1	10/17/07 13:38	JAP	2399282
o-Xylene	ND <			1	1	10/17/07 13:38	JAP	2399282
Methyl tert-butyl ether	ND <			8	1	10/17/07 13:38	JAP	2399282
Naphthalene	ND <			10	1	10/17/07 13:38	JAP	2399282
C5-C8 Aliphatics (Unadjusted)	ND <			200	1	10/17/07 13:38	JAP	2399281
C9-C12 Aliphatics (Unadjusted)	ND <			100	1	10/17/07 13:38	JAP	2399281
C9-C10 Aromatics	ND <			30	1	10/17/07 13:38	JAP	2399282
C5-C8 Aliphatics (Adjusted)	ND <			200	1	10/17/07 13:38	JAP	2399282
C9-C12 Aliphatics (Adjusted)	ND <			100	1	10/17/07 13:38	JAP	2399282
Surr: 2,5-Dibromotoluene	122		%	70-130	1	10/17/07 13:38	JAP	2399281
Surr: 2,5-Dibromotoluene	116		%	70-130	1	10/17/07 13:38	JAP	2399282

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-201 **Collected:** 10/10/2007 11:30 **SPL Sample ID:** 07100405-04

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL	Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)			**MCL _VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND <		1	1	10/17/07 14:07	JAP	2399284
Toluene	ND <		1	1	10/17/07 14:07	JAP	2399284
Ethylbenzene	ND <		1	1	10/17/07 14:07	JAP	2399284
m,p-Xylene	ND <		2	1	10/17/07 14:07	JAP	2399284
o-Xylene	ND <		1	1	10/17/07 14:07	JAP	2399284
Methyl tert-butyl ether	ND <		8	1	10/17/07 14:07	JAP	2399284
Naphthalene	ND <		10	1	10/17/07 14:07	JAP	2399284
C5-C8 Aliphatics (Unadjusted)	ND <		200	1	10/17/07 14:07	JAP	2399283
C9-C12 Aliphatics (Unadjusted)	ND <		100	1	10/17/07 14:07	JAP	2399283
C9-C10 Aromatics	ND <		30	1	10/17/07 14:07	JAP	2399284
C5-C8 Aliphatics (Adjusted)	ND <		200	1	10/17/07 14:07	JAP	2399284
C9-C12 Aliphatics (Adjusted)	ND <		100	1	10/17/07 14:07	JAP	2399284
Surr: 2,5-Dibromotoluene	123		% 70-130	1	10/17/07 14:07	JAP	2399283
Surr: 2,5-Dibromotoluene	117		% 70-130	1	10/17/07 14:07	JAP	2399284

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-202 **Collected:** 10/10/2007 9:00 **SPL Sample ID:** 07100405-05

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				**MCL_VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND <			1	1	10/17/07 14:37	JAP	2399285
Toluene	ND <			1	1	10/17/07 14:37	JAP	2399285
Ethylbenzene	ND <			1	1	10/17/07 14:37	JAP	2399285
m,p-Xylene	ND <			2	1	10/17/07 14:37	JAP	2399285
o-Xylene	ND <			1	1	10/17/07 14:37	JAP	2399285
Methyl tert-butyl ether	ND <			8	1	10/17/07 14:37	JAP	2399285
Naphthalene	ND <			10	1	10/17/07 14:37	JAP	2399285
C5-C8 Aliphatics (Unadjusted)	ND <			200	1	10/17/07 14:37	JAP	2399286
C9-C12 Aliphatics (Unadjusted)	ND <			100	1	10/17/07 14:37	JAP	2399286
C9-C10 Aromatics	ND <			30	1	10/17/07 14:37	JAP	2399285
C5-C8 Aliphatics (Adjusted)	ND <			200	1	10/17/07 14:37	JAP	2399285
C9-C12 Aliphatics (Adjusted)	ND <			100	1	10/17/07 14:37	JAP	2399285
Surr: 2,5-Dibromotoluene	122		%	70-130	1	10/17/07 14:37	JAP	2399286
Surr: 2,5-Dibromotoluene	113		%	70-130	1	10/17/07 14:37	JAP	2399285

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID TRIP BLANK **Collected:** 10/10/2007 0:00 **SPL Sample ID:** 07100405-06

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				MCL_VPH_EPH_ALL		Units: ug/L		
Benzene	ND <			1	1	10/17/07 12:09	JAP	2399276
Toluene	ND <			1	1	10/17/07 12:09	JAP	2399276
Ethylbenzene	ND <			1	1	10/17/07 12:09	JAP	2399276
m,p-Xylene	ND <			2	1	10/17/07 12:09	JAP	2399276
o-Xylene	ND <			1	1	10/17/07 12:09	JAP	2399276
Methyl tert-butyl ether	ND <			8	1	10/17/07 12:09	JAP	2399276
Naphthalene	ND <			10	1	10/17/07 12:09	JAP	2399276
C5-C8 Aliphatics (Unadjusted)	ND <			200	1	10/17/07 12:09	JAP	2399275
C9-C12 Aliphatics (Unadjusted)	ND <			100	1	10/17/07 12:09	JAP	2399275
C9-C10 Aromatics	ND <			30	1	10/17/07 12:09	JAP	2399276
C5-C8 Aliphatics (Adjusted)	ND <			200	1	10/17/07 12:09	JAP	2399276
C9-C12 Aliphatics (Adjusted)	ND <			100	1	10/17/07 12:09	JAP	2399276
Surr: 2,5-Dibromotoluene	126		%	70-130	1	10/17/07 12:09	JAP	2399275
Surr: 2,5-Dibromotoluene	115		%	70-130	1	10/17/07 12:09	JAP	2399276

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-204 **Collected:** 10/10/2007 13:30 **SPL Sample ID:** 07100405-07

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				**MCL_VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND <			1	1	10/17/07 15:06	JAP	2399288
Toluene	ND <			1	1	10/17/07 15:06	JAP	2399288
Ethylbenzene	ND <			1	1	10/17/07 15:06	JAP	2399288
m,p-Xylene	ND <			2	1	10/17/07 15:06	JAP	2399288
o-Xylene	ND <			1	1	10/17/07 15:06	JAP	2399288
Methyl tert-butyl ether	ND <			8	1	10/17/07 15:06	JAP	2399288
Naphthalene	ND <			10	1	10/17/07 15:06	JAP	2399288
C5-C8 Aliphatics (Unadjusted)	ND <			200	1	10/17/07 15:06	JAP	2399287
C9-C12 Aliphatics (Unadjusted)	ND <			100	1	10/17/07 15:06	JAP	2399287
C9-C10 Aromatics	ND <			30	1	10/17/07 15:06	JAP	2399288
C5-C8 Aliphatics (Adjusted)	ND <			200	1	10/17/07 15:06	JAP	2399288
C9-C12 Aliphatics (Adjusted)	ND <			100	1	10/17/07 15:06	JAP	2399288
Surr: 2,5-Dibromotoluene	123		%	70-130	1	10/17/07 15:06	JAP	2399287
Surr: 2,5-Dibromotoluene	113		%	70-130	1	10/17/07 15:06	JAP	2399288

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-5 **Collected:** 10/10/2007 9:30 **SPL Sample ID:** 07100405-08

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)					**MCL _VPH_EPH_ALL**	**Units: ug/L**		
Benzene	ND <			1	1	10/17/07 2:25	JAP	2400669
Toluene	ND <			1	1	10/17/07 2:25	JAP	2400669
Ethylbenzene	ND <			1	1	10/17/07 2:25	JAP	2400669
m,p-Xylene	ND <			2	1	10/17/07 2:25	JAP	2400669
o-Xylene	ND <			1	1	10/17/07 2:25	JAP	2400669
Methyl tert-butyl ether	ND <			8	1	10/17/07 2:25	JAP	2400669
Naphthalene	ND <			10	1	10/17/07 2:25	JAP	2400669
C5-C8 Aliphatics (Unadjusted)	ND <			200	1	10/17/07 2:25	JAP	2400670
C9-C12 Aliphatics (Unadjusted)	ND <			100	1	10/17/07 2:25	JAP	2400670
C9-C10 Aromatics	ND <			30	1	10/17/07 2:25	JAP	2400669
C5-C8 Aliphatics (Adjusted)	ND <			200	1	10/17/07 2:25	JAP	2400669
C9-C12 Aliphatics (Adjusted)	ND <			100	1	10/17/07 2:25	JAP	2400669
Surr: 2,5-Dibromotoluene	100		%	70-130	1	10/17/07 2:25	JAP	2400670
Surr: 2,5-Dibromotoluene	91.7		%	70-130	1	10/17/07 2:25	JAP	2400669

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Client Sample ID MW-6 **Collected:** 10/10/2007 10:00 **SPL Sample ID:** 07100405-09

Site: SUNOCO DUNS #0374-5593

Analyses/Method	Result	QUAL		Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE PETROLEUM HYDROCARBONS (WATER)				**MCL_VPH_EPH_ALL**		**Units: ug/L**		
Benzene	ND <			1	1	10/17/07 16:19	JAP	2399290
Toluene	ND <			1	1	10/17/07 16:19	JAP	2399290
Ethylbenzene	ND <			1	1	10/17/07 16:19	JAP	2399290
m,p-Xylene	ND <			2	1	10/17/07 16:19	JAP	2399290
o-Xylene	ND <			1	1	10/17/07 16:19	JAP	2399290
Methyl tert-butyl ether	ND <			8	1	10/17/07 16:19	JAP	2399290
Naphthalene	ND <			10	1	10/17/07 16:19	JAP	2399290
C5-C8 Aliphatics (Unadjusted)	ND <			200	1	10/17/07 16:19	JAP	2399289
C9-C12 Aliphatics (Unadjusted)	ND <			100	1	10/17/07 16:19	JAP	2399289
C9-C10 Aromatics	ND <			30	1	10/17/07 16:19	JAP	2399290
C5-C8 Aliphatics (Adjusted)	ND <			200	1	10/17/07 16:19	JAP	2399290
C9-C12 Aliphatics (Adjusted)	ND <			100	1	10/17/07 16:19	JAP	2399290
Surr: 2,5-Dibromotoluene	128		%	70-130	1	10/17/07 16:19	JAP	2399289
Surr: 2,5-Dibromotoluene	120		%	70-130	1	10/17/07 16:19	JAP	2399290

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count
>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

Quality Control Documentation

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Quality Control Report

SUNOCO, INC

5795-05

Analysis: Volatile Petroleum Hydrocarbons (water) **WorkOrder:** 07100405
Method: MA_VPH_EPH_ALL **Lab Batch ID:** R163972

Method Blank

RunID: HPCC_071016A-2399274 Units: ug/L
Analysis Date: 10/17/2007 11:39 Analyst: JAP

Analyte	Result	Rep Limit
C5-C8 Aliphatics (Unadjusted)	ND <	200
C9-C12 Aliphatics (Unadjusted)	ND <	100
Surr: 2,5-Dibromotoluene	119.4	70-130

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
07100405-01A	MW-1
07100405-02A	MW-101
07100405-03A	MW-102
07100405-04A	MW-201
07100405-05A	MW-202
07100405-06A	TRIP BLANK
07100405-07A	MW-204
07100405-09A	MW-6

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

RunID: HPCC_071016A-2399269 Units: ug/L
Analysis Date: 10/17/2007 10:12 Analyst: JAP

Analyte	LCS Spike Added	LCS Result	LCS Percent Recovery	LCSD Spike Added	LCSD Result	LCSD Percent Recovery	RPD	RPD Limit	Lower Limit	Upper Limit
C5-C8 Aliphatics (Unadjusted)	300	304	101	300	301	100	0.9	20	70	130
C9-C12 Aliphatics (Unadjusted)	220	216	98.3	220	212	96.2	2.1	20	70	130
Surr: 2,5-Dibromotoluene	100	123	123	100	111	111	10.4	30	70	130

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Quality Control Report

SUNOCO, INC

5795-05

Analysis: Volatile Petroleum Hydrocarbons (water) **WorkOrder:** 07100405
Method: MA_VPH_EPH_ALL **Lab Batch ID:** R163972

Method Blank

RunID: HPCC_071016A-2399273 Units: ug/L
Analysis Date: 10/17/2007 11:39 Analyst: JAP

Analyte	Result	Rep Limit
Benzene	ND <	1.0
C5-C8 Aliphatics (Adjusted)	ND <	200
C9-C10 Aromatics	ND <	30
C9-C12 Allphatics (Adjusted)	ND <	100
Ethylbenzene	ND <	1.0
m,p-Xylene	ND <	2.0
Methyl tert-butyl ether	ND <	8.0
Naphthalene	ND <	10
o-Xylene	ND <	1.0
Toluene	ND <	1.0
Surr: 2,5-Dibromotoluene	110.8	70-130

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
07100405-01A	MW-1
07100405-02A	MW-101
07100405-03A	MW-102
07100405-04A	MW-201
07100405-05A	MW-202
07100405-06A	TRIP BLANK
07100405-07A	MW-204
07100405-09A	MW-6

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

RunID: HPCC_071016A-2399270 Units: ug/L
Analysis Date: 10/17/2007 10:12 Analyst: JAP

Analyte	LCS Spike Added	LCS Result	LCS Percent Recovery	LCSD Spike Added	LCSD Result	LCSD Percent Recovery	RPD	RPD Limit	Lower Limit	Upper Limit
Benzene	25.0	19.1	76.2	25.0	19.0	75.8	0.6	19	70	130
C9-C10 Aromatics	40.0	36.3	90.7	40.0	35.5	88.7	2.2	20	70	130
Ethylbenzene	25.0	19.8	79.3	25.0	19.9	79.4	0.1	17.6	70	130
m,p-Xylene	100	79.8	79.8	100	79.5	79.5	0.4	17.4	70	130
Methyl tert-butyl ether	75.0	53.5	71.3	75.0	54.5	72.7	2.0	25.8	70	130
Naphthalene	50.0	42.3	84.6	50.0	41.6	83.2	1.7	27.4	70	130
o-Xylene	50.0	38.3	76.7	50.0	37.6	75.2	1.9	17.9	70	130
Toluene	75.0	58.0	77.3	75.0	57.6	76.8	0.6	17.5	70	130
Surr: 2,5-Dibromotoluene	100	108	108	100	105	105	3.3	30	70	130

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

10/24/2007 2:53:00 PM

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Quality Control Report

SUNOCO, INC

5795-05

Analysis: Volatile Petroleum Hydrocarbons (water) **WorkOrder:** 07100405
Method: MA_VPH_EPH_ALL **Lab Batch ID:** R164008

Method Blank

RunID: HPCC_071016B-2400668 Units: ug/L
Analysis Date: 10/17/2007 1:57 Analyst: JAP

Samples In Analytical Batch:

Lab Sample ID	Client Sample ID
07100405-08A	MW-5

Analyte	Result	Rep Limit
Benzene	ND <	1.0
C5-C8 Aliphatics (Adjusted)	ND <	200
C9-C10 Aromatics	ND <	30
C9-C12 Aliphatics (Adjusted)	ND <	100
Ethylbenzene	ND <	1.0
m,p-Xylene	ND <	2.0
Methyl tert-butyl ether	ND <	8.0
Naphthalene	ND <	10
o-Xylene	ND <	1.0
Toluene	ND <	1.0
Surr: 2,5-Dibromotoluene	91.2	70-130

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

RunID: HPCC_071016B-2400663 Units: ug/L
Analysis Date: 10/17/2007 0:35 Analyst: JAP

Analyte	LCS Spike Added	LCS Result	LCS Percent Recovery	LCSD Spike Added	LCSD Result	LCSD Percent Recovery	RPD	RPD Limit	Lower Limit	Upper Limit
Benzene	25.0	18.5	73.9	25.0	18.5	74.1	0.2	19	70	130
C9-C10 Aromatics	40.0	36.7	91.8	40.0	36.5	91.2	0.7	20	70	130
Ethylbenzene	25.0	19.0	76.0	25.0	19.0	75.9	0.1	17.6	70	130
m,p-Xylene	100	75.9	75.9	100	75.7	75.7	0.3	17.4	70	130
Methyl tert-butyl ether	75.0	58.1	77.5	75.0	58.2	77.6	0.2	25.8	70	130
Naphthalene	50.0	38.4	76.8	50.0	37.1	74.2	3.5	27.4	70	130
o-Xylene	50.0	37.6	75.2	50.0	37.2	74.4	1.1	17.9	70	130
Toluene	75.0	54.9	73.2	75.0	55.0	73.3	0.2	17.5	70	130
Surr: 2,5-Dibromotoluene	100	102	102	100	95.4	95.4	6.6	30	70	130

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

10/24/2007 2:53:01 PM

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Quality Control Report

SUNOCO, INC

5795-05

Analysis: Volatile Petroleum Hydrocarbons (water) **WorkOrder:** 07100405
Method: MA_VPH_EPH_ALL **Lab Batch ID:** R164008

Method Blank

RunID: HPCC_071016B-2400667 Units: ug/L
Analysis Date: 10/17/2007 1:57 Analyst: JAP

Samples in Analytical Batch:

Lab Sample ID	Client Sample ID
07100405-08A	MW-5

Analyte	Result	Rep Limit
C5-C8 Aliphatics (Unadjusted)	ND <	200
C9-C12 Aliphatics (Unadjusted)	ND <	100
Surr: 2,5-Dibromotoluene	100.1	70-130

Laboratory Control Sample/Laboratory Control Sample Duplicate (LCS/LCSD)

RunID: HPCC_071016B-2400664 Units: ug/L
Analysis Date: 10/17/2007 0:35 Analyst: JAP

Analyte	LCS Spike Added	LCS Result	LCS Percent Recovery	LCSD Spike Added	LCSD Result	LCSD Percent Recovery	RPD	RPD Limit	Lower Limit	Upper Limit
C5-C8 Aliphatics (Unadjusted)	300	291	96.9	300	289	96.4	0.5	20	70	130
C9-C12 Aliphatics (Unadjusted)	220	213	97.0	220	208	94.5	2.6	20	70	130
Surr: 2,5-Dibromotoluene	100	110	110	100	102	102	7.8	30	70	130

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

10/24/2007 2:53:01 PM

Sample Receipt Checklist

And

Chain of Custody

LAFAYETTE LABORATORY
500 AMBASSADOR CAFFERY PARKWAY
SCOTT, LA 70583
(337) 237-4775

Sample Receipt Checklist

Workorder:	07100405	Received By:	JLK
Date and Time Received:	10/11/2007 9:30:00 AM	Carrier name:	FedEx-Std 1 Day PM
Temperature:	4.5°C	Chilled by:	Water Ice

1. Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐	
2. Custody seals intact on shippping container/cooler?	Yes ☑	No ☐	Not Present ☐	
3. Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑	
4. Chain of custody present?	Yes ☑	No ☐		
5. Chain of custody signed when relinquished and received?	Yes ☑	No ☐		
6. Chain of custody agrees with sample labels?	Yes ☑	No ☐		
7. Samples in proper container/bottle?	Yes ☑	No ☐		
8. Sample containers intact?	Yes ☑	No ☐		
9. Sufficient sample volume for indicated test?	Yes ☑	No ☐		
10. All samples received within holding time?	Yes ☑	No ☐		
11. Container/Temp Blank temperature in compliance?	Yes ☑	No ☐		
12. Water - VOA vials have zero headspace?	Yes ☑	No ☐	VOA Vials Not Present ☐	
13. Water - Preservation checked upon receipt (except VOA*)?	Yes ☐	No ☐	Not Applicable ☑	

*VOA Preservation Checked After Sample Analysis

SPL Representative: _____ Contact Date & Time: _____

Client Name Contacted: _____

Non Conformance Issues: _____

Client Instructions: _____

0110405

Page 1 of 1

Chain of Custody Record

On-site Time:	Temp 0.0
Off-site Time:	Temp 0.0
Sky Conditions:	
Meteorological Events:	
Wind Speed: 0.0	Direc

Sunoco DUNS #: 03745593
Region: Northeast
State or Lead Regulatory Agency: MA DEP
Requested Due Date (mm/dd/yy): Standard
COC Tracking Number: 78445-2007

Lab Name:	SOUTHERN PETROLEUM LABORATORY	Facility Address:	88-90 SOUTH MAPLE STREET
Address:	500 Ambassador Caffery Parkway	Facility City, State:	WESTFIELD MA
	Scott, LA 70583	Site Lat/Long:	42.111223 -72.764268
Lab PM:	Eloy Granados	Sunoco PM Contact:	Bill Brochu
Tele/Fax:	717-656-2300 / 717-656-2681	Address:	41 Rumsford St,
Report Type & QC Level:	US EPA Region 5 EDMAN no QC		Concord, NH, 3301
E-mail EDD To:	SunocoENFOS@deltaenv.com	Tele/Fax:	(603) 715-1220 (866) 257-9205

Consultant/Contractor:	CORPORATE ENVIRONMENTAL		
Address:	127 Hartwell Street,		
	West Boylston, MA, 01583		
Consultant/Contractor Project No.:	5795-05		
Consultant/Contractor PM:	Scott VanderSea		
Tele/Fax:	508-835-8822	508-835-8812	
Invoice to:	CEA		

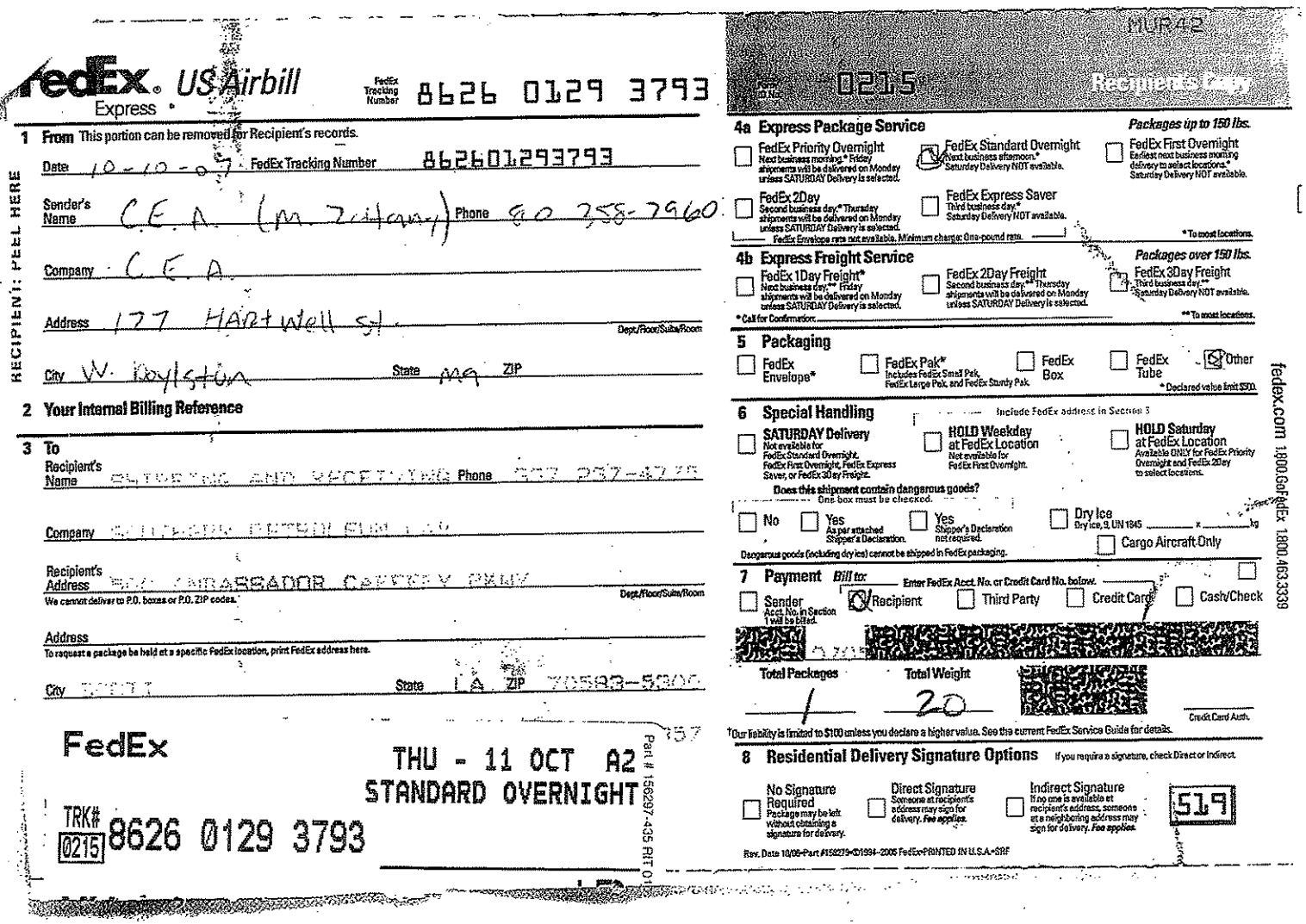
Lab Bottle Order No:

Item No.	Sample Description	Time	Date	Matrix: Liquid	Solid	Gas	Laboratory No.	No. of Containers	Preservative: HCL	Requested Analysis: Massachusetts VPH		Sample Point Lat/Long and Comments
1	MW-1	8:30	10-10-07	WG				3	X	X	3	
2	MW-101	10:45		WG				3	X	X	3	
3	MW-102	12:30		WG				3	X	X	3	
4	MW-201	11:30		WG				3	X	X	3	
5	MW-202	9:00		WG				3	X	X	3	
6	~~[illegible]~~ Trip Blank	—		WG				3	X	X	3	
7	MW-204	1:30		WG				3	X	X	3	
8	MW-3B	—		WG				0		X	0	
9	MW-4	—		WG				0		X	0	
10	MW-5	9:30		WG				3	X	X	3	W-1 (FS4)
11	MW-6	10.00	↓	WG				3	X	X	3	RS-76 (2W)

Sampler's Name:	Zoltany	Relinquished By / Affiliation	Date	Time	Accepted By / Affiliation	Date	Time
Sampler's Company:	CORPORATE ENVIRONMENTAL ADVIS	M. Zoltany CEA			FED Ex #826 0129 3783		
Shipment Date:		FED Ex	10/11/07	0900	[signature]	10/11/07	0900
Shipment Method:		[signature]	10/11/07	0932	[signature]	10/11/07	0932
Shipment Tracking No:							

Special Instructions: Must met MA DEP GW-1 Groundwater Standards. Email report to dazukauskas@cea-inc.com and svandersea@cea-inc. com

Custody Seals In Place (Yes) No | Temp Blank (Yes) No | Cooler Temperature on Receipt 4.5 °F/C | Trip Blank (Yes) No



FedEx US Airbill
Express

FedEx Tracking Number 8626 0129 3793

MUR42

Form ID No. 0215

Recipient's Copy

RECIPIENT: PEEL HERE

1 From This portion can be removed for Recipient's records.

Date 10-10-07 FedEx Tracking Number 862601293793

Sender's Name C.E.A. (m. Zuliani) Phone 800 258-7960

Company C.E.A.

Address 177 Hartwell St. Dept/Floor/Suite/Room

City W. Boylston State MA ZIP

2 Your Internal Billing Reference

3 To

Recipient's Name [illegible] Phone [illegible]

Company [illegible]

Recipient's Address [illegible] Dept/Floor/Suite/Room

We cannot deliver to P.O. boxes or P.O. ZIP codes.

Address

To request a package be held at a specific FedEx location, print FedEx address here.

City [illegible] State LA ZIP 70583-5300

4a Express Package Service *Packages up to 150 lbs.*

- FedEx Priority Overnight — Next business morning.* Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
- FedEx Standard Overnight — Next business afternoon.* Saturday Delivery NOT available. ☒
- FedEx First Overnight — Earliest next business morning delivery to select locations.* Saturday Delivery NOT available.
- FedEx 2Day — Second business day.* Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
- FedEx Express Saver — Third business day.* Saturday Delivery NOT available.

FedEx Envelope rate not available. Minimum charge: One-pound rate. *To most locations.

4b Express Freight Service *Packages over 150 lbs.*

- FedEx 1Day Freight* — Next business day.** Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
- FedEx 2Day Freight — Second business day.** Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
- FedEx 3Day Freight — Third business day.** Saturday Delivery NOT available.

*Call for Confirmation. **To most locations.

5 Packaging

- FedEx Envelope*
- FedEx Pak* — Includes FedEx Small Pak, FedEx Large Pak, and FedEx Sturdy Pak.
- FedEx Box
- FedEx Tube
- ☒ Other

*Declared value limit $500.

6 Special Handling Include FedEx address in Section 3

- SATURDAY Delivery — Not available for FedEx Standard Overnight, FedEx First Overnight, FedEx Express Saver, or FedEx 3Day Freight.
- HOLD Weekday at FedEx Location — Not available for FedEx First Overnight.
- HOLD Saturday at FedEx Location — Available ONLY for FedEx Priority Overnight and FedEx 2Day to select locations.

Does this shipment contain dangerous goods? One box must be checked.

- No
- Yes — As per attached Shipper's Declaration.
- Yes — Shipper's Declaration not required.
- Dry Ice — Dry Ice, 9, UN 1845 ____ x ____ kg

Dangerous goods (including dry ice) cannot be shipped in FedEx packaging.

- Cargo Aircraft Only

7 Payment *Bill to:* Enter FedEx Acct. No. or Credit Card No. below.

- Sender — Acct. No. in Section 1 will be billed.
- ☒ Recipient
- Third Party
- Credit Card
- Cash/Check

Total Packages: 1 Total Weight: 20

†Our liability is limited to $100 unless you declare a higher value. See the current FedEx Service Guide for details.

Credit Card Auth.

8 Residential Delivery Signature Options If you require a signature, check Direct or Indirect.

- No Signature Required — Package may be left without obtaining a signature for delivery.
- Direct Signature — Someone at recipient's address may sign for delivery. *Fee applies.*
- Indirect Signature — If no one is available at recipient's address, someone at a neighboring address may sign for delivery. *Fee applies.*

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fedex.com 1.800.GoFedEx 1.800.463.3339

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THU - 11 OCT A2
STANDARD OVERNIGHT

TRK# 0215 8626 0129 3793

Part # 156297-435 RIT 0

157

APPENDIX 3: REQUIRED VPH DATA REPORTING FORMAT/INFORMATION

SAMPLE INFORMATION

Matrix	☑ Aqueous ☐ Soil ☐ Sediment ☐ Other:		
Containers	☑ Satisfactory ☐ Broken ☐ Leaking		
Sample Preservatives	Aqueous	☑ ☑ pH≤2 ☐ pH> Comment:	
	Soil or Sediment	☐ ☐ Samples NOT preserved in Methanol or air-tight container	mL Methanol/g soil
		☐ Samples rec'd in Methanol: ☐ covering soil ☐ not covering soil	☐ 1:1 +/- 25%
		☐ Samples rec'd in air-tight container:	☐ Other:
Temperature	☑ Received on Ice ☐ Received at 4 °C ☐ Other:		

VPH ANALYTICAL RESULTS

Method for Ranges: MADEP VPH 04-1.1
Method for Target Analytes: 8021B
VPH Surrogate Standards

PID: 2,5-Dibromotoluene
FID: 2,5-Dibromotoluene

			Client ID	MW-1	MW-101	MW-102	MW-210
			SPL Number	7100405-01	07100405-02	07100405-03	07100405-04
			Date Collected	10/10/2007	10/10/2007	10/10/2007	10/10/2007
			Date Received	10/11/2007	10/11/2007	10/11/2007	10/11/2007
			Date Extracted	N/A	N/A	N/A	N/A
			Date Analyzed	10/17/2007	10/17/2007	10/17/2007	10/17/2007
			Dilution Factor	1	1	1	1
			% Moisture (soil)	N/A	N/A	N/A	N/A
RANGE/TARGET ANALYTE	Elution Range	RL	Units				
Unadjusted C5-C8 Aliphatics[1]	N/A	75	ug/L	ND	ND	ND	ND
Unadjusted C9-C12 Aliphatics[1]	N/A	100	ug/L	ND	ND	ND	ND
Benzene	C5-C8 Aliphatic	5	ug/L	ND	ND	ND	ND
Ethylbenzene	C9-C12 Aliphatic	5	ug/L	ND	ND	ND	ND
Methyl-tert-butylether	C5-C8 Aliphatic	15	ug/L	ND	ND	ND	ND
Naphthalene	N/A	10	ug/L	ND	ND	ND	ND
Toluene	C5-C8 Aliphatic	15	ug/L	ND	ND	ND	ND
m- & p- Xylenes	C9-C12 Aliphatic	20	ug/L	ND	ND	ND	ND
o-Xylene	C9-C12 Aliphatic	10	ug/L	ND	ND	ND	ND
C5-C8 Aliphatic Hydrocarbons[1,2]	N/A	75	ug/L	ND	ND	ND	ND
C9-C12 Aliphatic Hydrocarbons[1,3]	N/A	100	ug/L	ND	ND	ND	ND
C9-C10 Aromatic Hydrocarbons[1]	N/A	30	ug/L	ND	ND	ND	ND
PID Surrogate %Recovery	N/A	N/A	N/A	102	108	116	117
FID Surrogate %Recovery	C5-C8 Aliphatic	N/A	N/A	108	115	122	123
Surrogate Acceptance Range	N/A	N/A	N/A	70-130%	70-130%	70-130%	70-130%

[1]Hydrocarbon Range data exclude concentrations of any surrogate(s) and/or internal standards eluting in that range

[2]C_5-C_8 Aliphatic Hydrocarbons exclude the concentration of Target Analytes eluting in that range

[3]C_9-C_{12} Aliphatic Hydrocarbons exclude conc of Target Analytes eluting in that range AND concentration of C_9-C_{10} Aromatic Hydrocarbons

APPENDIX 3: REQUIRED VPH DATA REPORTING FORMAT/INFORMATION

	C5-C8 Aliphatic	C9-C12 Aliphatic	C9-C10 Aromatic
Percent Recovery - Matrix (Spike) - PID	N/A	N/A	N/A
Relative Percent Difference - PID Duplicate	N/A	N/A	N/A
Percent Recovery - Matrix (Spike) - FID	N/A	N/A	N/A
Relative Percent Difference - FID Duplicate	N/A	N/A	N/A
Percent Recovery - Fortified Blank (Spike) - PID	N/A	N/A	N/A
Percent Recovery - Fortified Blank (Spike) - FID	N/A	N/A	N/A

COMMENTS:

CERTIFICATION

Were all QA/QC procedures REQUIRED by the VPH Method followed?	☑ Yes	☐ No-Details Attached
Were all performance/acceptance standards for the required QA/QC procedures achieved?	☑ Yes	☐ No-Details Attached
Were any significant modifications made to the VPH method, as specified in Section 11.3?	☑ No	☐ Yes-Details Attached

I attest under the pains and penalties of perjury that, based upon my inquiry of those individuals immediately responsible for obtaining the information, the material contained in this report is, to be best of my knowledge and belief, accurate and complet

SIGNATURE: _____ POSITION: GC/MS Analyst

PRINTED NAME: Jeremy Palmer DATE: 10/18/07

APPENDIX 3: REQUIRED VPH DATA REPORTING FORMAT/INFORMATION

SAMPLE INFORMATION

Matrix	☑ Aqueous ☐ Soil ☐ Sediment ☐ Other:		
Containers	☑ Satisfactory ☐ Broken ☐ Leaking:		
Sample Preservatives	Aqueous	☑ ☑ pH≤2 ☐ pH>2 Comment:	
	Soil or Sediment	☐ ☐ Samples NOT preserved in Methanol or air-tight container	mL Methanol/g soil
		☐ Samples rec'd in Meth ☐ covering soil ☐ not covering soil	☐ 1:1 +/- 25%
		☐ Samples rec'd in air-tight container	☐ Other:
Temperature	☑ Received on Ice ☐ Received at 4 °C ☐ Other:		

VPH ANALYTICAL RESULTS

Method for Ranges: MADEP VPH 04-1.1
Method for Target Analytes: 8021B
VPH Surrogate Standards

PID: 2,5-Dibromotoluene
FID: 2,5-Dibromotoluene

			Client ID	MW-6			
			SPL Number	07100405-09			
			Date Collected	10/10/2007			
			Date Received	10/11/2007			
			Date Extracted	N/A	N/A	N/A	N/A
			Date Analyzed	10/17/2007			
			Dilution Factor	1			
			% Moisture (soil)	N/A	N/A	N/A	N/A
RANGE/TARGET ANALYTE	**Elution Range**	**RL**	**Units**				
Unadjusted C5-C8 Aliphatics[1]	N/A	75	ug/L	ND	ND	ND	ND
Unadjusted C9-C12 Aliphatics[1]	N/A	100	ug/L	ND	ND	ND	ND
Benzene	C5-C8 Aliphatic	5	ug/L	ND	ND	ND	ND
Ethylbenzene	C9-C12 Aliphatic	5	ug/L	ND	ND	ND	ND
Methyl-tert-butylether	C5-C8 Aliphatic	15	ug/L	ND	ND	ND	ND
Naphthalene	N/A	10	ug/L	ND	ND	ND	ND
Toluene	C5-C8 Aliphatic	15	ug/L	ND	ND	9.3	ND
m- & p- Xylenes	C9-C12 Aliphatic	20	ug/L	ND	ND	ND	ND
o-Xylene	C9-C12 Aliphatic	10	ug/L	ND	ND	ND	ND
C5-C8 Aliphatic Hydrocarbons[2]	N/A	75	ug/L	ND	ND	ND	ND
C9-C12 Aliphatic Hydrocarbons[1,3]	N/A	100	ug/L	ND	ND	ND	ND
C9-C10 Aromatic Hydrocarbons[1]	N/A	30	ug/L	ND	ND	ND	ND
PID Surrogate %Recovery	N/A	N/A	N/A	120	102	103	106
FID Surrogate %Recovery	C5-C8 Aliphatic	N/A	N/A	128	98.6	103	105
Surrogate Acceptance Range	N/A	N/A	N/A	70-130%	70-130%	70-130%	70-130%

[1]Hydrocarbon Range data exclude concentrations of any surrogate(s) and/or internal standards eluting in that range

[2]C_5-C_8 Aliphatic Hydrocarbons exclude the concentration of Target Analytes eluting in that range

[3]C_9-C_{12} Aliphatic Hydrocarbons exclude conc of Target Analytes eluting in that range AND concentration of C_9-C_{10} Aromatic Hydrocarbons

APPENDIX 3: REQUIRED VPH DATA REPORTING FORMAT/INFORMATION

	C5-C8 Aliphatic	C9-C12 Aliphatic	C9-C10 Aromatic
Percent Recovery - Matrix (Spike) - PID	N/A	N/A	N/A
Relative Percent Difference - PID Duplicate	N/A	N/A	N/A
Percent Recovery - Matrix (Spike) - FID	N/A	N/A	N/A
Relative Percent Difference - FID Duplicate	N/A	N/A	N/A
Percent Recovery - Fortified Blank (Spike) - P	N/A	N/A	N/A
Percent Recovery - Fortified Blank (Spike) - F	N/A	N/A	N/A

COMMENTS:

CERTIFICATION

Were all QA/QC procedures REQUIRED by the VPH Method followed?	☑ Yes	☐ No-Details Attached
Were all performance/acceptance standards for the required QA/QC procedures achieved?	☑ Yes	☐ No-Details Attached
Were any significant modifications made to the VPH method, as specified in Section 11.3?	☑ No	☐ Yes-Details Attached

I attest under the pains and penalties of perjury that, based upon my inquiry of those individuals immediately responsible for obtaining the information, the material contained in this report is, to be best of my knowledge and belief, accurate and complet

SIGNATURE: [signature] POSITION: GC Vol Analyst

PRINTED NAME: Jeremy Palmer DATE: 10/18/07

APPENDIX 3: REQUIRED VPH DATA REPORTING FORMAT/INFORMATION

SAMPLE INFORMATION

Matrix	☑ Aqueous	☐ Soil	☐ Sediment	☐ Other:
Containers	☑ Satisfactory	☐ Broken	☐ Leaking:	
Sample Preservatives	Aqueous	☑ ☑ pH≤2	☐ pH>2	Comment:
	Soil or Sediment	☐ ☐ Samples NOT preserved in Methanol or air-tight container		mL Methanol/g soil
		☐ Samples rec'd in Meth ☐ covering soil ☐ not covering soil		☐ 1:1 +/- 25%
		☐ Samples rec'd in air-tight container		☐ Other:
Temperature	☑ Received on Ice	☐ Received at 4 °C	☐ Other:	

VPH ANALYTICAL RESULTS

Method for Ranges: MADEP VPH 04-1.1
Method for Target Analytes: 8021B
VPH Surrogate Standards

PID: 2,5-Dibromotoluene
FID: 2,5-Dibromotoluene

			Client ID	MW-202	TRIP BLANK	MW-204	MW-5
			SPL Number	07100405-05	07100405-06	07100405-07	07100405-08
			Date Collected	10/10/2007	10/10/2007	10/10/2007	10/10/2007
			Date Received	10/11/2007	10/11/2007	10/11/2007	10/11/2007
			Date Extracted	N/A	N/A	N/A	N/A
			Date Analyzed	10/17/2007	10/17/2007	10/17/2007	10/17/2007
			Dilution Factor	1	1	1	1
			% Moisture (soil)	N/A	N/A	N/A	N/A
RANGE/TARGET ANALYTE	Elution Range	RL	Units				
Unadjusted C5-C8 Aliphatics[1]	N/A	75	ug/L	ND	ND	ND	ND
Unadjusted C9-C12 Aliphatics[1]	N/A	100	ug/L	ND	ND	ND	ND
Benzene	C5-C8 Aliphatic	5	ug/L	ND	ND	ND	ND
Ethylbenzene	C9-C12 Aliphatic	5	ug/L	ND	ND	ND	ND
Methyl-tert-butylether	C5-C8 Aliphatic	15	ug/L	ND	ND	ND	ND
Naphthalene	N/A	10	ug/L	ND	ND	ND	ND
Toluene	C5-C8 Aliphatic	15	ug/L	ND	ND	ND	ND
m- & p- Xylenes	C9-C12 Aliphatic	20	ug/L	ND	ND	ND	ND
o-Xylene	C9-C12 Aliphatic	10	ug/L	ND	ND	ND	ND
C5-C8 Aliphatic Hydrocarbons[1,2]	N/A	75	ug/L	ND	ND	ND	ND
C9-C12 Aliphatic Hydrocarbons[1,3]	N/A	100	ug/L	ND	ND	ND	ND
C9-C10 Aromatic Hydrocarbons[1]	N/A	30	ug/L	ND	ND	ND	ND
PID Surrogate %Recovery	N/A	N/A	N/A	113	115	113	91.7
FID Surrogate %Recovery	C5-C8 Aliphatic	N/A	N/A	122	126	123	100
Surrogate Acceptance Range	N/A	N/A	N/A	70-130%	70-130%	70-130%	70-130%

[1]Hydrocarbon Range data exclude concentrations of any surrogate(s) and/or internal standards eluting in that range

[2]C_5-C_8 Aliphatic Hydrocarbons exclude the concentration of Target Analytes eluting in that range

[3]C_9-C_{12} Aliphatic Hydrocarbons exclude conc of Target Analytes eluting in that range AND concentration of C $_8$-C_{10} Aromatic Hydrocarbons

APPENDIX 3: REQUIRED VPH DATA REPORTING FORMAT/INFORMATION

	C5-C8 Aliphatic	C9-C12 Aliphatic	C9-C10 Aromatic
Percent Recovery - Matrix (Spike) - PID	N/A	N/A	N/A
Relative Percent Difference - PID Duplicate	N/A	N/A	N/A
Percent Recovery - Matrix (Spike) - FID	N/A	N/A	N/A
Relative Percent Difference - FID Duplicate	N/A	N/A	N/A
Percent Recovery - Fortified Blank (Spike) - P	N/A	N/A	N/A
Percent Recovery - Fortified Blank (Spike) - F	N/A	N/A	N/A

COMMENTS:

CERTIFICATION

Were all QA/QC procedures REQUIRED by the VPH Method followed?	☑ Yes	☐ No-Details Attached
Were all performance/acceptance standards for the required QA/QC procedures achieved?	☑ Yes	☐ No-Details Attached
Were any significant modifications made to the VPH method, as specified in Section 11.3?	☑ No	☐ Yes-Details Attached

I attest under the pains and penalties of perjury that, based upon my inquiry of those individuals immediately responsible for obtaining the information, the material contained in this report is, to be best of my knowledge and belief, accurate and complete.

SIGNATURE: _____ POSITION: GC VOA Analyst

PRINTED NAME: Jenney Palmer DATE: 10/18/07

APPENDIX C

METHOD 3 RISK CHARACTERIZATION

SUNOCO STATION
88-90 South Maple Street
Westfield, Massachusetts

Release Tracking Numbers 1-15718 and 1-16079

January 8, 2008

Prepared for:
SUNOCO, INC. (R&M)
4 Bellows Road, PO Box 1262
Westborough, Massachusetts 01581

Prepared by:
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CEA File No. 5795-05

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ACRONYMS and ABBREVIATIONS

ACEC	Area of Critical Environmental Concern
AST	Above Ground Storage Tank
AUL	Activity and Use Limitation
BWSC	Bureau of Waste Site Cleanup
CEA	Corporate Environmental Advisors, Inc.
CMR	Code of Massachusetts Regulations
COCs	Chemicals of Concern
ELCR	Excess Lifetime Cancer Risk
EPA	United States Environmental Protection Agency
EPH	Extractable Petroleum Hydrocarbons
EPC	Exposure Point Concentration
GW-1, 2, and 3	Groundwater Categories
HI	Hazard Index
IRA	Immediate Response Action
LSP	Licensed Site Professional
MADEP	Massachusetts Department of Environmental Protection
MCP	Massachusetts Contingency Plan
MDL	Method Detection Limit
NAPL	Non-Aqueous Phase Liquid
OHM	Oil and Hazardous Materials
OSHA	Occupational Safety and Health Administration
PID	Photoionization Detector
PVC	Polyvinyl-Chloride
ppb	parts per billion
ppm(v)	parts per million (by volume)
RAF	Relative Absorption Factor
RAM	Release Abatement Measure
RAO	Response Action Outcome
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RNF	Release Notification Form
RTN	Release Tracking Number
S-1, 2, and 3	Soil Categories
TOVs	Total Organic Vapors
TPH	Total Petroleum Hydrocarbons
TSD	Treatment, Storage and Disposal Facility
USGS	United States Geologic Survey
UST	Underground Storage Tank
UCL	Upper Concentration Limit
VPH	Volatile Petroleum Hydrocarbons

1.0 INTRODUCTION

On behalf of Sunoco, Inc. (R&M), Corporate Environmental Advisors, Inc. (CEA) has prepared this Method 3 Risk Characterization (Method 3) for the Sunoco Service Station property located at 88-90 South Maple Street in Westfield, Massachusetts (herein the Site). The property is listed as a disposal site with the Massachusetts Department of Environmental Protection (MADEP) due to the failure of the tank tightness test conducted on the regular unleaded dispenser line associated with the underground storage tank (UST) system on April 12, 2005. Upon repair of the dispenser line, the MADEP was notified of the threat of release condition on April 15, 2005 and release tracking number (RTN) **1-15718** was assigned to the Site.

On November 17, 2005, sampling of the soil stockpile associated with the petroleum release revealed the presence of polychlorinated biphenyls (PCBs) at 2.31 milligrams per kilogram (mg/kg) which exceeded the Massachusetts Contingency Plan (MCP) RCS-1 reportable concentration of 2 mg/kg. PCBs were also reported at a concentration of 32.05 mg/kg in a composite sample (T1) collected during additional excavation conducted at the Site in November 2005. A Release Notification Form (RNF) was submitted to MADEP on February 8, 2006, and RTN **1-16079** was assigned to the PCB condition.

Response actions conducted to address the OHM impacts at the Site included excavation and off-site removal of petroleum-impacted soils, and an extensive program of soil and groundwater monitoring for volatile petroleum hydrocarbon (VPH) compounds via MADEP methods. The purpose of this risk characterization is to assess the level of risk associated with the residual OHM under current and future site conditions. Information compiled as part of this Method 3 is used to determine if a condition of No Significant Risk (NSR) exists or has been achieved at the Site, and whether an Activity and Use Limitation (AUL) is warranted to maintain the condition of NSR at the Site.

2.0 BACKGROUND

On June 13, 1988, three 10,000 gallon USTs were removed from the Site. Filed screening of soils encountered in the tank excavation exhibited TIC readings greater than 100 ppmv. On June 21, 1988, MADEP issued a Notice of Responsibility (NOR) to F.L. Roberts & Company, Inc. (F.L. Roberts) which assigned RTN **1-0489** to the Site. On October 25, 1989, MADEP requested a Phase 1 Limited Site Assessment be conducted for the Site by January 25, 1990. A sixty-day extension was subsequently approved by the MADEP.

In 1990, limited assessment activities were conducted at the Site including advancement of soil borings and installation of four overburden monitoring wells (MW-1 through MW-4). Groundwater samples collected from the wells were sampled for benzene, toluene, ethylbenzene, xylenes (BTEX), methyl tertiary butyl ether (MTBE) and acetone. On April 27, 1990, a Phase I Limited Site Assessment Report was submitted to MADEP which recommended that further assessment be conducted to evaluate the presence of acetone and MTBE in groundwater.

In March 1993, two additional monitoring wells (MW-5 and MW-6) were installed at the Site and groundwater sampling was conducted. On April 28, 1993, a Site Assessment Report was submitted to MADEP which concluded that no spillage of gasoline had occurred at the Site based on the results of the groundwater sampling activities. On August 2, 1995, a Phase I Completion Report and RAO Statement were submitted to MADEP, on behalf of F.L. Roberts. The report(s) concluded that a condition of NSR existed at the Site.

On April 12, 2005, a tank tightness test failed on the regular unleaded dispenser line associated with the UST system. On April 15, 2005, the MADEP was notified of the threat of release condition, and RTN **1-15718** was issued to the Site. On April 19, 2005, the MADEP issued a NOR to Sunoco stating that Immediate Response Action (IRA) activities must be completed by April 15, 2006.

On April 14 and 15, 2005, CEA supervised the excavation and repair of the dispenser piping. Soil was excavated from an approximate 9-foot long and 3.5-foot wide trench. On April 27, 2005, the trench was expanded to expose the regular and ultra gasoline dispenser lines, to check for potential leaks and to install cathodic protection. Approximately 5 cubic yards of petroleum-impacted soil was generated between April 15 and 27, 2005. Composite soil samples collected from the limits of the excavation were submitted to Accutest Laboratories of New England (Accutest), a Massachusetts Certified Laboratory for analysis of volatile petroleum hydrocarbons (VPH) via MADEP methods. An IRA Completion Report was submitted to MADEP for RTN **1-15718** on February 7, 2006.

In November 2005, additional soil excavation was conducted at the Site. On November 17, 2005, sampling of the soil stockpile revealed the presence of PCBs at 2.31 mg/kg which exceeded the MCP RCS-1 of 2 mg/kg, which constituted a 120-day reporting condition. PCBs were also reported at a concentration of 32.05 mg/kg in composite sample T1 collected from the excavation area. On February 8, 2006, a RNF was submitted to MADEP for the PCB release condition and RTN **1-16079** was assigned to the Site.

On April 24, 2006, the Phase I Initial Site Investigation and Tier Classification were submitted to MADEP for RTN **1-15718**. The Phase I Report concluded that VPH fractions were present in soils and groundwater above Method 1 S-1 Standards and/or Method 1 GW-2 and/or GW-3 standards, respectively, and that comprehensive response actions were necessary at the Site. The Site was classified as a Tier II disposal site with an NRS score of 288. On February 8, 2007, RTN **1-16079** was linked to the RTN **1-15718**, the primary RTN for the Site. In May, July and October 2007, groundwater sampling was conducted at the Site to assess post-excavation groundwater quality conditions.

A Method 3 Risk Characterization was selected to characterize the risk of harm at the disposal site. This risk characterization follows DEP's *Guidance for Disposal Site Risk Characterization in Support of the Massachusetts Contingency Plan*, BWSC/ORS-95-141 (DEP, 1995 as amended April 1996) and the MCP. Pursuant to DEP guidelines and requirements of the MCP, this Method 3 is comprised of:

- Characterization of Risk to Safety;
- Characterization of Risk to Human Health;
- Characterization of Risk to Public Welfare; and
- Characterization of Risk to the Environment: Stage I Environmental Screening.

3.0 SITE INFORMATION

3.1 Identification of Current Site Activities and Uses

The Sunoco Service Station Site is located in a commercial and residential area of Westfield. The Site operates as retail gasoline service station and a car wash. The property consists of 56,628 square feet and is developed by a 1,728 square foot, one story concrete cinderblock building built in 1988, and consisting of convenience store retail sales floor, offices, storage space, and restrooms. Also located to the rear of the Site is a 3,120-square foot one story, concrete cinderblock building built in 1985 which consists of an automated carwash.

Residential properties abut the Site to the east and across South Maple Street to the north and northeast. A wooded area abuts the Site to the south. Commercial properties are located along South Maple and Mill Street to the west of the Site. Overhead telephone utilities enter the Site from South Maple Street. An underground electric line runs from the street to a transformer on the eastern side of the property then to the convenience store building. The station building is heated with natural gas. Water service and the sewer line enter the Site from South Maple Street. Stormwater runoff is managed through catch basins located on South Maple Street, which discharge to the municipal drain system.

Six gasoline dispenser islands exist at the Site which are piped to three 10,000-gallon USTs located in the southern portion of the property behind the convenience store. **Figure 2A (Site Layout)** depicts pertinent Site features.

According to the MADEP **Site Scoring Map (Figure 3)** and the **21E Resource Priority Map (Figure 4)**, the Site is not located within an Interim Wellhead Protection Area (IWPA), Approved Zone 2, Zone A of a Class A Surface Water Body, or within a Potential Drinking Water Source Area. No known private drinking water supply wells are located within 500 feet of the site. The Site and surrounding properties are supplied with municipal water and sewer service provided by the City of Westfield.

The closest surface water body to the Site is Little River which is located approximately 200 feet to the south of the Site. Protected Open Space is located within approximately 1,000 feet to the south, and within approximately a half-mile to the west and east of the Site. The Site is also located within a FEMA 100-year floodplain, to the south and southeast. According to the Natural Heritage and Endangered Species Program (NHESP) Southwick Quad (October 1, 2006), a priority habitat of rare species and estimated habitat of rare wildlife is located within 0.5 miles west of the Site.

3.2 Identification of Reasonably Foreseeable Future Site Activities and Uses

In consideration of past uses, location and zoning constraints, future use of the Site is expected to be commercial. However, for purposes of this risk characterization, it is assumed that future use of the property is unrestricted and may include commercial, industrial and/or residential use.

3.3 Identification of Site Groundwater and Soil Categories

The MADEP has developed specific categories applicable to soil and groundwater for use in the characterization of risk posed by disposal sites. These categories, which describe the potential for exposure to OHM, are used to identify the applicable standards and to determine the need for additional response actions. The MCP soil and groundwater categories are considered general indicators of exposure potential in this Method 3.

Groundwater beneath the Site is categorized based upon its potential for human consumption, potential to volatilize into indoor air, and its potential to discharge to surface water. Soils at the disposal site are categorized based on current and future potential receptors, frequency of use, intensity of activities, and accessibility of the soils.

3.3.1 Applicable MCP Groundwater Categories

Three groundwater categories (GW-1, 2, and 3) have been established in the MCP for the purpose of describing three types of OHM exposure, in accordance with the criteria set forth in Section 40.0932 of the MCP:

- Category GW-1 applies to groundwater in a Current or Potential Drinking Water Source Area.
- Category GW-2 applies to groundwater located less than 15 feet below ground surface and within 30 feet laterally of an occupied building or structure, due to the potential for volatiles in groundwater to travel through soil gas into indoor air.
- Category GW-3 applies to groundwater which has the potential to reach surface water bodies of the Commonwealth.

More than one category may apply to groundwater at disposal sites. At a minimum, all groundwater in Massachusetts is classified as GW-3. Therefore, groundwater Category GW-3 applies to the entire Site. Depth to groundwater has been measured at less then 15 feet below grade. Therefore, groundwater Category GW-2 applies to groundwater at the site that is within 30 feet of the station building.

The Site is not located within a current or potential drinking water source area. Therefore, Category GW-1 does not apply to groundwater beneath the Site.

3.3.2 Applicable MCP Soil Categories

According to Section 40.0933 of the MCP, three soil categories (S-1, 2, and 3) have been established in the MCP to assess potential exposures based upon conservative exposure scenarios that factor the activities of children and adults on the site and the accessibility of the impacted soil. Category S-1 soils have the highest potential for exposure, and S-3 category soils the lowest. Soils located at a depth of 0-3 feet below grade are considered "accessible" in unpaved areas. Soils located at a depth of 3-15 feet below grade in unpaved areas and 0-15 feet below grade in paved areas are considered "potentially accessible." Soils located at a depth of greater than 15 feet below grade or beneath the footprint of a building or other permanent structure are considered "isolated subsurface soil" (310 CMR 40.0933).

The Site is currently in use as a gasoline service station and convenience store. Therefore, under current site conditions, the *frequency of use for both children and adults* is characterized as *high*. Current site activities and uses are characterized as *low intensity* for both adults and children since it is unlikely that activities are occurring at the Site on a regular basis which would result in soil disturbance. Under current Site conditions, unpaved soils from 0-3' below grade are categorized as S-2 whereas paved soils from 0-3' are S-3. Note that with the exception of a number of landscaped areas, the Site is completely covered with pavement.

Future uses of the Site are considered to be unrestricted and may be commercial, industrial or residential. Therefore, under future site conditions, the *frequency of use for both children and adults* is characterized as *high*. Future site activities and uses are also characterized as *high intensity* for both adults and children since it is possible that future activities may occur at the Site which would result in soil disturbance throughout the 0-15 foot depth interval. Therefore, soil category S-1 applies to all soils located from 0-15 feet below grade for unrestricted future site uses. The following soil categories apply to the Site:

Soil Exposure Point	**Categories (Current/Future)**
Soils 0-3 Feet (unpaved):	S-2/S-1 (GW-3)
Soils 0-3 Feet (paved):	S-3/S-1 (GW-3)
Soils 3-15 Feet (paved & unpaved):	S-3/S-1 (GW-3)
Soils > 15 Feet, beneath footprint of building or in right-of-way	S-3/S-3 (GW-3)

4.0 CHARACTERIZATION OF RISK TO SAFETY

Pursuant to 310 CMR 40.0960, an evaluation of risk of harm to safety is conducted herein to assess whether any unsafe conditions are present at the Site due to the release of OHM and/or due to assessment or response actions conducted at the Site which:

1. have the potential to increase the exposure of a receptor to the OHM present at the Site, and/or
2. pose a threat of physical harm or bodily injury to the applicable receptors.

The evaluation of risk of harm to safety is based upon the information and data collected at the Site relative to site conditions, presence of OHM, and applicable receptors and exposure pathways. This information is compared to applicable or suitably analogous safety standards to determine whether any unsafe conditions are present at the Site.

For purposes of this evaluation, suitably analogous safety standards are considered: (1) state and federal rules and regulations related to the proper management and storage of potentially hazardous materials, and (2) safety standards related to the management of potentially hazardous site conditions such as open excavations. Note that potentially unsafe conditions at the Site which are not related to the release of OHM or related response actions are not considered to pose a risk of harm to safety, pursuant to M.G.L. Ch21E. Based on site reconnaissance activities, there are no:

- Rusted or corroded drums or containers, open pits, lagoons or other dangerous structures,
- Threats of fire or explosion, including the presence of explosive vapors resulting from the release of OHM, or
- Any uncontained materials which exhibit the characteristics of corrosivity, reactivity or flammability described in 310 CMR 40.0347.

Therefore, a condition of NSR of harm to safety exists at the Site.

5.0 CHARACTERIZATION OF RISK TO HUMAN HEALTH

This human health risk characterization has been completed to assess the potential human health impacts from exposure to OHM-impacted soils at the disposal site. It includes:

- Site background information on current and reasonably foreseeable land use, and soil and groundwater categories.
- Hazard identification to address selection of the Chemicals of Concern (COCs) associated with the Site, toxicity profiles or descriptive summaries are provided for each COC, and applicable or suitability analogous health standards are identified.
- A summary of dose-response data for subchronic, chronic and carcinogenic effects for the COCs.
- An exposure assessment that identifies human receptors who may come in contact with the COCs. Exposure profiles that summarize likely exposures and estimates of dose (the amount of chemical absorbed into the body) by people who are exposed.
- Estimates of hazard indices and excess lifetime cancer risk from exposures to the COCs.
- A discussion of the uncertainties associated with estimates of dose and risk.

5.1 Hazard Identification

5.1.1 Description of Soil Impacts

In April 2005, petroleum-impacted soils were initially encountered at relatively shallow depths in the vicinity of the product dispenser in Excavation Area No. 1 (**Figure 2A**). Excavation activities conducted in April 2005 and November 2005 removed the OHM-impacted soils represented by soil samples Sample-3 and '2 S-B-2'. However, petroleum-impacted soils continued to be encountered in this area, as indicated in the results for soil sample R-7 (7') which was collected in the same general area in November 2005.

Table 1A presents the VPH soil analytical results for the Site. This table identifies which soil samples represent soils which have been over-excavated at the Site, and thus have been eliminated from further consideration in this Method 3. As indicated in **Table 1A**, elevated levels of the C5-C8 aliphatic and C9-C10 aromatic fractions currently exist at soil sample location R-7 (7') (i.e., the former location of '2 S-B-2'). No other soil samples collected anywhere at the Site revealed significant levels of VPH impacts.

Tables 1B and 1C present the soil analytical results for PCBs and metals at the Site. PCB impacts have been encountered in shallow soils (2-3 feet below grade) located to the right of the convenience store, as indicated by soil sample T1 composite which revealed PCBs at 32.05 mg/kg. Three additional composite soil samples collected within the T1 composite sampling area (T1-A, T1-B and T1-C) also revealed elevated PCB levels. PCBs were not detected elsewhere at the Site above the RCS-1. No metals have been identified in soils above MADEP background levels for "natural soils" (**Table 1C**).

5.1.2 Description of Groundwater Impacts

Table 2A presents the recent VPH groundwater analytical results for the Site. As indicated in **Table 2A,** there are no current VPH impacts to groundwater. Low levels of VPH compounds were detected in MW-3B and MW-6 during the recent May 8, 2007 sampling event. However, with the exception of MTBE, all other VPH compounds were below laboratory reporting limits (RLs) during the July 2007 sampling event. All VPH compounds including naphthalene were below laboratory RLs during the October 2007 sampling event.

Note that assessment activities conducted for RTN **1-0489** had identified relatively low levels of lead in groundwater samples collected at the Site. However, as indicated in **Table 2B**, groundwater samples collected from downgradient monitoring wells MW-4 and MW-6 in August 2005 and analyzed for RCRA 8 metals revealed detectable levels of barium, only. Barium was reported at concentrations of 134 ug/L and 109 ug/L in wells MW-4 and MW-6, respectively, well below the Method 1 GW-3 Standard of 50,000 ug/L. No other metals (including lead) were detected in the groundwater samples.

5.1.3 Description of Indoor Air Impacts

Based on the concentrations and location of the VPH impacts to soil and groundwater at the Site, no indoor air impacts due to OHM in soils or groundwater are likely to occur on the property.

5.1.4 Background Concentrations

As defined in the MCP, background concentrations are those levels of OHMs that would exist in the absence of the disposal site and are:

- ubiquitous and consistently present in the environment at and in the vicinity of the disposal site of concern, and attributable to geologic or ecological conditions, or atmospheric deposition of industrial process or engine emissions;
- attributable to coal ash or wood ash associated with fill material;
- releases to groundwater from a public water supply system; or
- petroleum residues that are incidental to normal operation of motor vehicles.

In accordance with DEP's *Background Levels of Polycyclic Aromatic Hydrocarbons (PAHs) and Metals in Soil-Technical Update* (DEP, 2002e), PAHs and/or metals detected in soil samples are typically compared to MADEP-established background concentrations for "natural soils" to assess whether the occurrence of such compounds are likely to be attributable to background conditions. Due to the nature of the release (i.e., gasoline), metals and PAHs are not considered to be chemicals of concern (COCs) for soil or groundwater at the Site. The COCs at this Site are VPH compounds and PCBs which have been detected in soils in the vicinity of the pump islands and UST area at the Site. Note that barium has recently been detected in groundwater at relatively low levels, and is likely to be a background condition.

For purposes of this RAO, all OHM currently present in soil at the Site, above laboratory reporting limits, are considered to be above site-specific background levels. There are no current impacts to groundwater.

5.1.5 Chemicals of Concern

Soil laboratory analytical results considered in this Method 3 were collected between March 1993 and June 2007. Groundwater analytical results are available for this Site dating back to March 1990 as part of assessment activities conducted for RTN **1-0489** which was closed out in August 1995. Soil data collected since April 2005 were collected to address RTNs **1-15718 & 1-16079.** All available soil data deemed representative of current soil quality conditions are considered in this Method 3. The groundwater data considered in this Method 3 were collected between 2005 and 2006, and are presented in **Tables 2A and 2B.**

All VPH, VOC, EPH and metals constituents reported in Site media above laboratory reporting limits (RLs) are considered COCs and are carried through the risk characterization unless:

- the OHM is present at a low concentration and low frequency (<5%),
- the OHM is present at a concentration consistent with background and is not associated with historical activities at the property, or
- the OHM is associated with field or laboratory contamination.

Table 3 presents the selection of COCs for soils at the disposal site. This table identifies the maximum and average soil concentrations obtained from 0-15' below grade across the Site. For purposes of this Method 3, all VPH constituents reported above laboratory RLs are included as COCs for soils. All metals were below MADEP background levels for "natural soils" and are excluded as COCs. There are currently no impacts to groundwater at the Site.

5.1.6 Toxicity Profiles

Toxicity profiles for COCs at the disposal site provide descriptive summaries of adverse health effects associated with exposure to these compounds. Toxicological properties provide background information on the derivation of public health standards and include dose-response information for the COCs. References used to obtain toxicity data include the following sources:

- Integrated Risk Information System (IRIS)(EPA, 2007), a database maintained by the EPA;
- Implementation of the MADEP VPH/EPH Approach – Final Policy (MADEP, 2002);
- Massachusetts Contingency Plan, 310 CMR 40.0000 (MADEP, 2006);
- Guidance for Disposal Site Risk Characterization, In Support of the MCP. (MADEP, 1995);
- Documentation for the Development of the MCP Numerical Standards (MADEP, 2007); and
- relevant information provided by other sources as noted.

Toxicity profiles for the COCs are included in **Appendix B**. The May 2002 *Updated Petroleum Hydrocarbon Fraction Toxicity Values for the VPH/EPH/APH Methodology* (MADEP 2002) is included in **Appendix B** in lieu of toxicity profiles for the carbon fractions.

5.2 Dose-Response Assessment

A summary of toxicity data including the chronic and subchronic reference dose (RfD), reference concentrations (RfC), critical effects/target organs, oral slope factor, inhalation cancer unit risk, and weight-of-evidence classes of the soil COCs are presented in **Table 4.** This information is later coupled with knowledge of the nature and magnitude of potential exposures to characterize risk. The dose-response assessment describes the observed effects in humans and/or laboratory animals associated with particular exposures of the COCs.

The dose-response information is divided into three major categories:

- Toxicity information associated with threshold (non-carcinogenic) health effects.
- Toxicity information concerning carcinogenicity, either from human epidemiological data or from laboratory studies.
- The Relative Absorption Factors (RAFs) used to relate the toxicity information identified from the literature to the exposure pathways of concern at the disposal site under investigation.

5.2.1 Threshold Effect

The EPA has established reference dose (RfD) values to evaluate exposures to impacted soil and reference concentration (RfC) values to evaluate inhalation exposures. Information on RfDs and RfCs are provided below. The RfD and RfC values are generated by EPA based on the assumption that threshold levels exist at and below which no adverse non-carcinogenic health effects would be expected. The chronic RfDs and RfCs are considered to be the levels unlikely to cause significant adverse health effects associated with a threshold mechanism of action in humans exposed for a lifetime. Uncertainty factors, generally multiples of 10, are incorporated in the derivation of the chronic RfDs and RfCs to account for interspecies variation, exposure duration and protection of sensitive populations.

The RfDs and RfCs are used as reference points for gauging the potential effects of exposures. Usually, exposures that are less than the RfDs or RfCs are not likely to be associated with health risks. Compounds with relatively small RfDs or RfCs are more toxic than compounds with larger RfDs or RfCs. RfDs and RfCs are expressed as mg/kg/day and are typically based on administered doses. Where the chronic RfD or RfC is used to evaluate long term and lifetime exposures, the subchronic RfD or RfC is used to evaluate short-term exposures. RfDs and RfCs are used for comparison with calculated intake levels, as discussed in the risk characterization section.

5.2.2 Carcinogenic Effects

Unlike non-carcinogenic health effects, the dose-response assessment for carcinogens assumes that no threshold dose exists for carcinogenicity. Therefore, no dose of a carcinogenic substance (other than no exposures) is associated with zero risk (MassDEP, 1995). EPA evaluates available toxicity data and, based on this evaluation, assigns the chemical a weight-of-evidence class for carcinogenicity.

The weight-of evidence classification rates the likelihood that a compound is a human carcinogen and how it may qualitatively effect the interpretation of potential health risks. The EPA weight-of-evidence refers to evidence of carcinogenicity, with Group A signifying a known human carcinogen, Groups B1 and B2 signify probable human carcinogens, Group C indicates possible human carcinogens, Group D is not classified, and Group E indicates no evidence of carcinogenicity to humans. **Table 4** identifies the weight-of evidence classification of the COCs.

5.2.3 Relative Absorption Factors

The Relative Absorption Factor (RAF) relates the exposure and absorption estimated for the exposure pathway under evaluation to the exposure and absorption in the toxicological study in which the dose-response information is based. The RAF is dimensionless and pathway specific (MADEP, 1996). MADEP's Office of Research and Standards (ORS) has developed RAFs for subchronic, chronic and carcinogenic exposure evaluations, which are summarized in **Table 5** for the soil COCs. The RAF is used to account for differences in the absorption of a COC under assumed exposure conditions at a disposal site relative to the absorption of the COC under the experimental conditions upon which the dose-response value is based. RAFs are used in lieu of absorption efficiencies to ensure that the exposures evaluated at the disposal site are comparable to the toxicity information in the literature.

The RAF is used to adjust the calculated exposure (e.g., the soil ingestion exposure of a construction worker) in such a way that is comparable to the toxicity information (e.g., derived from a study in which rats were administered by gavage, a chemical dissolved in olive oil).

5.2.4 Chemicals without Complete Toxicity Data

Dose-response information (i.e., reference doses, reference concentrations, cancer slope factors, etc.) were obtained for all non-carcinogenic and/or carcinogenic health effects (if applicable) for all COCs.

5.3 Exposure Assessment

The objective of an exposure assessment is to estimate a receptor's type and magnitude of exposure to COCs at a Site. This assessment assumes that future land use at this property is unrestricted. An exposure assessment brings together information regarding:

- the source of the OHM impacts and release into the environment;
- migration through environmental media;
- point of human contact with the impacted media; and
- routes of exposure.

To estimate exposures, the information presented on current and/or future land use is used to develop exposure profiles for those human receptors identified as having potential to come into contact with impacted media. A summary of the information considered and the decision rationale for selecting the exposure pathways to include in this assessment are presented the following sections.

5.3.1 Development of Exposure Profiles

Exposure profiles were developed for all potential human receptors at the property. A summary of information including human receptors, age, and body weight is presented in **Table 6**. Exposures to each receptor are evaluated for potential non-carcinogenic subchronic effects and/or longer-term (chronic) exposures. Subchronic non-cancer effects are evaluated for all human receptors having an exposure period ranging from less than one to 7 years (commercial worker, construction, trespasser and resident). Chronic non-cancer effects are evaluated for all receptors having an exposure period greater than 7 years, only (i.e., all except the construction worker who has a 6-month exposure period, only).

Increased cancer risks associated with lifetime exposures are also evaluated in this Method 3 for all receptors. Acute exposures are not evaluated in this Method 3 because exposures to the COCs are unlikely to pose acute health effects at the concentrations reported in site media.

5.3.1.1 Identification of Potential Human Receptors

Potential human receptors at the disposal site are assumed to include:

- Current or future commercial workers,
- Potential future construction or utility repair/installation workers,
- Current or future site visitors or trespassers (including children),
- Potential future residents (children and adults), and
- Personnel involved in site assessment.

All OHM impacts present at the Site are located at depths greater than 3 feet below grade from paved areas. Therefore, there are no current exposures to soils occurring at the Site. Under future site conditions, excavation and site redevelopment activities may occur allowing potential future exposure to soils which currently exist at depths greater that 3 feet below grade by a commercial worker, construction worker, utility worker, trespasser and/or resident.

A construction worker would typically contact OHM-impacted soils for the duration of a construction project while performing excavation work. A future utility worker would be exposed to impacted soils infrequently during maintenance and/or repair of subsurface utilities. The risks for the construction worker scenario overestimate those of the utility worker and the site assessment worker. Therefore, the utility worker and site assessment worker is not evaluated herein.

5.3.1.2 Identification of Exposure Point Concentrations

Exposure points are areas or points where human receptors may potentially come into contact with impacted media. In accordance with the MassDEP *Guidance for Disposal Site Risk Characterization - In Support of the MCP (BWSC/ORS-95-141)*, each soil sample location listed in the attached soil tables represents a separate and distinct exposure point. As a conservative measure, this Method 3 assumes exposure to the maximum and average concentrations of all soil COCs from 0-15 feet below grade as a worst-case and realistic-case exposure condition, respectively.

5.3.1.3 Identification of Exposure Routes/Pathways

An exposure route is the mechanism by which a receptor comes into contact with site-related OHM such as ingestion, inhalation, or dermal absorption. An exposure pathway is the course that an OHM takes via a migration pathway, exposure point, and an exposure route resulting in exposure of a receptor to the OHM. The exposure profile summary presented in **Table 6** includes exposure frequency, exposure duration, exposure periods and averaging periods for each potential receptor.

Table 7 presents a summary of the exposure pathway evaluation for the Site. As indicated in **Table 7**, soil is the only media of concern for human exposure at the Site. Potential exposures to OHM in groundwater through direct contact or ingestion are considered unlikely, since groundwater is not used as a potable water source and dewatering activities would be conducted prior to any construction work. Note that throughout the duration of a 6-month construction project, it is assumed that a construction worker would spend most of their time above ground surface rather than below grade within an excavation area. Therefore, exposures involving inhalation of vapors from soil or groundwater are considered to be insignificant from a risk standpoint and are not considered further in this Method 3.

Based on the location and depth of VPH impacts in soils and groundwater at the Site, potential impacts on the indoor air quality of onsite buildings due to releases of OHM from the Site are unlikely.

Summary of Exposure Pathways Analysis

Based on the concentrations, locations and type of OHM identified at the Site, soils are the medium through which human exposures may occur. For purposes of this Method 3, the following exposure pathways are assumed to exist at the property for current and/or future site activities and uses:

- Future commercial workers may come into contact with soils from 0-15' below grade via direct contact and/or incidental ingestion,
- Future construction workers could come into direct contact with (dermal absorption) or ingest (ingestion) impacted soil (0-15') during excavation activities, or inhale/ingest soil-derived dust,
- Future trespassers may access the Site and come into contact with soils from 0-15' below grade via direct contact and/or incidental ingestion,
- Future residents may contact OHM-impacted soils (0-15') via ingestion and/or direct contact while digging or during recreational activities.

5.3.2 Quantitative Estimates of Exposure

Exposure assumptions, and contact and intake rates for soil-related exposures for a commercial worker, construction worker, trespasser and resident are presented in **Table 8**.

The potential exposures to receptors are quantified based on exposure factors that are used to estimate the dose of OHM experienced by a potential receptor. The exposure factors include:

- Concentration of OHM
- Frequency of Exposure
- Duration of Exposure Period
- Averaging Period
- Body Weight
- Duration of Exposure Event
- Relative Absorption Factor
- Unit Conversion

A discussion of exposure assumptions is presented below for each potential receptor identified.

Commercial Worker

A current or potential future commercial worker engaged in occasional outdoor activity represents a human exposure scenario with a moderate potential for exposure to OHM-impacted soil. The commercial worker evaluated herein is based on the Industrial/Outdoor Commercial Worker presented in MassDEP's "Weighted Skin-Soil Adherence Factors" (MADEP 2002) which considers light to moderately intense activities such as working around truck loading/unloading areas or outdoor dumpsters. The commercial worker is evaluated for non-cancer short-term (subchronic) and long-term (chronic) exposures. Subchronic exposures are evaluated for a one-year exposure period and chronic exposures consider a 30-year exposure period. An increased cancer risk estimate for soil-related exposure to carcinogens is also assessed for the commercial worker. As a conservative measure, exposures are evaluated for a female adult aged 18<45 years, weighing 58 kg. Although the commercial worker is engaged only in occasional outdoor activity, and considering the effects of inclement weather, as a conservative measure exposures are expected to occur 5 times per week for a 30-year period. A commercial worker is assumed to ingest 50 milligrams (mg) of soil per event (or day).

To evaluate dermal exposure to soil, a commercial worker is assumed to have an exposed skin surface area of 3,477 square centimeters (cm^2) representing exposed face, hands, forearms and feet. A soil adherence factor of 0.03 mg of soil per cm^2 of exposed skin is used (MassDEP, 2002d).

Construction Worker

A construction worker has the potential to be exposed to OHM-impacted soil during excavation activities and may involve direct contact with soil throughout an excavation/subsurface stage of a construction project. A construction worker engaged in subsurface excavation activities at the Site represents the human exposure scenario with the greatest likelihood of exposure to the COCs. Exposures to a construction worker are evaluated for potential subchronic effects, only, as longer term (chronic) exposures are not expected to occur. The increased cancer risk for long-term exposure to carcinogens is also assessed for a construction worker.

The exposure profile developed for a construction worker is expected to represent a maximally-exposed individual at the Site. The maximally-exposed individual is that person whose activities realistically result in exposures from all of the realistic exposure pathways identified at the Site (MassDEP, 1995). Therefore, a person who, as an adult, completes construction activities at the Site is considered to be a maximally-exposed individual. The exposures are evaluated for an adult over 18 years old weighing 58 kg, which is approximately 154 pounds. As prescribed by MADEP guidance, this stage of construction is assumed to last for 6 months and exposure is assumed to occur 5 days per week (120 days out of 180 days). An averaging period of 6 months is used in the subchronic evaluation (which is equal to the exposure period), and an averaging period of 70 years is used for the carcinogenic evaluation.

Using the MassDEP-enhanced exposure soil ingestion rate for excavation activities, a construction worker who does not take precautions to minimize dermal contact, ingestion or inhalation of impacted soils during construction activities is assumed to ingest 100 mg of soil per event (or day).

To evaluate dermal exposures to soil, a construction worker is assumed to have an exposed skin surface area of 3,477 cm^2 representing exposed face, hands, forearms, and feet and a soil adherence factor of 0.29 mg of soil per cm^2 of exposed skin is typically used (MADEP, 2002). However, since future excavation beneath the water table is possible, this Method 3 uses a soil adherence factor (AF) of 1.0 which is the default AF for exposure to wet soils.

To evaluate inhalation exposures to impacted soil-derived fugitive dust, a construction worker is assumed to inhale windborne dust from the impacted area during construction activities. The concentrations of OHM in fugitive dust particulate ($OHM_{particulate}$) are calculated by multiplying the maximum OHM concentration detected in soil by the respirable particulate concentration in air (PM_{10}) and a unit conversion factor. According to MADEP guidance (MADEP, 2002b), the PM_{10} value at construction sites is 60 micrograms per cubic meter ($\mu g/m^3$). A contribution factor of 100% is used to estimate the proportion (P = 1.0) of ambient particulate level contributed by the construction activities. The inhalation rate used in the calculations is 60 liters per minute (L/min), which is associated with activities involving heavy exertion (MADEP, 1995).

Trespasser

A trespasser or site visitor may access OHM-impacted soils under current or future site conditions. The maximum frequency that a child (9 years), child/teen (9<16 years) or adult (16<29 years) trespasser is expected to access the site is 2 times per week, for 7 out of 12 months each year (May through November, non-winter months). The subchronic exposure period for a child trespasser is 1 year. The chronic exposure periods for a child/teen and adult trespasser are 7 and 13 years, respectively.

The child, child/teen and adult trespasser receptor(s) presented herein are adapted from the "recreational adult" model presented in *Weighted Skin-Soil Adherence Factors* (MADEP, April 2002). Whereas the MADEP "trespasser" model only considers exposures to a receptors hands, forearms, and feet, the "recreational adult" model considers exposure to a receptor's hands, forearms, feet and lower legs. The trespasser receptor(s) presented herein have been adapted to consider exposure to a receptor's hands, forearms, feet and lower legs.

The corresponding adherence factors(s) for the MADEP's "trespasser" and "recreational adult" models are based on youth soccer activities (except where such values are unavailable and factors based on gardening are used). The adherence factors for the trespasser receptors presented on **Table 8** are based upon gardening which are more conservative than the soccer based adherence factors. As a result, the child/teen trespasser receptor is a conservative model which overestimates the exposure and risk to an adult trespasser, thus chronic exposure to an adult trespasser is not evaluated in this Method 3. Note that for exposure to sediment, this Method 3 uses the MassDEP default AF of 1.0 for exposure to wet soils. The trespasser also has the potential to have dermal contact with and/or ingest the impacted soil.

The soil ingestion rate of 50 milligrams per day (mg/day) is used for the child, child/teen and adult trespasser which is MADEP's recommended ingestion rate for children aged 6 years and older and adults.

Resident

Residents have a potential for exposure to OHM-impacted soil via direct contact and/or ingestion in the event that the Site is redeveloped for residential use. Exposures to a resident are evaluated for potential non-carcinogenic subchronic effects and longer term (chronic) exposures. The increased cancer risk for long-term exposure to carcinogens is also assessed for residential exposures.

Subchronic residential exposures are evaluated for an infant child (1<2 years) weighing 10.4 kg in contact with soil 5 times per week for 7 months out of the year (April through October). An infant child is assumed to ingest 100 mg of soil per event (or day).

To evaluate dermal exposure to soil, an infant child is assumed to have an exposed skin surface area of 1,673 cm^2 representing exposed face, hands, forearms, lower legs and feet with a soil adherence factor of 0.35 mg of soil per cm^2 of exposed skin (MassDEP 2002d). An infant child (1<2 years) is assessed for subchronic effects due to the higher potential for exposure and likelihood of ingestion and dermal contact to OHM-impacted soils at this age and presenting the most risk of experiencing subchronic effects from soil-related exposures.

Chronic residential exposures are evaluated for a young child (1<8 years) weighing 17 kg in contact with soil 5 times per week for 7 months out of the year (April through October) for a 7-year period. The young child is assumed to ingest 100 mg of soil per event (or day). To evaluate dermal exposure to soil, the young child is assumed to have an age-weighted average exposed skin surface area of 2,434 cm^2 representing exposed face, hands, forearms, lower legs and feet with a soil adherence factor of 0.35 mg of soil per cm^2 of exposed skin (MADEP 2002d). To evaluate cancer risks, a combined 30-year residential exposure to soil is typically used. This total exposure period is based upon a 7-year exposure by a young child (1<8 years), a 7-year exposure by a child/teen (8<15 years), and a 16-year exposure by an adult (15<31 years). The young child is assumed to ingest 100 mg of soil per day. The age-weighted average exposed skin surface area and soil adherence factors are shown in **Table 8**.

5.3.2.1 Hot Spots

According to the MCP, a hot spot is a discrete area where the concentrations of OHM are substantially higher than those concentrations in the surrounding area. In all cases, a discrete area where the concentration of an OHM is greater than a 100 times the concentration in the surrounding areas shall be considered a hot spot. Locations where concentrations are 10 to 100 times greater than the neighboring samples are considered hot spots if the frequency, intensity and/or duration of exposure in these areas would be greater than the surrounding area (unless the area showing the elevated concentrations was the direct result of a remediation/excavation program). No "Hot Spots" as defined in the MCP have been identified in soil at the Site.

5.3.2.2 Exposure/Risk Equations – Soil Exposure Pathway

An Average Daily Dose (ADD) is calculated for use in the quantitative risk characterization. The RAF for a particular chemical is the ratio of the absorption efficiency for the route and medium of exposure being evaluated to the absorption efficiency for the route and medium of the exposure from which the dose-response value was derived. The product of the dose estimate and the RAF gives an ADD that can be appropriately compared to toxicity values in order to generate risk estimates. The ADD is calculated for use in quantitative risk evaluations. Subchronic and/or chronic ADDs are calculated to assess potential non-carcinogenic health effects. Lifetime ADD (LADD) is calculated to assess potential carcinogenic health effects.

The ADD received by a receptor via direct contact with soil (or sediment) containing OHM (ADD_{soil}) is the sum of the average daily doses resulting from incidental ingestion and dermal absorption of that soil. The incidental soil ingestion, direct contact and/or dust inhalation subchronic, chronic and/or lifetime ADD for each COC are calculated using the equations presented in the following tables. Also listed below are the tables used to assess risk via the indoor air pathway for the resident.

Commercial Worker (Attachment A)

Table Aa - Soil Ingestion/Dermal Contact – Subchronic Exposure to Max 0-15' Soil Concentrations

Table Ab - Soil Ingestion/Dermal Contact – Chronic Exposure to Max 0-15' Soil Concentrations

Table Ac - Soil Ingestion/Dermal Contact – Lifetime Exposure to Max 0-15' Soil Concentrations

Table Aa1 - Soil Ingestion/Dermal Contact – Subchronic Exposure to Avg 0-15' Soil Concentrations

Table Ab1 - Soil Ingestion/Dermal Contact – Chronic Exposure to Avg 0-15' Soil Concentrations

Table Ac1 - Soil Ingestion/Dermal Contact – Lifetime Exposure to Avg 0-15' Soil Concentrations

Construction Worker (Attachment B)

Table Ba - Soil Ingestion/Dermal Contact - Subchronic Exposure to Max 0-15' Soil Concentrations

Table Bb - Dust Inhalation - Subchronic Exposure to Max 0-15' Soil Concentrations

Table Bc - Soil Ingestion/Dermal Contact - Lifetime Exposure to Max 0-15' Soil Concentrations

Table Bd - Dust Inhalation - Lifetime Exposure to Max 0-15' Soil Concentrations

Table Ba1 - Soil Ingestion/Dermal Contact - Subchronic Exposure to Avg 0-15' Soil Concentrations

Table Bb1 - Dust Inhalation - Subchronic Exposure to Avg 0-15' Soil Concentrations

Table Bc1 - Soil Ingestion/Dermal Contact - Lifetime Exposure to Avg 0-15' Soil Concentrations

Table Bd1 - Dust Inhalation - Lifetime Exposure to Avg 0-15' Soil Concentrations

Trespasser (Attachment C)

Table Ca - Soil Ingestion/Dermal Contact - Subchronic Exposure to Max 0-15' Soil Concentrations

Table Cb - Soil Ingestion/Dermal Contact - Chronic Exposure to Max 0-15' Soil Concentrations

Table Cc - Soil Ingestion/Dermal Contact - Lifetime Exposure to Max 0-15' Soil Concentrations

Table Ca1 - Soil Ingestion/Dermal Contact - Subchronic Exposure to Avg 0-15' Soil Concentrations

Table Cb1 - Soil Ingestion/Dermal Contact - Chronic Exposure to Avg 0-15' Soil Concentrations

Table Cc1 - Soil Ingestion/Dermal Contact - Lifetime Exposure to Avg 0-15' Soil Concentrations

Resident (Attachment D)

Table Da - Soil Ingestion/Dermal Contact - Subchronic Exposure to Max 0-15' Soil Concentrations

Table Db - Soil Ingestion/Dermal Contact - Chronic Exposure to Max 0-15' Soil Concentrations

Table Dc - Soil Ingestion/Dermal Contact - Lifetime Exposure to Max 0-15' Soil Concentrations

Table Da1 - Soil Ingestion/Dermal Contact - Subchronic Exposure to Avg 0-15' Soil Concentrations

Table Db1 - Soil Ingestion/Dermal Contact - Chronic Exposure to Avg 0-15' Soil Concentrations

Table Dc1 - Soil Ingestion/Dermal Contact - Lifetime Exposure to Avg 0-15' Soil Concentrations

The equations used in this risk characterization for calculating the ADD for inhalation are the updated equations set forth in the *Characterization of Risks Due to Inhalation of Particulates by Construction Workers-Technical Update* (MADEP-ORS, April 2002). The ADD received by a receptor via inhalation of impacted soil-derived fugitive dust containing OHM is divided into two parts: ADD for effects on the gastrointestinal (GI) system ($ADD_{inh\text{-}GI}$) and respiratory system ($ADD_{inh\text{-}res}$). The $ADD_{inh\text{-}res}$ is further converted to Average Daily Exposure ($ADE_{inh\ res}$) to determine the non-cancer and cancer risks for compatibility with dust inhalation dose-response values. The $ADD_{inh\text{-}GI}$ and $ADE_{inh\text{-}res}$ for each COC are calculated for the construction worker using the equations presented in **Attachment B.**

The risk calculation tables showing the formulas, assumptions and values used to characterize risk associated with soil and/or soil-derived dust are presented in **Attachments A, B, C and D.**

5.4 Risk Characterization

This baseline risk characterization assesses total site risk using a Method 3 approach, as outlined in Section 40.0990 of the MCP. This risk characterization evaluates the risks posed by OHM impacts under existing site conditions assuming no additional response actions are conducted.

As discussed previously, removal of OHM-impacted soils, NAPL bailing and MNA has been conducted at the Site. As a conservative measure, this Method 3 assumes exposure to the maximum and average OHM concentrations currently present in soils at the Site, as a worst-case and realistic-case exposure evaluation, respectively. A summary of the human health risks associated with exposure to the maximum 0-15' soil concentrations is presented in **Table 9.** A summary of the human health risks associated with exposure to the average 0-15' soil concentrations is presented in **Table 10.**

Non-cancer risks are evaluated using the hazard index (HI). For non-cancer risks posed by soil, the HI is a ratio of the estimated ADD (mg/kg/day) and the reference dose (RfD) for soil-related exposures. For exposure to soil-derived dust by a construction worker, the HI is the ratio of the soil dust concentrations (ug/m^3) and the reference concentration (RfC). The RfDs and RfCs are based on the assumption that thresholds exist for non-cancer health effects. The subchronic and chronic RfDs and RfCs are associated with the exposure dose or concentration(s) unlikely to cause significant non-carcinogenic adverse health effects in humans having exposure to soil or soil-derived dust for short-term and long-term time periods, respectively.

Chemical-specific hazard ratios are summed for all complete exposure pathways to arrive at a cumulative hazard index for all COCs in all exposure routes at all exposure points for the appropriate exposure period. The MassDEP has set a total site non-cancer risk limit of 1.0. If the hazard index has a value of less than or equal to 1.0, a condition of No Significant Risk is concluded to exist for the respective scenarios.

The excess lifetime cancer risk (ELCR) from exposure to soil carcinogens is typically calculated by multiplying the lifetime ADD (LADD) (mg/kg/day) by the slope factor (1/mg/kg/day). For indoor air exposures, the ELCR is determined by multiplying the soil dust EPC (ug/m^3) by the unit risk factor ($1/ug/m^3$). The increased individual lifetime cancer risk associated with a given exposure is expressed as a small fraction that represents the incremental increase in an individual's lifetime risk or chance of developing cancer that is attributable to that exposure. The MCP identifies an overall site target ELCR level of 1.0×10^{-5} or 1 in 100,000. Another way to view a 1-in-100,000 risk is that given an exposure to 100,000 persons, one additional cancer may occur from the exposure.

If an ELCR value calculated for the disposal site exceeds the MCP Cumulative Receptor Cancer Risk Limit of 1×10^{-5}, then exposure poses a significant risk of harm to human health based on the risk of cancer health effects and are considered an unacceptable level of risk. Note that there are no human carcinogens with published oral slope factors or inhalation UR Factors selected as COCs at the site. Therefore, no cancer risk evaluations are conducted.

The construction worker exposure profile is expected to represent a maximally-exposed individual at the Site. The maximally exposed individual is that person whose activities realistically result in exposures from all of the realistic exposure pathways identified at the Site (MADEP, 1995). A person engaged in subsurface soil excavation within the impacted area, comes into contact with impacted soil, and breathes the impacted soil-derived dust is generally considered to be the maximally-exposed individual. However, due to the sensitivity of the child residential receptor evaluated in this Method 3, the residential model is in fact the exposure scenario which is most likely to show non-cancer or cancer risks which exceed the MADEP-established non-cancer and cancer risk thresholds.

5.4.1 Calculations of Health Risks via Exposure to Soils

The non-cancer and cancer risks resulting from exposure to the soil COCs for the commercial worker, construction worker, trespasser and resident have been calculated in **Attachments A, B, C and D**, respectively. The risk results for worst-case and realistic-case exposure conditions are summarized in **Tables 9 and 10**, respectively, and discussed below.

5.4,1.1 Current/Future Commercial Worker – Exposure to Max 0-15' Soil Concentrations

The soil ingestion and dermal absorption subchronic and chronic HIs for a commercial worker exposed to the maximum OHM levels in 0-15' soils are calculated in **Tables Aa and Ab**, respectively. The cumulative soil ingestion and dermal absorption subchronic HI is 0.49. The cumulative soil ingestion and dermal absorption chronic HI is 1.3. The cumulative incidental soil ingestion and dermal absorption ELCR is 2.0 x 10-5 for exposure to the maximum OHM levels **(Table Ac)**. Based on this evaluation, a worst-case exposure to soils from 0-15' poses a level of chronic non-cancer and lifetime cancer risk to the commercial worker above the MADEP risk limits **(Table 9).**

5.4.1.2 Current/Future Commercial Worker – Exposure to Avg 0-15' Soil Concentrations

The soil ingestion and dermal absorption subchronic and chronic HIs for a commercial worker exposed to the average OHM levels in 0-15' soils are calculated in **Tables Aa1 and Ab1**, respectively. The cumulative soil ingestion and dermal absorption subchronic HI is 0.06. The cumulative soil ingestion and dermal absorption chronic HI is 0.17. The cumulative incidental soil ingestion and dermal absorption ELCR is 2.7 x 10-6 for exposure to the average OHM levels **(Table Ac1)**. Based on this evaluation, a realistic-case exposure to soils from 0-15' poses a level of non-cancer and cancer risk to the commercial worker below the MADEP risk limits **(Table 10).**

5.4.1.3 Future Construction Worker – Exposure to Max 0-15' Soil Concentrations

The soil ingestion/dermal absorption subchronic HI and dust inhalation HI for a construction worker exposed to the maximum OHM in 0-15' soils are calculated in **Tables Ba and Bb,** respectively. For a worst-case exposure, the combined soil ingestion, dermal contact and soil-derived dust inhalation subchronic HI is 5.5. The cumulative incidental soil ingestion, soil dermal absorption and dust inhalation ELCR is 3.6 x 10-6 for exposure to the maximum 0-15' soil OHM **(Tables Bc and Bd).** Based on this evaluation, a worst-case exposure to soils from 0-15' poses a level of non-cancer and cancer risk to the construction worker above the MADEP risk limits **(Table 9).** However, a worst-case exposure to soils from 0-15' poses a level of lifetime cancer risk to the construction worker below the MADEP risk limits.

5.4.1.4 Future Construction Worker – Exposure to Avg 0-15' Soil Concentrations

The soil ingestion/dermal absorption subchronic HI and dust inhalation HI for a construction worker exposed to the average OHM in 0-15' soils are calculated in **Tables Ba1 and Bb1,** respectively. For a realistic-case exposure, the combined soil ingestion, dermal contact and soil-derived dust inhalation subchronic HI is 0.72. The cumulative incidental soil ingestion, soil dermal absorption and dust inhalation ELCR is 4.9 x 10-7 for exposure to the average 0-15' soil OHM **(Tables Bc1 and Bd1).** Based on this evaluation, a realistic-case exposure to soils from 0-15' poses a level of non-cancer and cancer risk to the construction worker below the MADEP risk limits **(Table 10).**

5.4.1.5 Future Trespasser - Exposure to Max 0-15' Soil Concentrations

The soil ingestion and dermal absorption subchronic and chronic HIs for a trespasser exposed to the maximum OHM levels in 0-15' soils are calculated in **Tables Ca and Cb**, respectively. The cumulative soil ingestion and dermal absorption subchronic HI is 0.82. The cumulative soil ingestion and dermal absorption chronic HI is 1.1. The cumulative incidental soil ingestion and dermal absorption ELCR is 9.3 x 10-6 for exposure to the maximum 0-15' soil levels **(Table Cc)**.

Based on this evaluation, a worst-case exposure to soils from 0-15' poses a level of chronic non-cancer risk to the trespasser above the MADEP risk limits **(Table 9).** However, a worst-case exposure to soils from 0-15' poses a level of subchronic non-cancer risk and lifetime cancer risk to the trespasser below the MADEP risk limits **(Table 9).**

5.4.1.6 Future Trespasser - Exposure to Avg 0-15' Soil Concentrations

The soil ingestion and dermal absorption subchronic and chronic HIs for a trespasser exposed to the average OHM levels in 0-15' soils are calculated in **Tables Ca1 and Cb1**, respectively. The cumulative soil ingestion and dermal absorption subchronic HI is 0.11. The cumulative soil ingestion and dermal absorption chronic HI is 0.14. The cumulative incidental soil ingestion and dermal absorption ELCR is 1.2 x 10-6 for exposure to the average 0-15' soil levels **(Table Cc1).** Based on this evaluation, a realistic-case exposure to soils from 0-15' poses a level of non-cancer and cancer risk to the trespasser below the MADEP risk limits **(Table 10).**

5.4.1.7 Future Resident – Exposure to Max 0-15' Soil Concentrations

The soil ingestion and dermal absorption subchronic and chronic HIs for a resident exposed to the maximum OHM levels in 0-15' soils are calculated in **Tables Da and Db**, respectively. As indicated in **Table 9**, the cumulative subchronic HI is 8.1. The cumulative chronic HI is 10.8. The cumulative incidental soil ingestion and dermal absorption ELCR is 6.3 x 10-5 for exposure to the maximum OHM levels in 0-15' soils **(Table Dc).** Based on this evaluation, a worst-case exposure to soils from 0-15' poses a level of non-cancer and cancer risk to the resident above the MADEP risk limits **(Table 9).**

5.4.1.8 Future Resident – Exposure to Avg 0-15' Soil Concentrations

The soil ingestion and dermal absorption subchronic and chronic HIs for a resident exposed to the average OHM levels in 0-15' soils are calculated in **Tables Da1 and Db1**, respectively. As indicated in **Table 10**, the cumulative subchronic HI is 1.1. The cumulative chronic HI is 1.3. The cumulative incidental soil ingestion and dermal absorption ELCR is 8.4 x 10-6 for exposure to the average OHM levels in 0-15' soils **(Table Dc1).** Based on this evaluation, a realistic-case exposure to soils from 0-15' below grade poses a level of non-cancer risk to the resident above the MADEP risk limits **(Table 10).** However, a realistic-case exposure to soils from 0-15' poses a level of lifetime cancer risk to the resident below the MADEP risk limits.

5.4.2 Comparison to Applicable or Suitably Analogous Health Standards

No applicable or suitably analogous human health standards for soil were identified during this assessment.

5.5 Uncertainty Analysis

This section of the report outlines various sources of uncertainty in the risk assessment. The uncertainty associated with this risk characterization is the result of the uncertainty associated with the data, as well as the assumptions used in developing the exposure scenarios. In this section, uncertainties in the risk assessment are identified and discussed.

General sources of uncertainty include:

- Environmental Sampling
- Laboratory Analysis
- Hazard Identification
- Exposure Assessment
- Exposure Point Concentration Modeling
- Development of Exposure Profiles
- Risk Characterization

Any sampling and analysis program has uncertainties associated with how well the samples collected represent conditions present and the analytical capabilities of the instrumentation used in the sample analyses.

In developing exposure scenarios, simplifying assumptions are used to calculate dose. The assumptions used may tend to result in overestimating or underestimating dose. In general, conservative assumptions are used to avoid underestimation.

As a conservative measure, the maximum soil concentrations were initially used in the risk characterization for all human receptors to evaluate "worst case" exposure conditions. The use of maximum concentrations in soil as the exposure point concentration and the inclusion of OHM not associated with releases from the Site overestimates the exposure and risk posed by the Site.

Uncertainties associated with toxicological data often include uncertainties associated with animal experimentation, extrapolating from high experimental doses to low environmental exposures, and extrapolating from animal models to humans. In addition, where toxicity data are not available, potential impacts are not included in the estimates of hazard and risk. This will underestimate risk.

Given the variety of uncertainties associated with each step of the risk assessment process, no numerical estimate of uncertainty has been made. The evaluation should not be considered a determination of absolute risks, but rather a method to determine whether or not the site poses a significant risk of harm to human health.

5.6 Summary of Human Health Risk Characterization

A Method 3 Risk Characterization (Method 3) was conducted to evaluate the human health risks associated with the occurrence of OHM in soil and groundwater at the 88-90 South Maple Street disposal site property located in Westfield, Massachusetts. The Method 3 evaluated the risks posed to all anticipated current and/or future human receptors at the property including a commercial worker, construction worker, trespasser and resident. For soils, each receptor was evaluated for exposure to the maximum and average OHM levels present in soils from 0-15' below grade, as a worst-case and realistic-case exposure evaluation, respectively.

Groundwater was not deemed a media of concern since there are no current impacts to groundwater on the property. Also, groundwater is not used as a potable water supply and direct exposure to groundwater during future construction activities would be mitigated by dewatering. Based on the location and concentrations of VPH compounds in soil, impacts on indoor air quality of onsite or offsite buildings are not expected to occur.

The Method 3 concluded that under worst-case exposure conditions, the non-cancer and/or excess lifetime cancer risk posed to the commercial worker, construction worker, trespasser and resident exceed the MADEP non-cancer and cancer risk thresholds. Under realistic-case exposure conditions, the non-cancer risk posed to a resident exceeds the MADEP non-cancer and cancer risk thresholds. Therefore, a condition of No Significant Risk (NSR) of harm to human health does not exist at the disposal site and an Activity and Use Limitation is required to achieve a condition NSR of harm to human health at the Site.

6.0 CHARACTERIZATION OF RISK TO PUBLIC WELFARE

The risk of harm to public welfare is characterized according to Section 40.0994 of the MCP to identify issues that are not otherwise considered in the characterization of risk of harm to health, safety and the environment. The characterization of risk to public welfare has two parts:

- It considers nuisance conditions, loss of property value, restriction of another person's property, monetary and non-monetary costs that may accrue related to the site such as degradation of public or private resources; and
- It is also characterized by comparing the EPCs of OHM detected at the site to Method 3 Upper Concentration Limits (UCLs) listed in Section 40.0996(7) of the MCP. Soil and groundwater UCLs are concentrations of OHM that, if exceeded, indicate the potential for significant risk of harm to public welfare and the environment under future conditions.

No community in the vicinity of the disposal site(s) experiences significant adverse impacts to public welfare based on nuisance conditions, loss of property value, restriction of another person's property, or monetary and non-monetary costs that may accrue related to the site(s). In addition, no OHM were reported in the soil or groundwater samples above UCLs, and no NAPL is currently present at the Site.

Therefore, a level of no significant risk of harm to public welfare exists because:

- The community that is currently affected, and/or those for which it is reasonably foreseeable to conclude could be affected by the release in the future, experiences no significant adverse impacts to public welfare;
- No OHM concentrations in soil or groundwater currently exceed applicable UCLs; and
- No nuisance conditions exist or will result from the release of OHM attributable to the disposal site(s), including:
    1. The breathing zone of ambient or indoor air are currently and will, in the reasonably foreseeable future, remain free from persistent, noxious odors,
    2. Municipal drinking water is accessible and will, in the reasonably foreseeable future, remain free from noxious taste and odors; and
    3. Livestock is and will remain, in the reasonably foreseeable future, free from harmful effects. Since no livestock are present on-site or in the vicinity of the site, the human health and environmental risk characterizations conducted for the site are also protective of livestock exposures.

7.0 CHARACTERIZATION OF RISK TO THE ENVIRONMENT

A Stage I Environmental Screening has been completed to characterize the potential risk of harm to wildlife habitats and biota at and in the vicinity of the site due to exposure to OHM impacts attributable to the site. This screening is based upon available site, receptor and exposure information obtained from previous investigations and site visits. The objective of this screening is to establish whether a level of No Significant Risk of harm to the environment exists or has been achieved at the Site.

7.1 Potential Environmental Receptors

According to the MADEP **Site Scoring Map (Figure 3)** and the **21E Resource Priority Map (Figure 4)**, the closest surface water body to the Site is Little River which is located approximately 200 feet to the south of the Site. Protected Open Space is located within approximately 1,000 feet to the south, and within approximately a half-mile to the west and east of the Site. The Site is also located within a FEMA 100-year floodplain, to the south and southeast.

According to the Natural Heritage and Endangered Species Program (NHESP) Southwick Quad (October 1, 2006), a priority habitat of rare species and estimated habitat of rare wildlife is located within 0.5 miles west of the Site.

7.2 Environmental Risk Assessment

Under the MCP, environmental risk assessments are conducted using a Method 3, site-specific approach. A Method 3 risk characterization takes into account specific exposure patterns, chemical distributions and chemical mixtures. To facilitate the elimination of insignificant exposure pathways from further consideration, the screening level analysis establishes the need for a comprehensive and quantitative analysis of risk characterization. This more detailed analysis is referred to as a Stage II Environmental Risk Characterization. The Stage I Environmental Screening allows the risk assessor to eliminate from further evaluation those situations that clearly have not resulted or should not result in exposures that cause environmental harm.

This assessment follows current interim final guidance presented in Section 9.0 of the "Guidance for Disposal Site Risk Characterization" (MassDEP, 1996a). A brief discussion of the potential exposure pathways is presented below, followed by a characterization of potential risks to ecological receptors.

7.2.1 Stage I Environmental Screening

In Stage I, the available evidence is evaluated to determine whether plants and/or animals are currently exposed, or could potentially be exposed, to impacts at or from the disposal site. An exposure pathway is a link between an OHM impact source and receptors such as plants and animals. The term "complete exposure pathway" means that the impacts are actually reaching plants and animals, or are likely to do so in the future. If a potential exposure pathway is not complete and it is not likely to be complete in the future, hypothetical risks postulated for that pathway do not have to be considered further and do not have to be carried through the environmental risk characterization process. Potential exposure pathways include terrestrial soil (0 to 2 feet), surface water and sediment.

7.2.1.1 Terrestrial Soils

The first step of the Stage I Screening for terrestrial organisms and habitats is to evaluate the size of the affected habitat and assess whether it is connected to other open space or areas of concern. No further assessment is warranted when no areas of special concern or ACECs are affected and the area is not sufficient to support a balanced terrestrial community (MADEP, 1996). At this Site, all residual soil OHM impacts are located beneath pavement and the potential for transport of OHM in soils to a sensitive environmental receptor is negligible.

No further assessment of terrestrial impacts is necessary because:

- the size of the undeveloped portion of the disposal site (i.e., negligible) and not sufficient to support a balanced terrestrial community,
- there are no chemicals which are known to bioaccumulate present in the surface soils, and
- there are no priority habitats of rare species, estimated habitats of rare wildlife, or certified vernal pools located within 500 feet of the disposal site.

In addition, the Site is not considered a substantial habitat for terrestrial or avian receptors, pursuant to Sections 9.5.2.1 of the "Guidance for Disposal Site Risk Characterization" (MassDEP 1995). As discussed above, the OHM-impacted soils at the Site are located at the subsurface therefore there is little potential for soil at the disposal site to act as an exposure pathway.

[1]*Undeveloped land means open land. Undeveloped land is characterized by the presence of native vegetation, and does not include landscaped residential and commercial parcels, landscaped parks or golf courses (MassDEP 1995).*

7.2.1.2 Surface Water

OHM impacts have not been detected in groundwater at concentrations above Method 1 GW-3 Standards. However, due to the close proximity of the Site to the Little River, as a conservative measure, this Stage 1 evaluates the potential for OHM in groundwater to impact the river above MADEP surface water quality benchmarks (MADEP 2007). In order to assess the potential for any VPH constituent present in groundwater to impact the river, the MADEP dispersion model presented in the "Implementation of the VPH/EPH Approach", Final Policy, October 2002, was used to estimate the discharge concentrations on the river of the VPH compounds originating at the Site. Input to the model included a 30 x 30 foot source area, the average well-specific temporal average VPH concentration using data obtained since August 2006, and an assumed distance of 100 feet to the pond.

As indicated in **Appendix C, Table 1,** all discharge concentrations are below the applicable MADEP surface water quality benchmarks. Therefore, a condition of NSR of harm to surface water exists at the Site for current and future site conditions.

7.2.1.3 Sediment

There are no sediments directly associated with the Site and future adverse impacts on surface water quality are unlikely. Therefore, a condition of NSR of harm to sediments exists at the Site for current and future site conditions.

7.3 Summary of Environmental Risk Characterization

In summary, the environmental risk characterization demonstrates that:

- physical evidence of a continuing release of OHM, which significantly affects environmental receptors, does not exist at or from the disposal site to surface waters and/or wetlands;
- physical evidence of a release of OHM, which significantly affects environmental receptors, at or from the disposal site to surface waters and/or wetlands is unlikely to have occurred;
- evidence of biologically significant harm, known or believed to be associated with current or foreseeable future exposure to wildlife, fish, shellfish or other aquatic biota to OHM does not exist.

Therefore, this Stage I Environmental Screening has demonstrated that a condition of No Significant Risk of harm to the environment exists at the site.

8.0 RISK CHARACTERIZATION CONCLUSIONS

This Method 3 Risk Characterization evaluated the risks posed by the environmental conditions currently present at the disposal site located at 88-90 South Maple Street in Framingham, Massachusetts relative to the release of OHM at or from the property. The findings of the risk characterization are divided into the following four sections, as summarized below:

- Human health risk characterization;
- Characterization of risk to safety;
- Public welfare risk characterization; and
- Environmental risk characterization.

The Method 3 concluded that under worst-case exposure conditions, the non-cancer and/or excess lifetime cancer risk posed to the commercial worker, construction worker, trespasser and resident exceed

the MADEP non-cancer and cancer risk thresholds. Under realistic-case exposure conditions, the non-cancer risk posed to a resident exceeds the MADEP non-cancer risk threshold.

Based on the results presented herein, a condition of No Significant Risk (NSR) of harm to human health does not exist at the disposal site for unrestricted future site uses and conditions. An Activity and Use Limitation is required to limit human exposure to soils in order and to achieve and maintain a condition NSR of harm to human health at the Site.

The Method 3 has demonstrated that a condition of No Significant Risk of harm to public welfare exists at the Site and the Stage I Environmental Screening has demonstrated that a condition of No Significant Risk of harm to the environment exists at the Site. No current risk of harm to safety exists on the site from corroded drums, open pits, lagoons or other dangerous structures or site conditions. No other significant risk of harm to safety is known to exist at this time. Therefore, a condition of No Significant Risk of harm to safety exists at the site under current conditions.

Note that future activities conducted at this disposal site must comply with the MCP provisions established in 310 CMR 40.0032(3), which state:

> Soils containing oil or waste oil at concentrations less than a release notification threshold specified in 310 CMR 40.0300 and 40.1600, and that are not otherwise a hazardous waste, and soils that contain one or more hazardous materials at concentrations less than a release notification threshold, and that are not a hazardous waste may be transported from a disposal site without notification to or approval from the Department under the provisions of this Contingency Plan, provided that such soils:
>
> a) are not disposed or reused at locations where the concentrations of oil or hazardous materials in the soil would be in excess of a release notification threshold applicable at the receiving site, as delineated in 310 CMR 40.0300 and 40.1600; and
>
> b) are not disposed or reused at locations where existing concentrations of oil and/or hazardous materials at the receiving site are significantly lower than the levels of those oil or hazardous materials present in the soil being disposed or reused.

9.0 REFERENCES

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TABLES

Table 1A
Soil Analytical Results - VPH
88-90 South Maple Street
Westfield, MA

Sample ID	Date	Depth (feet)	C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics	Benzene	Toluene	Ethyl benzene	Total Xylenes	MtBE	Naph thalene	Total VOCs
MW-5*	3/17/1993	10.5'-12.5'	NA	NA	NA	<5.8	<5.8	<5.8	<5.8	NA	NA	ND
MW-6*	3/17/1993	11'-13'	NA	NA	NA	<5.5	<5.5	<5.5	<5.5	NA	NA	ND
Sample 1 **	04/14/05	2'	4.9	<2.4	<2.4	<0.12	0.64	0.12	0.48	3.79	<0.12	NA
Sample 2 **	04/12/05	2'	9.7	4.3	8.4	<0.11	0.90	0.30	1.63	2.89	<0.11	NA
Sample 3 **	04/13/05	2'	**3,410**	**1,300**	**1,040**	28.6	545	124	421	205	19.9	NA
Sample 4 ***	04/14/05	2'	4.5	2.4	<2.1	<0.11	0.38	<0.11	0.39	0.62	<0.11	NA
1 S-B-2' ***	4/27/2005	2'	9.63	<3.1	<3.1	<0.15	0.20	<0.15	0.17	7.35	0.17	NA
2 S-B-2' ***	4/27/2005	2'	**4,790**	**2,190**	**2,380**	30.3	**1,050**	416	**1,454**	204	**40.1**	NA
4 S-B-2' ***	4/27/2005	2'	8.2	<3.0	<3.0	<0.15	0.8	0.15	0.64	3.1	0.17	NA
5 S-COMP-2' ***	4/27/2005	2'	4.75	<3.6	<3.6	<0.18	<0.18	<0.18	0.18	0.21	<0.18	NA
Tank Field	11/16/2005	1' - 5'	41.7	26.6	70.6	0.16	7.52	4.19	21.2	10.5	3.62	NA
R-7'	11/18/2005	7'	**1,870**	935	**1,650**	5.76	291	132	539	23.8	32.9	NA
T1	11/17/2005	3'	8.95	3.45	9.89	0.23	0.75	0.34	1.71	0.27	0.72	NA
T2	11/17/2005	3'	3.2	0.61	0.98	0.071	0.24	0.074	0.26	<0.64	0.1	NA
T3	11/18/2005	3'	1.23	<0.31	0.48	<0.06	0.134	<0.06	0.16	<0.06	<0.06	NA
T4	11/18/2005	3'	2.9	0.96	<0.82	<0.16	<0.16	<0.16	<0.49	<0.16	<0.16	NA
T5	11/18/2005	3'	30.1	24.6	58.2	<0.11	3.47	1.92	14.36	0.53	1.83	NA
T6	11/18/2005	3'	21.7	27.7	52.9	<0.17	1.24	1.1	8.2	<0.17	1.05	NA
R-3'	12/19/2005	3'	36.9	64.4	77.9	<0.161	1.71	0.37	8.34	<0.161	2.6	NA
RS-2'	12/19/2005	2'	<1.38	0.65	0.77	0.094	0.13	<0.092	<0.28	0.12	<0.092	NA
RN-2'	12/19/2005	2'	1.58	1.48	1.16	<0.07	0.1	<0.07	<0.22	<0.07	<0.07	NA
MW-101 (15')	3/28/2007	15'	<4.7	<2.3	<0.7	0.07	0.19	<0.023	0.058	<0.19	<0.23	NA
MW-102 (15')	3/28/2007	15'	<5.6	<2.8	<0.84	<0.028	<0.028	<0.028	<0.084	<0.22	<0.28	NA
SB-103 (15')	3/28/2007	15'	72	170	**140**	0.061	0.22	0.88	2.8	<0.2	2.8	NA
SB-1 (14')	3/28/2007	14'	<5.2	2.8	1.3	0.047	0.15	0.034	0.135	<0.21	<0.26	NA
SB-2 (14')	3/28/2007	14'	<4.6	<2.3	<0.69	<0.023	0.046	<0.023	<0.069	<0.18	<0.23	NA
SB-3 (13')	3/28/2007	13'	<4.9	<2.5	<0.74	0.038	0.12	<0.025	<0.074	<0.2	<0.25	NA
SB-4 (13')	3/28/2007	13'	<5.1	<2.6	<0.77	0.026	0.079	<0.026	<0.077	<0.21	<0.26	NA
MW-201	6/25/2007	12-14'	4.95	97.2	54.4	<0.04	<0.04	0.5	0.5	<0.04	1.59	NA
MW-202	6/25/2007	12-14'	<1.56	<1.56	<1.56	<0.03	<0.03	<0.03	<0.06	<0.03	0.05	NA
MW-203	6/25/2007	10-12'	<1.39	<1.39	<1.39	<0.03	<0.03	<0.03	<0.06	<0.03	<0.03	NA
MW-204	6/25/2007	10-12'	<1.75	<1.75	<1.75	<0.04	<0.04	<0.04	<0.08	<0.04	<0.04	NA
Method 1 Standards[1]	S-1/GW-2, GW-3		100	1000	100	30	500	500	300/500	100	40/500	NA
	S-2/GW-2, GW-3		500	3000	500	200	1000	1000	300/1000	100/500	40/1000	NA
	S-3//GW-2, GW-3		500	5000	500	700/900	2000/3000	1000/3000	300/3000	100/500	40/3000	NA
MCP Upper Conc Limits (UCL)[1]			5000	20000	5000	9000	10000	10000	10000	5000	10000	NA

Notes:
All concentrations are in milligrams per kilogam (mg/kg)
Bold - concentration exceeds Method 1 Standards
< - compound was below the laboratory reporting limit
VPH - Volatile Petroleum Hydrocarbons

*Samples were analyzed for VOCs, MEK and TPH; only TPH was detected at 27 mg/kg (MW-5) and 44 mg/kg (MW-6)
** Soil samples taken on 4-14-2005 were excavated on 4-27-2005
*** Soil samples taken on 4-14-2005 and 4-27-2005 were excavated on 11-18-2005
Ref[1] 310 CMR 40 (November 2007)
MTBE - Methyl tert-butyl ether

Table 1B
Soil Analytical Results - PCBs
88-90 South Maple Street
Westfield, MA

Sample ID	Sample Date	Sample Depth (feet)	Total PCBs	PCB 1016 (mg/kg)	PCB 1221 (mg/kg)	PCB 1232 (mg/kg)	PCB 1242 (mg/kg)	PCB 1248 (mg/kg)	PCB 1254 (mg/kg)	PCB 1260 (mg/kg)	PCB 1262 (mg/kg)	PCB 1268 (mg/kg)
StockPile	11/17/2005	--	**2.31**	<0.031	<0.031	<0.031	<0.031	**2.31**	<0.031	<0.031	<0.031	<0.031
Tank Field	11/16/2005	3' - 5'	1.37	<0.028	<0.028	<0.028	<0.028	1.32	<0.028	0.046	<0.028	<0.028
T1	11/17/2005	3'	**32.05**	<0.61	<0.61	<0.61	<0.61	**31.7**	<0.61	0.35	<0.03	<0.03
T2	11/17/2005	3'	0.21	<0.031	<0.031	<0.031	<0.031	0.098	<0.031	0.11	<0.031	<0.031
T5	11/18/2005	3'	0.14	<0.03	<0.03	<0.03	<0.03	0.07	<0.03	0.065	<0.03	<0.03
T1-A	12/19/2005	2'	**2.97**	<0.03	<0.03	<0.03	<0.03	**2.97**	<0.03	<0.03	<0.03	<0.03
TI-B	12/19/2005	2'	**3.42**	<0.03	<0.03	<0.03	<0.03	**3.42**	<0.03	<0.03	<0.03	<0.03
T1-C	12/19/2005	2'	**8.33**	<0.15	<0.15	<0.15	<0.15	**8.33**	<0.03	<0.03	<0.03	<0.03
MW-101 (15')	3/28/2007	15'	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	--	--
MW-102 (15')	3/28/2007	15'	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	--	--
SB-103 (15')	3/28/2007	15'	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037	--	--
SB-1 (14')	3/28/2007	14'	0.33	<0.035	<0.035	<0.035	<0.035	0.33	<0.035	<0.035	--	--
SB-2 (14')	3/28/2007	14'	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	--	--
SB-3 (13')	3/28/2007	13'	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	<0.036	--	--
SB-4 (13')	3/28/2007	13'	0.19	<0.036	<0.036	<0.036	<0.036	0.19	<0.036	<0.036	--	--
MW-201	6/25/2007	12-14'	<0.0056	<0.0036	<0.0056	<0.0036	<0.0036	<0.0036	<0.0036	<0.0036	--	--
MW-202	6/25/2007	12-14'	<0.0036	<0.0036	<0.0057	<0.0036	<0.0036	<0.0036	<0.0036	<0.0036	--	--
MW-203	6/25/2007	10-12'	<0.0034	<0.0034	<0.0053	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	--	--
MW-204	6/25/2007	10-12'	0.0096	<0.0036	<0.0057	<0.0036	<0.0036	<0.0036	0.0096 J	<0.0036	--	--
Disposal	6/25/2007	NA	0.022	<0.0036	<0.0057	<0.0036	<0.0036	<0.0036	0.022	<0.0036	--	--
MCP Upper Conc Limits (UCL)[1]			100	100	100	100	100	100	100	100	100	100

Notes:
All concentrations are in milligrams per kilogam (mg/kg)
Bold - concentration exceeds Method 1 Standards
< - compound was below the laboratory reporting limit

Ref[1] 310 CMR 40 (November 2007)
PCBs - Polychlorinated Biphenyls

Table 1C
Soil Analytical Results - Metals
88-90 South Maple Street
Westfield, MA

Sample ID	Date	Depth (feet)	Arsenic (mg/kg)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)
StockPile	6/27/2005	NA	1.97 J	38.5	<0.071	15	13.1	0.016 J	<1.07	<0.186
StockPile	11/17/2005	NA	<1.62	37.3	<0.27	8.21	8.78	NA	<1.62	<1.08
MCP Upper Conc Limits (UCL)[1]			200	10000	300	2000	3000	300	8000	2000
MADEP Background Conc, Natural Soils			20	50	2	30	100	0.3	0.5	0.6

Notes:
All concentrations are in milligrams per kilogam (mg/kg)
J - approximate value
< - compound was below the laboratory reporting limit
Ref[2]. DEP's "Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil" (May 2002)

Table 2A
Groundwater Analytical Results - VPH
88-90 South Maple Street
Westfield, MA

Method 1 Standards[1]	C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics	Benzene	Toluene	Ethyl benzene	Total Xylenes	Naph thalene	MtBE
GW-2	3,000	5,000	7,000	2,000	50,000	20,000	9,000	1,000	50,000
GW-3	50,000	50,000	50,000	10,000	40,000	5,000	5,000	20,000	50,000
MCP UCLs[1]	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

Well ID	Sample Date	C5-C8 Aliphatics (ug/L)	C9-C12 Aliphatics (ug/L)	C9-C10 Aromatics (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl benzene (ug/L)	Total Xylenes (ug/L)	Naph thalene (ug/L)	MTBE (ug/L)
MW-1	08/01/05	<75	<25	<25	<5	<5	<5	<15	5	<5
	02/07/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	08/22/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	05/08/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-3B	02/07/06	2,920	1,070	2,520	252	2,060	676	2,238	95.4	2,320
	03/06/06	2,100	478	4,880	77.2	536	585	1,166	103	637
	05/08/07	616	2,012	2,000	9.5	6.5	32.0	256	68	18
MW-4	08/01/05	<75	<25	<25	<5	<5	<5	<15	<5	1,690 *
MW-5	08/01/05	<75	<25	<25	<5	<5	<5	<15	<5	<5
	02/07/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	08/22/06	<50	<50	<50	<2	<2	<2	<2	<3	<2
	05/08/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-6	08/01/05	<150	<50	<50	<10	<5	<5	<15	<5	1,570
	02/07/06	<50	<50	<50	446	12.3	<2	9.5	6.7	22,900
	08/22/06	<250	<250	<250	41	<10	<10	<10	<15	7,890
	05/08/07	3,095	<100	<30	3.2	1.4	<1	<3	<10	2,700
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	1800
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8

Table 2A
Groundwater Analytical Results - VPH
88-90 South Maple Street
Westfield, MA

Method 1 Standards[1]	C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics	Benzene	Toluene	Ethyl benzene	Total Xylenes	Naph thalene	MtBE
GW-2	3,000	5,000	7,000	2,000	50,000	20,000	9,000	1,000	50,000
GW-3	50,000	50,000	50,000	10,000	40,000	5,000	5,000	20,000	50,000
MCP UCLs[1]	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000

Well ID	Sample Date	C5-C8 Aliphatics (ug/L)	C9-C12 Aliphatics (ug/L)	C9-C10 Aromatics (ug/L)	Benzene (ug/L)	Toluene (ug/L)	Ethyl benzene (ug/L)	Total Xylenes (ug/L)	Naph thalene (ug/L)	MTBE (ug/L)
MW-101	05/08/07	<200	<100	<30	<1	<1	1.2	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-102	05/08/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-201	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-202	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
MW-204	07/12/07	<200	<100	<30	<1	<1	<1	<3	<10	<8
	10/10/07	<200	<100	<30	<1	<1	<1	<3	<10	<8

Notes
All concentrations are in micrograms per liter (ug/L)
< indicates compound was below the laboratory reporting limit
*MW-4 & MW-6 were analyzed for VOCs & EPH on 8/1/05. No EPH were detected.
*MTBE was the only VOC detected (1,690 ug/L). The VPH result for MTBE was <5.

Ref[1] 310 CMR 40 (Nov 2007)
VPH - Volatile Petroleum Hydrocarbons
MTBE - Methyl tert-butyl ether

Table 2B
Groundwater Analytical Results - Metals
88-90 South Maple Street
Westfield, MA

Method 1 Standards	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
GW-2	NA	NA	NA	NA	NA	NA	NA	NA
GW-3	900	50,000	4	300	10	20	100	7
MCP UCLs	9,000	100,000	50	3,000	150	200	1,000	1,000

Sample ID	Sample Date	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
MW-4	8/1/2005	<4	134	<1.2	<2.5	<3.8	<0.2	<7.5	<5
MW-6	8/1/2005	<4	109	<1.2	<2.5	<3.8	<0.2	<7.5	<5

Notes
All concentrations are in micrograms per liter (ug/L)
< indicates compound was below the laboratory reporting limit
Ref[1] 310 CMR 40 (Nov 2007)

Table 3
Selection of Chemicals of Concern for Soils
89-90 South Maple Street
Westfield, MA

OHM	MADEP Backgrouind Conc[1]	Soils (0-15)		Location of MAX Conc	Detection Frequency	Percent Detected	Selected as COC
		MAX Conc (mg/kg)	AVG Conc[2] (mg/kg)				
VPH							
C5-C8 Aliphatics	NA	1870	150	R-7 (7')	12 / 24	50%	Y
C9-C12 Aliphatics	NA	935	97	R-7 (7')	13 / 24	54%	Y
C9-C10 Aromatics	NA	1650	151	R-7 (7')	13 / 24	54%	Y
VPH Target Analytes							
Benzene	NA	5.76	0	R-7 (7')	10 / 24	42%	Y
Toluene	NA	291	17	R-7 (7')	16 / 24	67%	Y
Ethyl benzene	NA	132	10	R-7 (7')	10 / 24	42%	Y
Total Xylenes	NA	539	40	R-7 (7')	12 / 24	50%	Y
MtBE	NA	23.8	3	R-7 (7')	5 / 24	21%	Y
Naph thalene	0.5	**32.9**	3	R-7 (7')	10 / 24	42%	Y
Metals							
Arsenic	20	<1.62	<1.62	StockPile	0 / 1	0%	N
Barium	50	37.3	37.3	StockPile	1 / 1	100%	N
Cadmium	2	<0.27	<0.27	StockPile	0 / 1	0%	N
Chromium	30	8.21	8.21	StockPile	1 / 1	100%	N
Lead	100	8.78	8.78	StockPile	1 / 1	100%	N
Selenium	0.5	<1.62	<1.62	StockPile	0 / 1	0%	N
Silver	0.6	<1.08	<1.08	StockPile	0 / 1	0%	N
PCBs							
PCBs	NA	32.05	4.28	T-1 (3')	12 / 20	60%	Y

Notes:
1. Ref. MADEP's "Background Levels of PAHs and Metals in Soil" (May 2002), Natural Soils
2. Arithmetic average includes all samples from 0-15 ft below grade showing evidence of OHM impact
For compounds below laboratory RLs, 1/2 the RL is used in the calculation of the average concentration
Bold - concertration exceeds the MADEP Background Concentration.
VPH - Volatile Petroleum Hydrocarbons COC - Chemical of Concern
EPH - Extractable Petroleum Hydrocarbons
COC Criteria:
1. OHMs present at moderate to high frequency of detection (>10%) and moderate to high concentration;
2. OHMs present are at concentrations above background, and/or they are associated with historical activities at the Site; and
3. OHMs are not associated with field or laboratory contamination.

Table 4
Summary of Toxicity Data
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Oral RfD		Inhalation RfC		Oral Slope Factor	Inhalation Cancer Unit Risk	Weight of Evidence	Ref
	Subchronic* (mg/kg/d)	Chronic (mg/kg/d)	Subchronic (ug/m3)	Chronic (ug/m3)	1/(mg/kg/d)	1/(ug/m3)		
VPH								
C5-C8 Aliphatics	4.0E-01	4.0E-02	2.0E+02	2.0E+02	NC	NC	NA	1
C9-C12 Aliphatics	1.0E+00	1.0E-01	2.0E+02	2.0E+02	NC	NC	NA	1
C9-C10 Aromatics	3.0E-01	3.0E-02	5.0E+01	5.0E+01	NC	NC	NA	1
VPH Target Analytes								
Benzene	1.00E-02	4.00E-03	9.00E+01	3.00E+01	5.50E-02	7.80E-06	A	1
Toluene	8.0E-01	8.0E-02	4.0E+02	4.0E+02	NC	NC	D	1, 2
Ethylbenzene	1.0E+00	1.0E-01	1.0E+03	1.0E+03	NC	NC	D	1
Total Xylenes	2.0E-01	2.0E-01	6.0E+01	1.0E+02	NC	NC	D	1
Methyl tert-butyl ether	1.0E+00	1.0E-01	3.0E+03	3.0E+03	NC	NC	NA	1
Naphthalene	2.0E-01	2.0E-02	3.0E+00	3.0E+00	NC	NC	D	1
PCBs								
PCBs	5.0E-05	2.0E-05	2.00E-02	2.00E-02	2.0E+00	1.0E-04	B2	1

References

1. MCP Toxicity Workbook, MA DEP ORS (January 2006)
2. Integrated Risk Information System, U.S. EPA. October 21, 2004

RfC = Reference Concentration
RfD = Reference Dose

Notes:
NC = Not a Class A or B Carcinogen
NA = Not Available or Not Applicable
NV = Not Volatile

Table 5
Relative Absorption Factors
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Relative Absorption Factors						Reference
	Soil						
	Subchronic		Chronic		Cancer		
	Ingestion	Dermal	Ingestion	Dermal	Ingestion	Dermal	
VPH							
C5-C8 Aliphatics	1	1	1	1	NC	NC	1
C9-C12 Aliphatics	1	0.5	1	0.5	NC	NC	1
C9-C10 Aromatics	1	0.5	1	0.5	NC	NC	1
Target VPH Analytes							
Benzene	1	0.08	1	0.08	1	0.08	1
Toluene	1	0.12	1	0.12	NC	NC	1
Ethylbenzene	1	0.2	1	0.2	NC	NC	1
Total Xylenes	1	0.12	1	0.12	NC	NC	1
MTBE	1	0.1	1	0.1	NC	NC	1
Naphthalene	0.36	0.1	0.36	0.1	NC	NC	1
PCBs							
PCBs	0.85	0.16	0.85	0.16	0.85	0.16	1

References:

1. MCP Toxicity Workbook, MA DEP ORS (January 2006)
2. IRIS EPA, 2006

Notes:

NC = Not a Class A or B carcinogen

NA = Not Applicable or Not Available

Table 6
Exposure Profile Summary
88-90 South Maple Street
Westfield, MA

Exposure	Age (years)	Body Weight (kg)	Exposure Frequency (EF)	Exposure Event Duration (ED)	Exposure Period (EP)	Averaging Period (AP)
Subchronic:						
Construction Worker	18	58	5 events/7 days	1 day/event	6 months	6 months
Commercial Worker	18 < 45	58	5 events/7 days	1 day/event	1 year	1 year
Child Trespasser	9<10	29.6	2 events/7 days	1 day/event	7 months	7 months
Child Resident	1 < 2	10.4	5 events/7 days	1 day/event	7 months	7 months
Chronic:						
Commercial Worker	18 < 45	58	5 events/7 days	1 day/event	30 years	30 years
Child/Teen Trespasser	9 < 16	43.5	2 events/7 days	1 day/event	7/12 mos for 7 yrs	7 years
Child Resident	1 < 8	16.8	5 events/7 days	1 day/event	7/12 mos for 7 yrs	7 years
Lifetime (CA Risk)						
Construction Worker	18	58	5 events/7 days	1 day/event	6 months	70 years
Commercial Worker	18 < 45	58	5 events/7 days	1 day/event	30 years	70 years
Child/Teen Trespasser	9< 16	43.5	2 events/7 days	1 day/event	7/12 mos for 7 yrs	70 years
Teen/Adult Trespasser	16 < 29	57.9	2 events/7 days	1 day/event	7/12 mos for 13 yrs	70 years
Child Resident	1 < 8	16.8	5 events/7 days	1 day/event	7/12 mos for 7 yrs	70 years
Child/Teen Resident	8 < 15	39.7	5 events/7 days	1 day/event	7/12 mos for 7 yrs	70 years
Adult Resident	15 < 31	54.2	5 events/7 days	1 day/event	7/12 mos for 16 yrs	70 years

References:

1. Guidance for Disposal Site Risk Characterization, Section 7.3 (DEP 1995)
2. DEP, Technical Update, Calculation of Enhanced Soil Ingestion Rate (April 2002)
3. DEP, Technical Update, Weighted Skin-Soil Adherence Factors (April 2002)
4. DEP, Technical Update, Characterization of Risks Due to Inhalation of Particulates by Construction Workers (April 2002)
5. EPA, Human Health Evaluation Manual, Supplemental Guidance, Summary of Standard Default Exposure Factors (March 1991)

Table 7
Exposure Pathways Screening
88-90 South Maple Street
Westfield, MA

Media	Exposure Points	Receptor	Timeframe	Exposure Route
Soils	Site-Wide Soils (0-15') (future use)	Commercial Worker	Current /Future	Ingestion, Dermal Contact
		Construction Worker	Potential Future	Ingestion, Dermal Contact, Inhalation
		Trespasser	Current / Future	Ingestion, Dermal Contact
		Resident	Potential Future	Ingestion, Dermal Contact (Produce Consumption)
Groundwater	Potential exposure through direct contact and/or ingestion of groundwater	Resident / Commercial Worker	NA	Groundwater beneath the Site is not a Current or Potential Drinking Water Source.
		Construction Worker	NA	Excavations would be dewatered prior to construction project
	Potential exposure through volatilization of OHM from groundwater into an occupied building or below grade excavation area	Commercial Worker/ Resident	NA	OHM levels in soisl and groundwater indicate adverse impacts to indoor air are unlikely
		Construction Worker	NA	A construction worker is not expected to spend significant amounts of time below ground surface

Notes:
Shaded areas indicate a current complete exposure pathway does not exist
OHM - Oil and/or Hazardous Material
NA - Not Applicable

Table 8
Contact and Intake Rates
88-90 South Maple Street
Westfield, MA

Receptor	Exposure Point Medium	Exposure Route	Exposure Variable	Ref
Commercial Worker	Soil	Ingestion	Relative Absorption Factor	1, 2, 3
			Ingestion Rate:	
			Chronic, Cancer Risk - 50 mg soil/day	4
		Dermal Contact	Relative Absorption Factor	1, 2, 3
			Surface Area	
			Chronic, Cancer Risk - 3,477 cm^{2} [(a)]	5
			Skin Soil Adherence Factor - 0.03 mg/cm^{2}	5
Construction Worker	Soil	Ingestion	Relative Absorption Factor	1, 2, 3
			Ingestion Rate:	
			Subchronic - 100 mg soil/day	4
			Cancer Risk - 100 mg soil/day	4
				4
		Dermal Contact	Relative Absorption Factor	1, 2, 3
			Surface Area	
			Subchronic - 3,477 cm^{2} [(a)]	5
			Cancer Risk - 3,477 cm^{2} [(a)]	5
			Skin Soil Adherence Factor - 0.29 mg/cm^{2}	5
	Soil-Derived Dust	Inhalation	Respirable particulate concentration in air (PM_{10})	
			PM_{10} = 60 ug/m^{3}	7
			Inh = 60 L/min	7
			Proportion, P = 1.0	7
Child / Child/Teen and Adult Trespasser	Soil	Ingestion	Relative Absorption Factor	1, 2
			Ingestion Rate:	
			Subchronic - 50 mg soil/day	4
			Chronic - 50 mg soil/day	4
			CA Risk - 50 mg soil/day	4
			Relative Absorption Factor	
		Dermal	Surface Area[c]	
			Sub/Chronic/CA - 3,656 $cm^{2(a)}$ (9 yrs)	5
			Sub/Chronic/CA - 4,727 $cm^{2(a)}$ (9< 16)	5
			Sub/Chronic/CA - 5,670 $cm^{2(a)}$ (16<29)	5
			Adherence Factor - 0.141 mg/cm^{2} [(a)]	
			Adherence Factor - 0.140 mg/cm^{2} [(a)]	
			Adherence Factor - 0.135 mg/cm^{2} [(a)]	5
			For Wet Soils, Adherence Factor is 1.0 as default	4

Table 8
Contact and Intake Rates
88-90 South Maple Street
Westfield, MA

Receptor	Exposure Point Medium	Exposure Route	Exposure Variable	Ref
Resident (Child and Older Child/ Adult)	Soil	Ingestion	Relative Absorption Factor	1, 2, 3
			Small Child (1<2 years)	
			Subchronic - 100 mg soil/day	4
			Child (1<8 years)	
			Chronic - 100 mg soil/day	4
			Child/Teen (8<15 years)	
			Cancer Risk - 50 mg soil/day	4
			Teen/Adult (15<31 years)	
			Cancer Risk - 50 mg soil/day	4
Resident (Child, Child/Teen and Adult)	Soil	Dermal Contact	Relative Absorption Factor	1, 2, 3
			Surface Area Child (1-2 years)	
			Subchronic - 1,673 cm^2 (b)	8
			Skin Soil Adherence Factor - 0.45 mg/cm^2	8
			Surface Area Child (1-8 years)	
			Chronic - 2,434 cm^2 (c)	8
			Skin Soil Adherence Factor - 0.35 mg/cm^2	8
			Surface Area Older Child/Adult (1 < 8 years)	
			Cancer Risk - 2,431 cm^2 (d)	5, 6, 8
			Skin Soil Adherence Factor - 0.35 mg/cm^2	8
			Surface Area Older Child/Adult (8 < 15 years)	
			Cancer Risk - 4,427 cm^2 (d)	5, 6, 8
			Skin Soil Adherence Factor - 0.14 mg/cm^2	8
			Surface Area Older Child/Adult (15 < 31 years)	
			Cancer Risk - 5,654 cm^2 (e)	5, 6, 8
			Skin Soil Adherence Factor - 0.13 mg/cm^2	8
		Vegetable Consumption	Intake Rate for Child (1<2 yrs)	
			Subchronic - 10,910 mg/day	9
			Intake Rate for Child (1<8 yrs)	
			Subchronic - 12,100 mg/day	9
			Plant Uptake Factor	
			Chromium - 0.095	3

Notes:

a. Skin surface area value calculated for face, hands, forearms, and feet of an 18 to 75 year old female (per Ref. 6).
b. Skin surface area value calculated for face, hands, forearms, lower legs and feet of a 1 to 2 year old female (per Ref. 6).
c. Skin surface area value calculated for face, hands, forearms, lower legs and feet of a 1 to 8 year old female (per Ref. 6).
d. Skin surface area value calculated for face, hands, forearms, lower legs and feet of a 1 to 6 year old female (per Ref 6).
e. Skin surface area value calculated for face, hands, forearms, lower legs and feet of a 6 to 31 year old female (per Ref. 6).

References:

1. Implementation of the VPH/EPH Approach, Final Policy, DEP ORS October 2002
2. Toxicity Information Sheet, Diesel #2 Fuel Release Assessment v2.4-Working Draft, MADEP ORS BWSC (8/20/02)
3. MCP Toxicity Workbook (DEP ORS, January 2006)
4. DEP, Technical Update, Calculation of Enhanced Soil Ingestion Rate (April 2002)
5. DEP, Technical Update, Weighted Skin-Soil Adherence Factors (April 2002)
6. DEP, Guidance for Disposal Site Risk Characterization (July 1995).
7. DEP, Technical Update, Characterization of Risks Due to Inhalation of Particulates by Construction Workers (4/02)
8. DEP, Development of S-1 Standards, Soil Exposure Spreadsheets (DEP Website, 1/2006)
9. DEP, Exposure Assumptions used to Estimate Intake Rates of Homegrown Produce (undated DEP spreadsheet)

Table 9
Summary of Human Health Risk Characterization
Exposure to Maximum Soil Concentrations (0-15')
88-90 South Maple Street
Westfield, MA

Time Period/ Risk	Receptor	Route of Exposure	Human Receptors/Future Potential Exposure Pathways			
			Commercial Worker	Construction Worker	Trespasser	Resident
			Site-Wide MAX (0-15')	Site Wide MAX (0-15')	Site Wide MAX (0-15')	Site Wide MAX (0-15')
Subchronic/ HI	Child (1<2 years)	Ingestion	--	--	--	3.74
		Dermal Absorption	--	--	--	4.33
	Teen (9<10 years)	Ingestion	--	--	0.27	--
		Dermal Absorption	--	--	0.55	--
	Adult (>18 years)	Ingestion	0.345	0.69	--	--
		Dermal Absorption	0.142	4.75	--	--
		Dust Inhalation[3]		0.077	--	--
	Cumulative Subchronic HI		0.49	**5.5**	0.82	**8.1**
Chronic/ HI	Child (1<8 years)	Ingestion	--	--	--	3.68
		Dermal Absorption	--	--	--	7.11
	Teen (9<16 yrs)	Ingestion	--	--	0.28	--
		Dermal Absorption	--	--	0.85	--
	Adult (>18 years)	Ingestion	0.91	--	--	--
		Dermal Absorption	0.43	--	--	--
	Cumulative Chronic HI		**1.3**	--	**1.1**	**10.8**
MCP Cumulative Receptor Non-Cancer Risk Limit =			**1.0**			
ELCR HI	Child (1<8 years)	Ingestion	--	--	--	1.4E-05
		Dermal Absorption	--	--	--	2.2E-05
	Teen (9<16 or 8<15 yrs)[1]	Ingestion	--	--	1.0E-06	2.9E-06
		Dermal Absorption	--	--	2.6E-06	6.7E-06
	Adult[2] (16<29 yrs or 15<31 yrs)	Ingestion	1.4E-05	4.8E-07	1.5E-06	4.8E-06
		Dermal Absorption	5.7E-06	3.1E-06	4.2E-06	1.3E-05
		Dust Inhalation[3]	--	1.7E-08		
	Cumulative ELCR		**2.0E-05**	3.6E-06	9.3E-06	**6.3E-05**
MCP Cumulative Receptor Cancer Risk Limit =			**1.0E-05**			

Notes:
1. Teen Site Visitor is 9<16 yrs; Teen Resident is 8<15 yrs
2. Adult Receptors are > 18 yrs except Trespasser (16<29 yrs) and Resident (15<31 yrs)
3. Dust inhalation is evaluated for the construction worker, only.
Bold indicates HI or ELCR exceeds the MADEP Risk Threshold

ELCR - Excess Lifetime Cancer Risk
EPC - Exposure Point Concentration
MAX - Maximum Soil Concentration
HI - Hazard Index

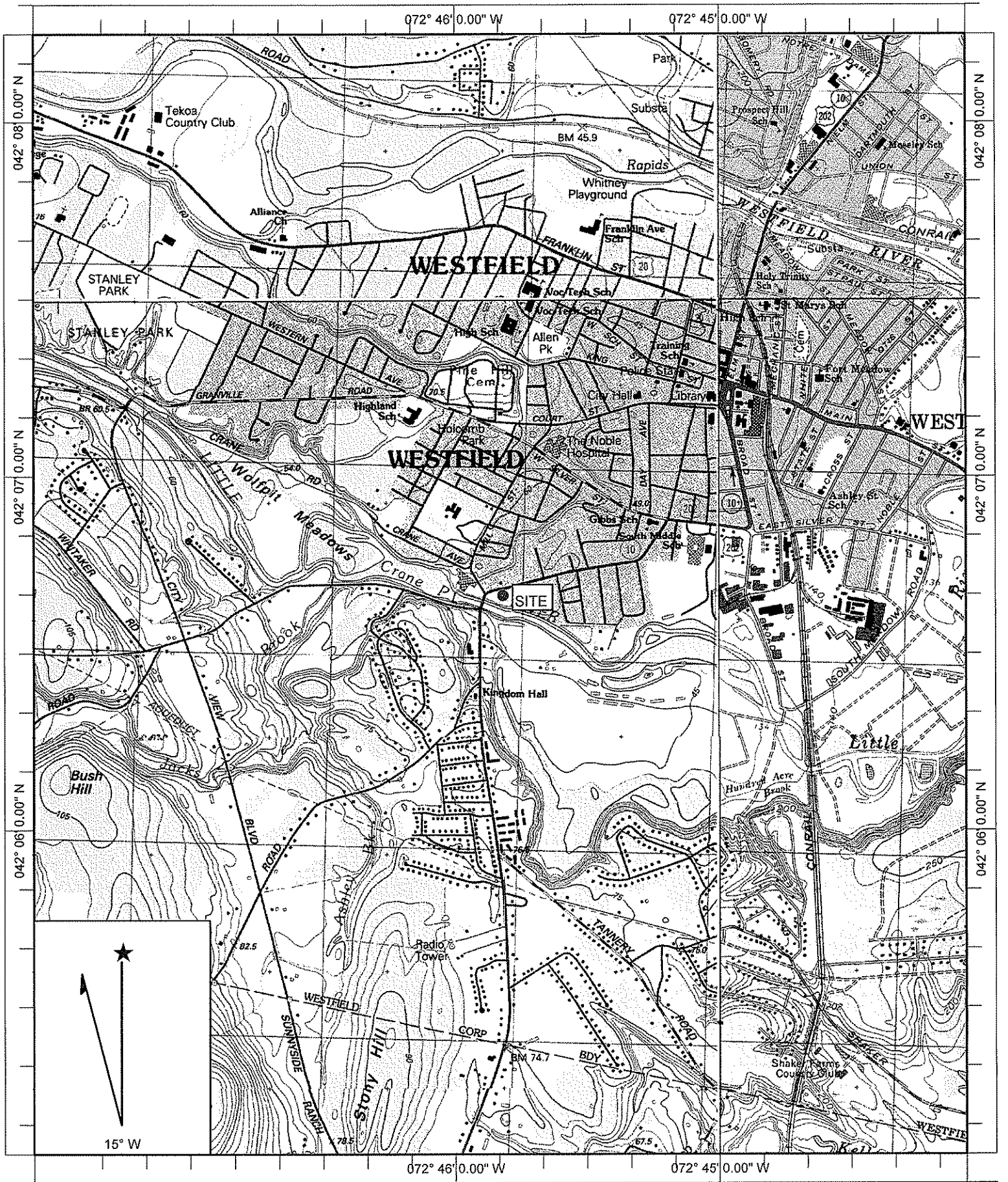
Table 10
Summary of Human Health Risk Characterization
Exposure to Average Soil Concentrations (0-15')
88-90 South Maple Street
Westfield, MA

Time Period/ Risk	Receptor	Route of Exposure	Human Receptors/Future Potential Exposure Pathways			
			Commercial Worker	Construction Worker	Trespasser	Resident
			Site-Wide AVG (0-15')	Site-Wide AVG (0-15')	Site-Wide AVG (0-15')	Site-Wide AVG (0-15')
Subchronic/ HI	Child (1<2 years)	Ingestion	--	--	--	0.49
		Dermal Absorption	--	--	--	0.56
	Teen (9<10 years)	Ingestion	--	--	0.04	--
		Dermal Absorption	--	--	0.07	--
	Adult (>18 years)	Ingestion	0.046	0.09	--	--
		Dermal Absorption	0.018	0.62	--	--
		Dust Inhalation[3]		0.010	--	--
	Cumulative Subchronic HI		0.06	0.72	0.11	**1.1**
Chronic/ HI	Child (1<8 years)	Ingestion	--	--	--	0.48
		Dermal Absorption	--	--	--	0.87
	Teen (9<16 yrs)	Ingestion	--	--	0.04	--
		Dermal Absorption	--	--	0.10	--
	Adult (>18 years)	Ingestion	0.12	--	--	--
		Dermal Absorption	0.05	--	--	--
	Cumulative Chronic HI		0.17	--	0.14	**1.3**
MCP Cumulative Receptor Non-Cancer Risk Limit =			**1.0**			
ELCR HI	Child (1<8 years)	Ingestion	--	--	--	1.8E-06
		Dermal Absorption	--	--	--	2.9E-06
	Teen (9<16 or 8<15 yrs)[1]	Ingestion	--	--	1.4E-07	3.8E-07
		Dermal Absorption	--	--	3.5E-07	8.9E-07
	Adult[2] (16<29 yrs or 15<31 yrs)	Ingestion	1.9E-06	6.4E-08	2.0E-07	6.4E-07
		Dermal Absorption	7.5E-07	4.2E-07	5.6E-07	1.8E-06
		Dust Inhalation[3]	--	2.3E-09		
	Cumulative ELCR		2.7E-06	4.9E-07	1.2E-06	8.4E-06
MCP Cumulative Receptor Cancer Risk Limit =			**1.0E-05**			

Notes:
1. Teen Site Visitor is 9<16 yrs; Teen Resident is 8<15 yrs
2. Adult Receptors are > 18 yrs except Trespasser (16<29 yrs) and Resident (15<31 yrs)
3. Dust inhalation is evaluated for the construction worker, only.
Bold indicates HI or ELCR exceeds the MADEP Risk Threshold

ELCR - Excess Lifetime Cancer Risk
EPC - Exposure Point Concentration
MAX - Maximum Soil Concentration
HI - Hazard Index

FIGURES



Name: SOUTHWICK
Date: 6/17/2005
Scale: 1 inch equals 2000 feet

Location: 042° 06' 40.0" N 072° 45' 49.7" W
Caption: Site Locus
Westfield Sunono
88-90 South Maple Street, Westfield, MA 01085

LITTLE RIVER

WOODED AREA

TREE LINE

APPROX. PROPERTY BOUNDARY

MW-203

MW-6

MW-204

GRASSY AREA

(3) EXISTING 10,000 GAL. USTs

PAVED AREA

EDGE OF PAVEMENT

(3) VENT PIPES

MW-4

SB-4

MW-2 (former)

GRASSY AREA

DISPOSAL SITE BOUNDARY

EXCAVATION AREA

SB-3

MW-3B

MW-1

SB-2

CAR WASH BLDG.

TRANSFORMER

EXCAVATION AREA

MW-101

EXISTING BUILDING

MW-5

PUMP PAD / CANOPY

SB-1

SEE EXCAVATION ENLARGEMENT NO. 2

UE

MW-102

PUMP ISLAND (TYPICAL)

SB-103

MW-201

SEE EXCAVATION ENLARGEMENT NO. 1

UNDERGROUND UTILITY CORRIDOR CONTAINING TELEPHONE, SEWER, WATER AND GAS LINES

PAVED AREA

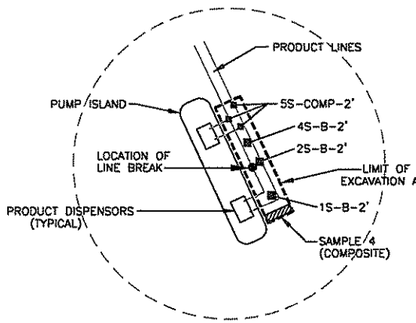
PRODUCT DISPENSOR (TYPICAL)

MW-202

STREET

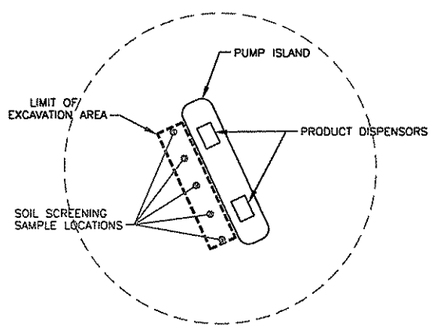
MAPLE

SOUTH



EXCAVATION AREA NO. 1

NOT TO SCALE



EXCAVATION AREA NO. 2

NOT TO SCALE

SCALE

0 20 40 60 80 FEET

(APPROX.)

LEGEND

- SOIL BORING
- EXISTING GROUNDWATER MONITORING WELL
- UE — UNDERGROUND ELECTRIC

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Assessments – Remediation – Emergency Response

127 HARTWELL ST. W.BOYLSTON, MA.

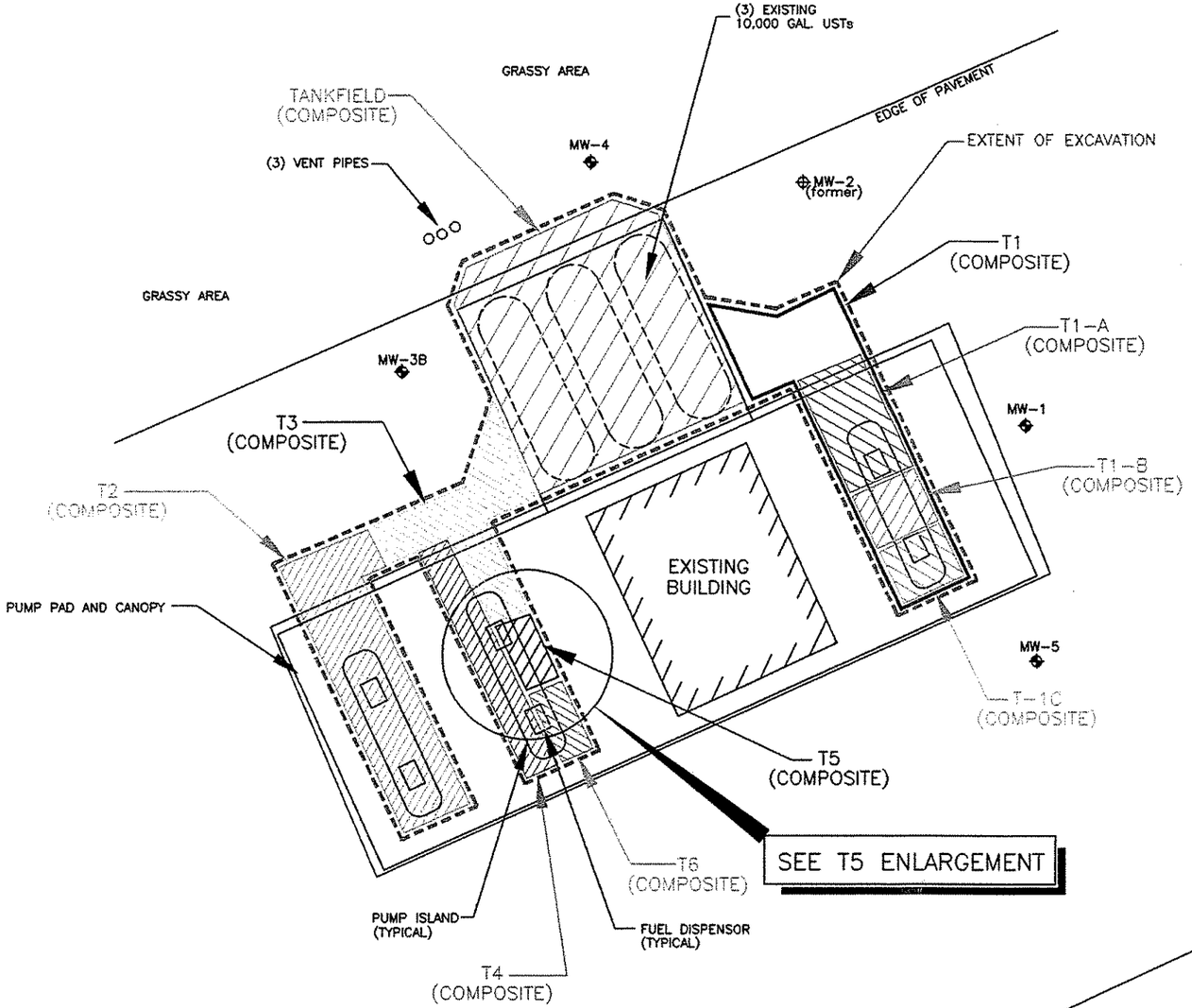
SCALE: AS SHOWN		DR. BY: K. HAZEL
DATE: 12/19/07	APP. BY: SEV	JOB NO.: 5795-05

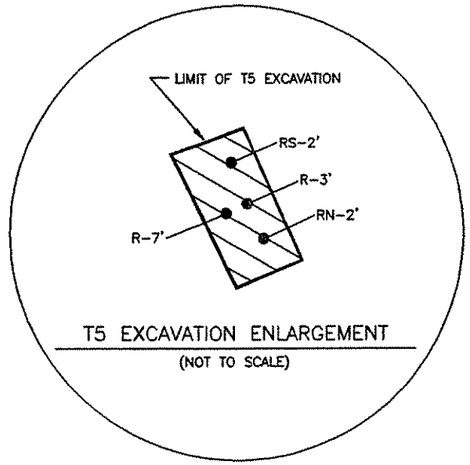
SITE LAYOUT
(APRIL 2005 EXCAVATION)

SUNOCO, INC.

88 SOUTH MAPLE ST. WESTFIELD, MA.

FIGURE-2A





T5 EXCAVATION ENLARGEMENT
(NOT TO SCALE)

SCALE

0 5 10 20 40 FT.

(APPROX.)

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Assessments – Remediation – Emergency Response

127 HARTWELL ST. W.BOYLSTON, MA.

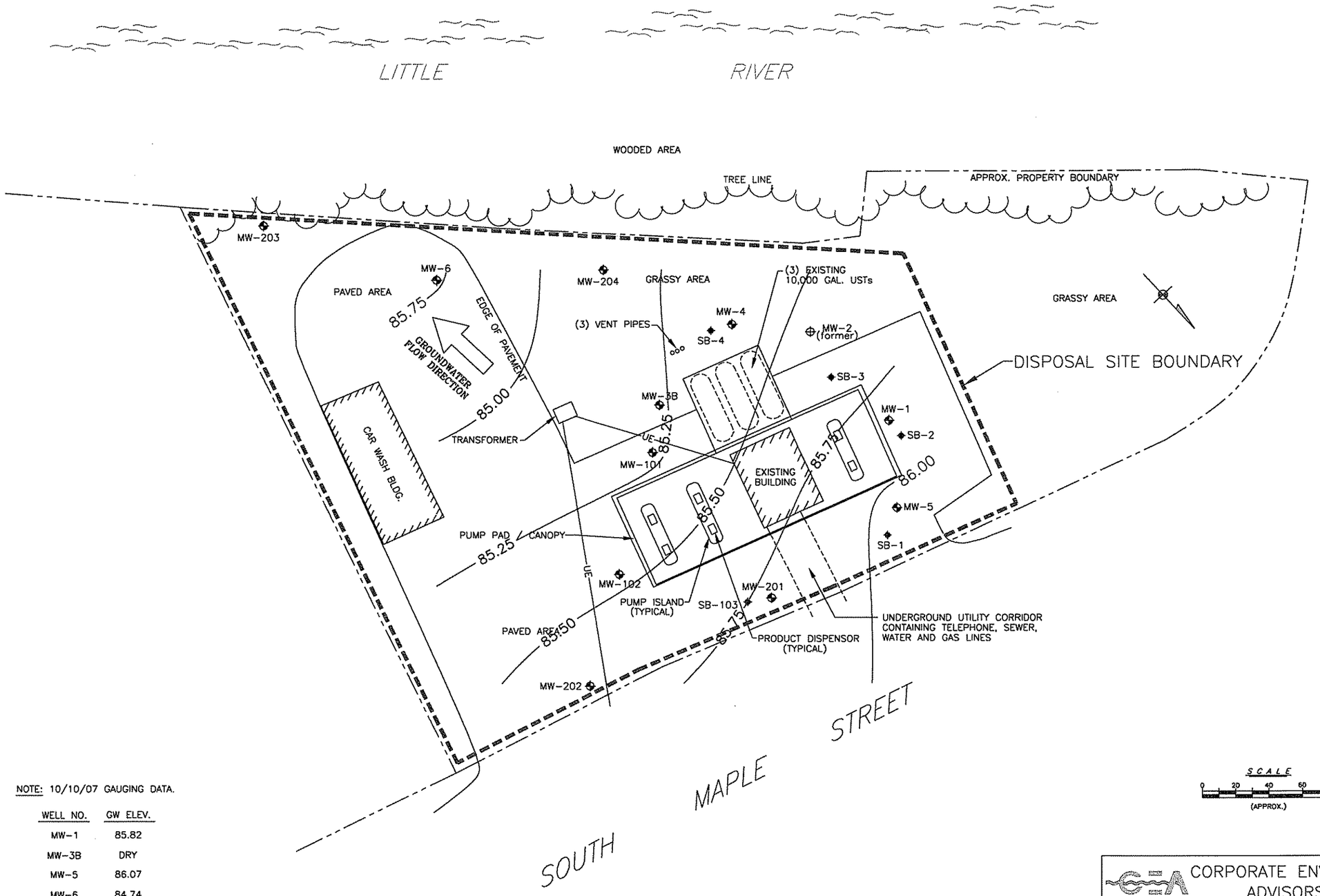
SCALE: AS SHOWN		DR. BY: K. HAZEL
DATE: 1/10/06	APP. BY: SEV	JOB NO.: 5795-05

EXCAVATION ENLARGEMENT
(11-12/2005 EXCAVATION)

SUNOCO, INC.

88 SOUTH MAPLE ST. WESTFIELD, MA.

FIGURE-2B



NOTE: 10/10/07 GAUGING DATA.

WELL NO.	GW ELEV.
MW-1	85.82
MW-3B	DRY
MW-5	86.07
MW-6	84.74
MW-101	85.20
MW-102	85.45
MW-201	85.79
MW-202	85.67
MW-203	DRY
MW-204	85.17

LEGEND

- ◆ – SOIL BORING
- ◆ – EXISTING GROUNDWATER MONITORING WELL
- —UE— – UNDERGROUND ELECTRIC

SCALE

0 20 40 60 80 FEET

(APPROX.)

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Assessments – Remediation – Emergency Response

127 HARTWELL ST. W.BOYLSTON, MA.

SCALE: AS SHOWN		DR. BY: K. HAZEL
DATE: 12/18/07	APP. BY: SEV	JOB NO.: 5795-05

SITE LAYOUT W/GROUNDWATER CONTOURS

SUNOCO, INC.

88 SOUTH MAPLE ST. WESTFIELD, MA.

FIGURE-2C

MA DEP - Bureau of Waste Site Cleanup

Site Scoring Map: 500 feet & 0.5 Mile Radii

SITE NAME:
Westfield Sunoco
88 South Maple Street
WESTFIELD, MA 01085
420640n 724548ew

Site Location

The information shown on this map is the best available at the date of printing. Please refer to the data source descriptions document.

MASSGIS Massachusetts Geographic Information System
Massachusetts Executive Office of Environmental Affairs - 2005

Roads: Limited Access, Divided, Major Road, Connector, Street, Track, Trail

Boundaries: Town, County, DEP Region; Train; Powerline; Pipeline; Aqueduct

Basins: Major, Sub; Streams: Perennial, Intermittent, Man Made Shore, Dams

Potentially Productive Aquifers: Medium,High Yield

Non-Potential Drinking Water Source Area: Medium,High Yield

EPA Sole Source Aquifer; FEMA 100-year floodplain

Public Water Supplies: Ground,Surface,Non Community

Approved Zone2; IWPA; Surface Water Supply Zone A

Hydrography: Water Features,Public Surface Water Supply

Wetlands: Fresh,Salt,NHESP Wetlands Habitat

Protected Open Space; ACEC

DEP Permitted Solid Waste Facilities; Certified Vernal Pools

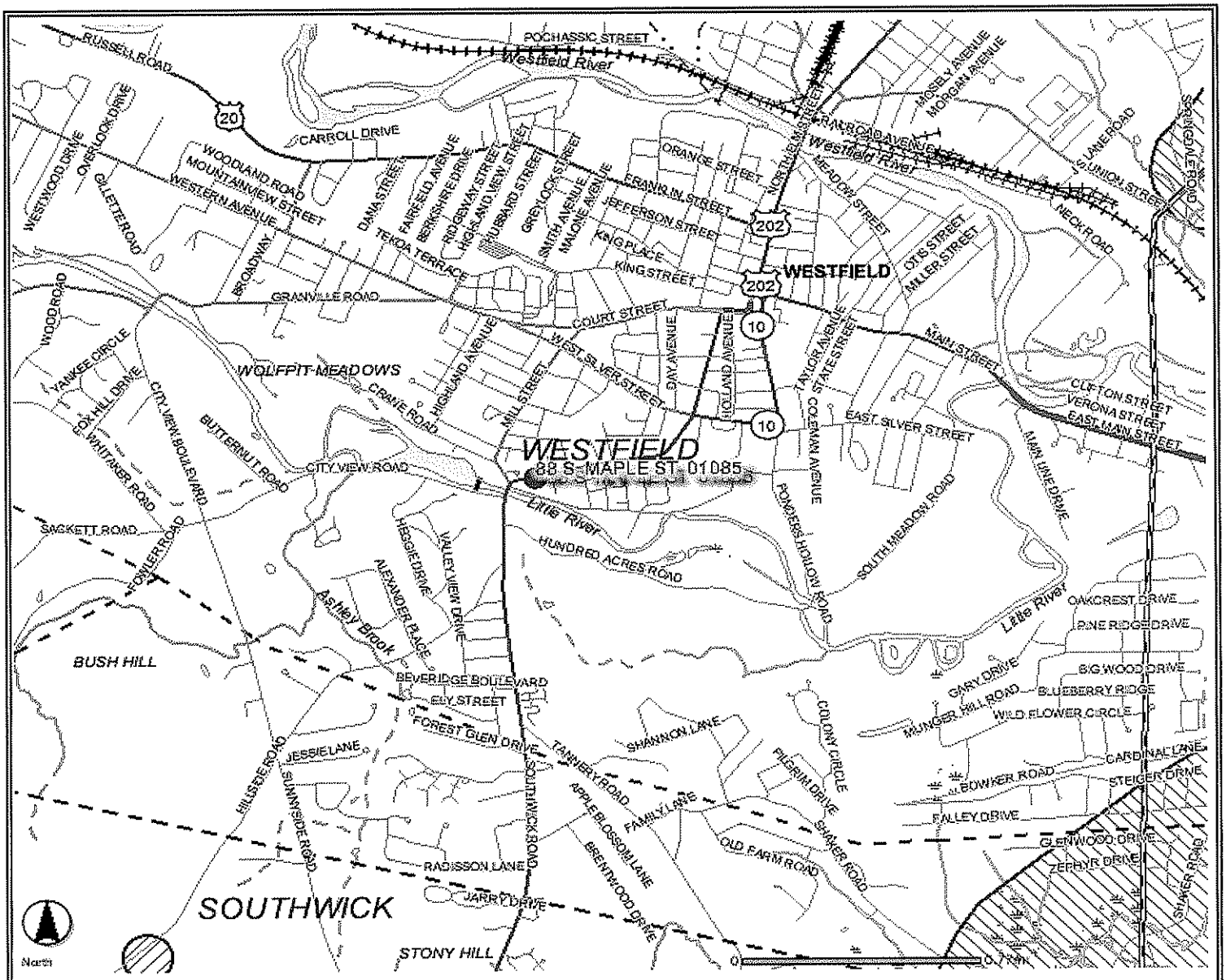
N NW NE W E SW SE S

SCALE 1:15000

0 1/2 MILES

0 1/2 KILOMETERS

August 01, 2005



- Zone IIs
- IWPAs
- Zone A
- Sole Source Aquifers
- Solid Waste Sites
- Protected Openspace
- ACECs
- NHESP Estimated Habitat of Rare Wildlife in Wetland Areas
- Certified Vernal Pools 2003 NHESP
- Subbasins
- Mass Major Basins
- DEP Region

Aquifers, By Yield
- HIGH YIELD
- MEDIUM YIELD

Non Potential Drinking Water Source Area
- HIGH YIELD
- MEDIUM YIELD

FEMA Floodplains
- 100 YEAR FLOODPLAIN

Hydrography
- WATER
- RESERVOIR
- WETLANDS
- SALTWATER WETLANDS
- FLATS,SHOALS

Rivers and Streams
- PERENNIAL
- INTERMITTENT
- SHORELINE
- MAN MADE SHORE
- DAM
- AQUEDUCT

EOT-OTP Roads
- LIMITED ACCESS HIGHWAY
- MULTILANE HWY, NOT LIMITED ACCESS
- OTHER NUMBERED HWY
- MAJOR ROAD - COLLECTOR
- MINOR STREET OR ROAD, RAMP

Tracks and Trails MHD
- TRACK
- TRAIL

Transmission Lines
- PIPELINE
- POWERLINE
- TRAIN

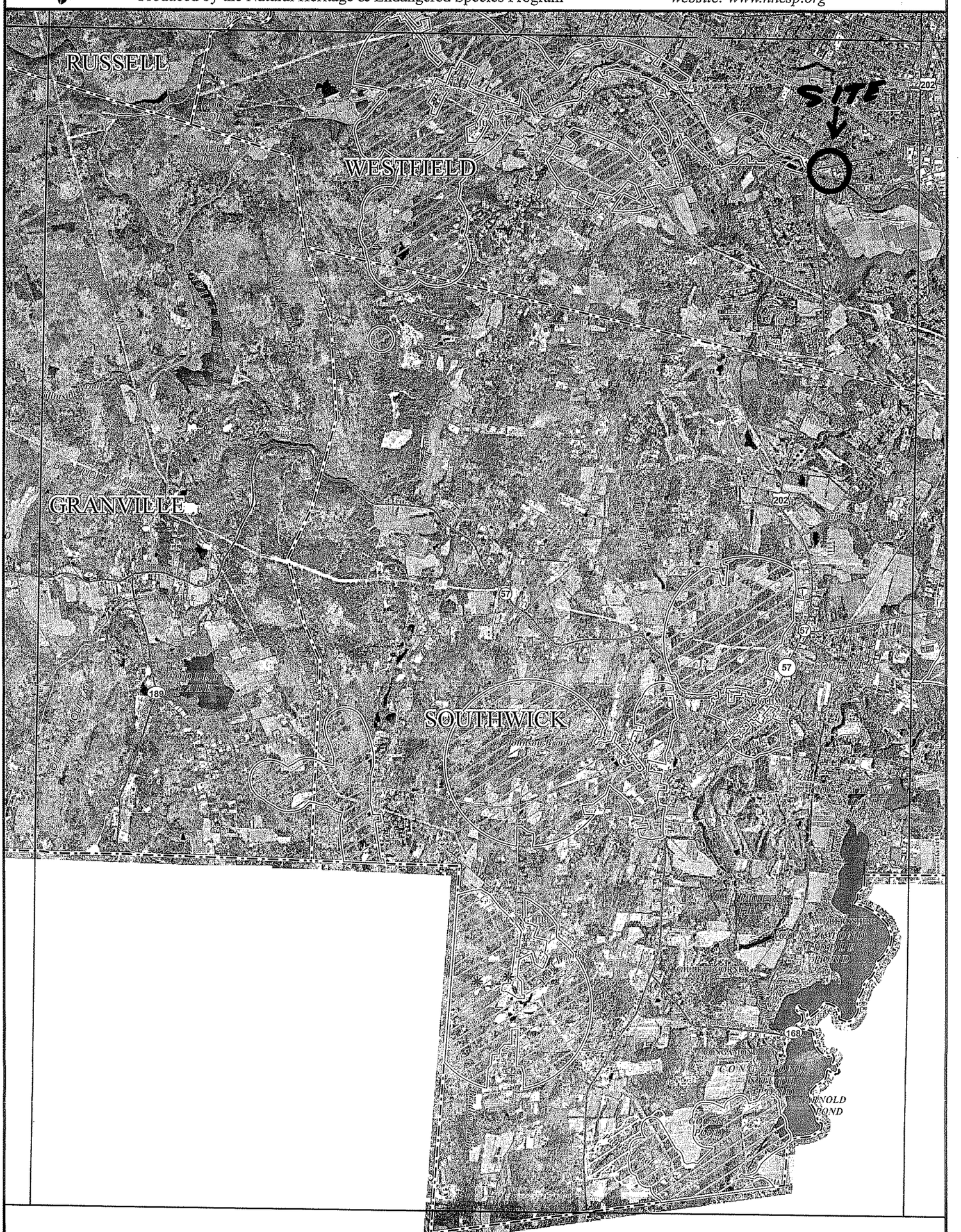
21E Resource Priority Map Sunoco Station 88-90 South Maple Street Westfield, MA	**Date:** March 12, 2007 **CEA Project No.: 5795-05**	CEA CORPORATE ENVIRONMENTAL ADVISORS, INC. **Figure 4**

APPENDIX A

Priority Habitats and Estimated Habitats - Effective October 1, 2006

Priority Habitats for use with the MA Endangered Species Act Regulations (321 CMR 10)
Estimated Habitats for use with the MA Wetlands Protection Act Regulations (310 CMR 10)

Produced by the Natural Heritage & Endangered Species Program *website: www.nhesp.org*



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p.122		p.124

Priority Habitat of Rare Species

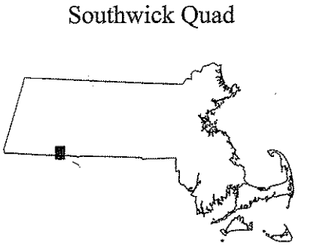
Priority Habitat of Rare Species and also Estimated Habitat of Rare Wildlife

*** Certified Vernal Pool (as of July 14, 2006)**

N

0 0.5 1 2 Miles

Southwick Quad



APPENDIX B

DRAFT

UPDATED PETROLEUM HYDROCARBON FRACTION TOXICITY VALUES FOR THE VPH/EPH/APH METHODOLOGY

Prepared for:

Bureau of Waste Site Cleanup
Massachusetts Department of Environmental Protection
Boston, MA

Prepared by:

Office of Research and Standards
Massachusetts Department of Environmental Protection
Boston, MA

May 2002

ORS Env

PREFACE

In 1994 the Massachusetts Department of Environmental Protection (MA DEP) described a new approach for the evaluation of human health risks from ingestion exposures to complex petroleum hydrocarbon mixtures (MA DEP, 1994). The basis of the new approach was treating groups of compounds as if they had similar toxicities, in the absence of specific toxicity information on all the members of the group. The report included oral toxicity values for each of the designated petroleum hydrocarbon fractions. Since that time, there have been more recent efforts by others on this topic and additional information has become available to serve as a basis for updating the toxicity values. This document contains reviews of the more recent information, revisions to the oral toxicity values proposed in the 1994 report and new inhalation toxicity values.

Readers will find different upper end hydrocarbon compound size cutoffs for the hydrocarbon ranges identified here and in the 1994 report, compared to those in other related supporting documentation for this approach (i.e., the MA DEP VPH/EPH analytical methods, risk spreadsheets for the MA DEP Bureau of Waste Site Cleanup). The Interim Final report (MA DEP, 1994) identified upper end size cutoffs for both the alkanes and aromatics of compounds with 32 carbon atoms (C_{32}). The analytical methods that were subsequently developed for the volatile (VPH) and extractable (EPH) fractions of petroleum hydrocarbon mixtures identified slightly different cutoffs based upon the limitations of the methods. The limit for alkanes extended to 36 carbon atoms (C_{36}), and that for aromatics was reduced to 22 carbon atoms (C_{22}). Data presently being reported to the Department reflect these upper end cutoffs. In order to avoid confusion with the information contained in the Interim Report, this report has continued to refer to the original upper end cutoffs, although the Waste Site Cleanup program is now using the analytically defined limits.

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EXECUTIVE SUMMARY

Petroleum hydrocarbon size-based fractions for use in evaluating the human health effects of exposures to complex mixtures of hydrocarbons were described by the Massachusetts Department of Environmental Protection (MA DEP) in 1994 along with oral toxicity values for each of the fractions. The Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) independently identified largely similar groupings of hydrocarbon fractions with somewhat different toxicity values in 1997. They also identified inhalation toxicity values.

The original studies used by the TPHCWG to derive their toxicity values were not previously available for independent review. They were obtained by MA DEP for this review. These studies plus more recent published literature were reviewed in the context of MA DEP's original toxicological evaluation to identify the most current and appropriate toxicity values for the hydrocarbon fractions for both oral and inhalation exposures. The two earlier sets of values plus MA DEP's currently proposed values are contained in Table 1.

With the exception of the lighter weight aliphatics fraction (C_5-C_8), differences between the earlier values and those proposed in this document were less than a factor of 10. The toxicity of the C_5-C_8 aliphatic fraction should continue to be driven by considerations for the potential neurotoxicity (peripheral neuropathy) from exposures to commercial hexanes and potential diketone metabolites of n-alkanes.

These toxicity values will be the updated toxicity values used as the basis for medium-specific cleanup standards in the state's hazardous waste site characterization and cleanup program and will serve as the appropriate fraction toxicity values in human-health risk assessments conducted under that and other state programs.

Table 1. Oral and Inhalation Toxicity Values for Petroleum Hydrocarbon Fractions

Exposure Route	Carbon Range*	1994 MA DEP mg/kg/d	TPHCWG* (1997b) (mg/kg/day)	2002 MA DEP Recommended Values (mg/kg/day)
Oral	**Aliphatic**			
	C_5 - C_8	0.06	5	0.06
	C_9-C_{18}	0.6	0.1	0.1
	C_{19} - C_{32}	6.0	2.0	2.0
	$C_{>16}$-C_{35}		2.0	-
	Aromatic			
	C_6 - C_8	Evaluate each chemical in the series separately	Benzene alone, 0.2 (C_7 – C_8)	Evaluate each chemical in the series separately
	C_9-C_{16}	-	0.04	
	C_{17}-C_{35}		0.03	
	C_9-C_{32}	0.03	-	0.03
			(mg/m^3)	(mg/m^3)
Inhalation	**Aliphatic**			
	C_5 - C_8	-	18.4	0.2
	C_9-C_{18}	-	1.0	0.2
	C_{19} - C_{32}	-	NA	NA**
	Aromatic			
	C_6 - C_8	-	Benzene alone 0.4 (C_7-C_8)	Use individual RfCs for compounds in this range
	C_9-C_{16}	-	0.2	0.02
	C_{17}-C_{32}	-	NA*	NA

* Ranges shown are those used by MA DEP. For simplicity, TPHCWG tox. values are shown with approximate carbon ranges, not their EC carbon ranges.

** NA – not applicable to inhalation exposures since compounds not volatile.

AUTHORS AND REVIEWERS

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Carol Rowan West	MA DEP, ORS

1.0 INTRODUCTION

A key component of the evaluation of petroleum contaminated waste sites is the assessment of potential human health risks from exposures to petroleum hydrocarbon compounds, usually present as mixtures. An improved method for the evaluation of health hazards posed by oral exposures to these complex mixtures was developed and described by MA DEP in 1994 (MA DEP, 1994) and in Hutcheson et al.(1996) and integrated into MA DEP's BWSC site characterization program. The method involves segregating the petroleum hydrocarbon compounds present in mixtures into broad chemical classes (alkane/cycloalkane, alkene and aromatics) and further into subgroups or fractions based upon their size (defined by number of carbons atoms in the compounds). These designations were made upon consideraton of the nature and degree of comparative toxicity of compounds and structure activity relationship (SAR) considerations.

For each subgroup of compounds, a "reference compound" was initially identified to represent the toxicity of all compounds in the range. It was usually chosen because its toxicity was relatively well characterized. For each reference compound, a US EPA-published oral reference dose value (RfD) was identified or, for those "reference compounds" without US EPA published values, an oral dose-response value was identified based on available toxicity information. A document describing how this method is to be used within the framework of the state's hazardous chemical waste site cleanup program has also been developed (MA DEP, 2001).

Subsequent to the completion of the first phase of this work in 1994, a national ad hoc workgroup known as the TPH (Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG), composed of representatives from the military, the oil and gas industry, the consulting community, academia and some regulatory agencies introduced its version of an approach (TPHCWG, 1997a,b) for evaluating both oral and inhalation exposures to petroleum hydrocarbons (PHCs).

The TPHCWG work consisted of presentation of a rationale for the designation of related groups of hydrocarbons. The groups were differentiated by their potential for leaching to ground water and volatilization to air. These potential mechanisms for environmental dispersion are described by the leaching (LF) and volatilization factors (VF) (see TPHCWG, Volume #3, 1997a for the details of the mathematical derivation of these factors). Aromatic or aliphatic TPH components having similar LF and VF values ranging one order of magnitude were grouped together as fractions having similar transport properties.

The size-differentiated petroleum hydrocarbon groups developed by the MA DEP (1994) and TPHCWG (1997a) differ slightly. The MA DEP based its TPH fractions on chemical structure, carbon number, and structure activity relationships. The TPHCWG-specified fractions are based on fate and transport considerations. The MA DEP-specified aliphatic subgroups include the C_5 - C_8, C_9 - C_{18}, and C_{19} - C_{32} carbon ranges. The aromatic subgroup is the C_9 - C_{32} carbon range. C_6 - C_8 compounds are evaluated individually. The TPHCWG specified many more groups for both the aliphatic and aromatic fractions. Since toxicity data for individual petroleum hydrocarbons (PHCs) within each of the many fate and transport fractions were unavailable, the same toxicity surrogates were usually applied by the TPHCWG to several sequential fractions which ultimately resulted in similar subgroups to those specified by MA DEP (Table 2).

Those groups specified by TPHCWG are delineated by compound size expressed as Equivalent Carbon numbers (EC). The EC is empirically determined based on the boiling point of the chemical normalized to the boiling point of n-alkanes, or its retention time in a boiling point GC column. ECs can have fractional components. They generally are very similar to the number of carbon atoms in the compounds for those having less than about 10 carbon atoms, but above that EC values for aromatics become less than those for aliphatics having the same number of carbon atoms. The MA DEP fractions are delineated by compound size expressed as the number of carbon atoms in each compound. The MA DEP nomenclature will be used in this report.

The oral toxicity values for the hydrocarbon groups identified by the TPHCWG were based on data from mixtures of chemicals of sizes generally falling within the hydrocarbon ranges. The TPHCWG also developed inhalation reference concentrations (RfCs) for the lower molecular weight aliphatic and aromatic PHCs occupying the same PHC classes used for oral exposures. The original supporting studies for the TPHCWG hydrocarbon fractions were not available for outside review at the time of release of the TPHCWG workproducts. These original documents were primarily contract laboratory technical reports and have since been provided to MA DEP for this review by the sponsoring organization. Additional toxicological information has also come available since both groups completed their work. The availability of this new information warrants a reevaluation of the toxicity values for oral and inhalation exposures to petroleum hydrocarbons.

This report:

1. comparatively evaluates the existing MA DEP, TPHCWG oral toxicity values and new literature and recommends MA DEP's preferred oral toxicity values, and

2. reviews the TPHCWG's inhalation toxicity values and their supporting studies, reviews the literature that appeared since TPHCWG values were developed and recommends fractional RfCs for the various petroleum hydrocarbon fractions to be used by MA DEP.

Table 2. Fractions Specified by MA DEP and the TPHCWG for Toxicological Evaluation

MA DEP Specified TPH Fractions	TPHCWG Specified TPH Fractions (based on fate & transport)	TPHCWG Specified TPH Fractions (for Tox. Evaluation)
Carbon Range*	Carbon Range*	Carbon Range**
Aliphatic	Aliphatic	Aliphatic
$C_5 - C_8$	$C_5 - C_6$	$C_5 - C_8$
	$C_{>6} - C_8$	
$C_9 - C_{18}$	$C_{>8} - C_{10}$	$C_{>8} - C_{16}$
	$C_{>10} - C_{12}$	
	$C_{>12} - C_{16}$	
$C_{19} - C_{32}$	$C_{>16} - C_{21}$	$C_{>16} - C_{35}$
	$C_{>21} - C_{35}$	
Aromatics	Aromatics	Aromatics
B, T, E, X individually	$C_{>7} - C_8$	$C_7 - C_8$
$C_9 - C_{32}$	$C_{>8} - C_{10}$	$C_{>8} - C_{16}$
	$C_{>10} - C_{12}$	
	$C_{>12} - C_{16}$	
	$C_{>16} - C_{21}$	$C_{>16} - C_{35}$

* carbon number-based

** equivalent carbon (EC) number- based

B = benzene, T = toluene, E = ethylbenzene, x = xylene

2.0 ASSESSMENT OF ORAL AND INHALATION TOXICITY INFORMATION

2.1 ALIPHATIC FRACTIONS TOXICITY VALUES

Inhaled or ingested volatile hydrocarbons have both general and specific effects. Many organic solvents, including petroleum hydrocarbons, have the potential on acute high-level vapor exposure to cause central nervous system (CNS) disturbances like disorientation, euphoria, giddiness, and confusion; progressing to unconsciousness, paralysis, convulsion and death from respiratory or cardiac arrest (Browning, 1965). These effects have been observed with aliphatic and aromatic compounds found within the C_5 - C_9 (aliphatics) and C_6 - C_{10} (aromatics) carbon ranges.

The acute narcotic effects of the volatile hydrocarbons result from direct chemical action. The similarity of CNS disruption produced by hydrocarbons of diverse structures suggest that these effects result from a common process which is physical interaction of the solvents with the cells of the CNS (Andrews and Snyder, 1991). For example, interaction of the lipid-soluble hydrocarbons with the synaptosomal membranes causes CNS toxicities. The potency of the CNS effects depends on the structure of the individual hydrocarbon molecule.

Other nonspecific effects of hydrocarbons are exhibited after prolonged exposure to these agents. The nonspecific effects observed in animals and humans are neurobehavioral toxicities. The neurobehavioral effects are manifested as sensory, cognitive, affective and motor abnormalities. There is some evidence suggesting that the mechanism of the behavioral effects is alterations in the utilization and turnover of biogenic amines in the brain. These effects occur at lower hydrocarbon concentrations than those producing morphological changes. Recent animal studies indicate that both aromatic (Korsak and Rydzynski, 1996; Gralewicz et al., 1997) and aliphatic (Lund et al., 1995) volatile hydrocarbons may cause nonspecific neurobehavioral toxicities with differing intensities depending on the structure of the hydrocarbon.

Distinct from the general CNS effects of hydrocarbons are their associated specific organ toxicities. Examples of such effects include the hematopoietic toxicity of benzene and the neurodegenerative toxicity of n-hexane. The specific toxicities of hydrocarbons may be directly related to their metabolites as is the case with benzene and n-hexane (Andrews and Snyder, 1991).

2.1.1 C_5 - C_8 Aliphatic Fraction – Oral RfD

2.1.1.1 Basis for Existing Toxicity Values. In the MA DEP methodology, n-hexane was selected as a representative reference compound for the toxicity of aliphatic hydrocarbons containing 5 to 8 carbon atoms since its toxicity was well characterized. Other compounds which occur in this group (n-pentane, n-heptane and n-octane) were hypothesized to be structurally predisposed to cause peripheral neuropathy like that produced by n-hexane, but to a lesser extent. Both n-hexane and n-heptane are metabolized to γ-diketone metabolites with 2,5-gamma spacing. When a series of 2,5-hexanedione analogues were tested, only those with 2,5-gamma spacing caused peripheral neurotoxicity (St Claire et al., 1988). Representation of the potential toxicities of other compounds in this range by the toxicity of n-hexane has been criticized by some as overly conservative because they interpret the peripheral neuropathy seen with n-hexane to be unique to that compound. Faced with some uncertainty about the toxicities of these compounds, MA DEP chose in 1994 to adopt a more health protective approach and retain the RfD of 0.06 mg/kg/day derived from a gavage study of n-hexane as a toxicity surrogate for this fraction.

The TPHCWG on the other hand evaluated two data sets to derive a representative toxicity value for this fraction. The first data set was on n-heptane, which has been studied because of its structural and metabolic similarity to n-hexane. The second data set includes toxicity studies on solvent mixtures containing hexane isomers.

1. n-Heptane

The animal studies evaluated by the work group included those of Frontali et al. (1981), Takeuchi et al. (1980, 1981), and API (1980). Frontali et al. (1981) exposed rats intermittently to either n-hexane (500, 1500, 2500, or 5000 ppm, 9 to 10 hours/day, or 5 to 6 days/week, up to 30 weeks), cyclohexane (1500 or 2500, 9 to 10 hours/day, 5 to 6 days/week, up to 30 weeks), n-pentane (3000 ppm, 9 hours/day, 5 days/week, up to 14 weeks), 2-methylpentane (1500 ppm, 9 hours/day, 5 days/week, up to 14 weeks), 3-methylpentane (1500 ppm, 9 hours/day, 5 days/week, up to 14 weeks), or n-heptane (1500 ppm, 9 hours/day, 5 days/week, up to 30 weeks). The authors reported that out of the various solvents tested, only n-hexane gave rise to histological signs of giant axonal degeneration at the highest exposure level with accompanying significant body weight reduction, giving a NOAEL 2500 ppm. n-Pentane and 2-methylpentane also caused significant body weight reductions at the exposure concentrations tested. According to the study, a γ-diketone metabolite, which is a toxic intermediate, was identified for only n-hexane. In another study (Bahima et al., 1984), however, rats exposed to 200 ppm n-heptane (6 hours/day, 5 days/week for 12 weeks produced the neurotoxic γ-diketone metabolite (2,5-heptanedione) as a minor urinary metabolite.

The study design of the Frontali et al. (1981) investigation makes it difficult to draw conclusions about the peripheral neurotoxicity of n-heptane, 2-methylpentane and 3-methylpentane. When animals were exposed to each of the above solvents at 1500 ppm, 9 hours/day, 5 days /week, for up to 14 weeks, none of the solvents demonstrated peripheral neurotoxicity. In a similar exposure scenario, n-hexane, which is the prototype peripheral neurotoxicant, also did not cause neuropathy in the test animals. These solvents were not tested at levels similar to those of n-hexane that caused peripheral neurotoxicity in the above cited study. Cyclohexane, however, appeared to cause no neural damage at the exposure level similar to the intermediate n-hexane concentration that caused some peripheral neurotoxicity.

When rats were exposed via inhalation to 3000 ppm n-hexane, n-pentane or n-heptane, 12 hours/day 7 days/week for 16 weeks, peripheral nerve damage occurred only with n-hexane (Takeuchi et. al., 1980; 1981). Rats exposed to 400 or 3000 ppm n-heptane 6 hours/day, 5 days/week for 26 weeks showed no signs of peripheral neurotoxicity (API, 1980).

n-Heptane appeared to produce no peripheral neurotoxicity directly in animals. However, a metabolite of n-heptane, 2,5-heptanedione, produced peripheral neurotoxicity similar to that of 2,5-hexanedione (metabolite of n-hexane) (Katz et al., 1980; Misumi and Nagano, 1984). The TPHCWG evaluated a quantitative pharmacokinetic study on n-hexane and n-heptane by Kreuzer et al. (1995). This evaluation was said to indicate that when rats and human volunteers were exposed to either n-hexane (up to 300 ppm) or n-heptane (up to 500 ppm), there was a 38 fold lower amount of urinary 2,5-heptanedione formed in humans and rats when compared to 2,5-hexanedione. Furthermore, based on 2 studies on 2,5-heptanedione and 2,5-hexanedione, 2,5-heptanedione was suggested to be 2.5 to 5 times less potent in producing peripheral neurotoxicity than 2,5-hexanedione. The work group concluded that the peripheral neurotoxicity risk from n-heptane exposure was at least 38 times lower than the risk from exposure to n-hexane. This factor of 38 was used to multiply the n-hexane RfD of 0.06 mg/kg/day. The n-hexane RfD was derived by the TPHCWG from an EPA derived inhalation RfC of 0.2 mg/m^3 for this compound by direct route-to-route extrapolation. The RfD estimated for n-heptane was 2 mg/kg/day.

2. Commercial Hexane

The other data set evaluated by the TPHCWG included animal studies performed on commercial hexane (CH) which was composed of 53% n-hexane. The other constituents included 3-methylpentane, methylcyclopentane, 2-methylpentane,

cyclohexane, 2,3-dimethylbutane, and <1% several minor compounds. Subchronic, chronic, and developmental/reproductive inhalation studies of CH mixtures demonstrated no peripheral nerve damage, and no CNS, reproductive or developmental toxicities in rats and mice. The studies are discussed below and summarized in Table 3.

Animal Studies

- Subchronic Inhalation Neurotoxicity Study of Commercial Hexane in Rats (API, 1990a). Rats were exposed to CH vapors at 0, 900, 3000 and 9000 ppm, (0, 3092, 10307, 30921 mg/m^3) for 6 hours/day, 5 days/week for 13 weeks. Treatment with commercial hexane at concentrations of up to 30921 mg/m^3 (9000 ppm) for 13 weeks had no effect on mortality, clinical condition, body weight, food consumption or gross pathology. There were no effects upon the behavioral parameters assessed as a functional observational battery and motor activity test. Neuropathological evaluations revealed no effects of treatment. The NOAEL in this study was reported to be 9000 ppm (30921 mg/m^3).

- Subchronic Inhalation Toxicity of Commercial Hexane in Rats and Mice (API, 1990b). Fischer 344 rats and B6C3F1 mice were exposed to 0, 900, 3000 or 9000 ppm (0, 3092, 10307, 30921 mg/m^3) commercial hexane vapor for 6 hours/day, 5 days/week for 13 weeks. A transient exposure-related excess lacrimation in both sexes of mice and female rats was observed, however no signs of exposure-related ocular diseases were observed. Clinical chemistry tests showed changes in the male rats in the high exposure group including increased platelets, creatinine, total protein and albumin, and a decrease in chloride levels. Absolute and relative liver weights were also increased in both species in the high concentration group except for the female rats. The kidney and the adrenal organ weight to body weight and organ weight to brain weight, ratios were significantly increased in the male and female rats exposed to 9000 ppm. These results were not observed in mice. Hemorrhage in the liver (high level only) and acute/subacute inflammation in the liver (high level only) and kidney (mid and high levels) were observed in male rats. No microscopic effects were seen in the mice. Based on these data, the NOAEL for commercial hexane in both species was 3000 ppm (10307 mg/m^3).

- Two Generation Reproduction Study of Inhaled Commercial Hexane in Rats (API, 1990c). Sprague-Dawley rats were exposed to commercial hexane vapor at 0, 900, 3000 or 9000 ppm (0, 3092, 10307, 30921 mg/m^3) for two generations, one litter per generation. A consistent pattern of adult toxicity at 9000 ppm, evidenced by reduced body weights in F_1 males and females (but not F_0 males or females) was observed. Reproductive parameters were not affected

in both the F_1 and F_2 generations. F_1 litters exhibited reduced body weight on lactational days 14 and 21 at 9000 ppm. The F_2 generation of pups exhibited reduced body weights from lactational day 7 to weaning on day 28 at 9000 ppm (30921 mg/m^3). The NOAEL for general toxicity in adults and offsprings in this study was 3000 ppm (10307 mg/m^3). The NOAEL for reproductive toxicity was at least 9000 ppm (30921 mg/m^3).

- Developmental Toxicity of Commercial Hexane Vapor in Rats (API, 1989a). Sprague-Dawley rats were exposed to commercial hexane vapor for six hours per day on gestational days 6 through 15 at concentrations of 0, 900, 3000 or 9000 ppm (0, 3092, 10307, 30921 mg/m^3). Maternal effects were observed at 3000 and 9000 ppm. Maternal toxicity at 9000 ppm included significant weight reduction and treatment-related color changes in the lung at necropsy. At 3000 ppm, body weight gain was reduced for gestation days 9 through 12 . No developmental toxicity was observed at any of the concentrations. The NOAELs for maternal and developmental toxicity were 900 and 9000 ppm respectively.

Table 3. API Sponsored Subchronic, Chronic, Reproductive and Developmental Inhalation Studies Evaluated by the TPHCWG in Their Oral RfD and Inhalation RfC Derivation Process for the C_5 - C_8 Aliphatic Fraction

Duration	Species	Study Design	Findings	NOAEL	Reference
Subchronic (Neurotoxicity)	Rat	0,900, 3000, or 9000 ppm 6 hours/day/ 5 days/week for 13 weeks	No neurobehavioral or neuropathologic effects	9000 ppm	API, 1990a
Subchronic (Systemic)	Mouse	0, 900, 3000, or 9000 ppm 6 hours/day, 5 days/week for 13 weeks	Transient exposure-related excess lacrimation, increased in absolute and relative liver weights in male and female mice at 9000 ppm	3000 ppm	API, 1990b
Subchronic (Systemic)	Rat	0,900, 3000, or 9000 ppm 6 hours/day/ 5 days/week for 13 weeks	Changes in clinical chemistry, significant increases in relative kidney and adrenal weights in male rats at 9000ppm; significantly increased relative adrenal weights in female rats at 9000 ppm; significantly increased liver weights at 9000 ppm in male rats and an upward trend in female rats; hemorrhage and acute/subacute inflammation of the liver in male rats at 9000 ppm; nephropathy in male rats at 3000 and 9000 ppm;	3000 ppm	API, 1990b
Chronic (Oncogenicity)	Rat	0, 900, 3000, or 9000 ppm 6 hours/day, 5 days/week for 2 years	Histologic evidence of mucosal irritation in nasal turbinates and larynx No neoplastic effects	No NOAEL identified for nasoturbinal effects	API, 1995
Chronic (Oncogenicity)	Mouse	0, 900, 3000, or 9000 ppm 6 hours/day, 5 days/week for 2 years	Liver tumor in female mice at 9000 ppm		API 1995
Reproductive.	Rat	0, 900, 3000, 9000 ppm 6 hours/day, 5 days/week, for two generations	Reduced body weight in both F_1 and F_2 generations at 9000 ppm.	30000	API, 1990C
Developmental	Rat	0, 900, 3000, 9000 ppm 6 hours/day on days 6 - 15 of gestation	Maternal effects were noted at 3000 and 9000 ppm. Significant weight reduction and treatment-related changes in the lung at 9000 ppm. Weight reduction at 3000 ppm.	900 ppm (maternal) 9000 ppm (develop.)	API, 1989a

Duration	Species	Study Design	Findings	NOAEL	Reference
Developmental	Mouse	0, 900, 3000, 9000 ppm 6 hr/day on days 6 – 15 of gestation	Slight maternal toxicity at 3000 and 9000 ppm. Significant increases in the incidence of color changes in the lungs and some increases in the frequency of dark brown foci in the lungs at 9000 ppm. Some color changes and dark brown foci in the lungs at 3000 ppm. Treatment-related increases in the incidence of skeletal variations at 9000 ppm.	900 ppm (maternal) 3000 ppm (develop.)	API, 1989b

- Developmental Toxicity of Commercial Hexane Vapor in CD-1 Mice (API, 1989b). Mice were exposed to commercial hexane vapor for six hours/day on gestational days 6 through 15 at concentrations of 0, 900, 3000 and 9000 ppm. Slight maternal toxicity was observed at 3000 and 9000 ppm. There was a significant increase in the incidence of color change in the lungs as well as an increased (non-statistically significant) number of dams (4 of 9) exhibiting dark brown foci in the lungs at 9000 ppm. At 3000 ppm, characteristic color changes in the lungs were noted in two (of 25) dams; in three other dams dark brown foci were observed in the lungs. Treatment-related increases in bilateral bone islands at the first lumbar arch and all intermediate unossified phalanges were observed at 9000 ppm. The NOAEL for maternal toxicity was 900 ppm and for developmental toxicity the NOAEL was 3000 ppm.

- Inhalation Oncogenicity Study of Commercial Hexane In Rats and Mice, Part I-rats. (API, 1995). Rats were exposed to 0, 900, 3000, 9000 ppm (to 0, 3092, 10307, 30921 mg/m^3) CH vapor for 2 years. Excess lacrimation increased in the commercial hexane exposed males at 3000 and 9000 ppm. Body weight gain was significantly reduced in the 3000 and 9000 ppm exposure groups. Microscopic morphologic abnormalities that were considered to be related to commercial hexane exposure were found in the nasal turbinates and the larynx only. The incidences and/or severities of these findings in the exposure groups were increased when compared to the respective controls (Table 4).

  Hypertrophy/hyperplasia of goblet cells in the nasoturbinal tissues, seen in numerous males and females, tended to occur more frequently in the exposure groups than in the controls. The severity showed a dose-related increase. Hyperplasia of the respiratory epithelium was seen more frequently and with greater severity in the exposure groups than in the controls. This response exhibited a positive dose-response relationship.

  Intracytoplasmic eosinophilic material in the respiratory and submucosal glandular epithelium and in the sustentacular cells of the olfactory epithelium were seen more frequently and with greater severity in the exposure groups than in the controls. In the males, the severities in Groups III and IV (3000 and 9016 ppm, respectively) were comparable and greater than those seen in Group II (900 ppm). In the females the severities in Groups II, III, and IV were essentially similar.

Microscopic findings associated with inflammatory changes in the nasoturbinal tissues seen in a number of males and females from the exposure and control groups occurred most frequently as follows: a) subacute (chronic active)/chronic inflammation of the nasal mucosa in the males, followed by the females, from Group IV (9016) ppm; b) inflammatory cells/cell debris in the nasal lumen in males from Group IV; c) edema of the nasal mucosa in males from Group IV. The authors concluded that a NOAEL was not identifiable from the data on the nasoturbinal tissues of the rats.

In the larynx, squamous/squamoid metaplasia/hyperplasia of the pseudostratified columnar epithelium was seen in a small number of animals from the control and exposure groups. In the males, the highest incidence was seen in Group IV (9016 ppm), followed by Group III (3000 ppm). In the females, the incidence in Groups III and IV was comparable, and greater than that seen in Group I (0 ppm). This finding was considered to be a localized response indicative of irritation. In all of the affected animals, the metaplastic epithelium was well differentiated and organized, with no evidence of atypia or dysplasia (Table 4).

An Inhalation Oncogenicity Study of Commercial Hexane In Rats and Mice, Part-II Mice. (API, 1995, Part II). Mice were exposed to 0, 900, 3000, 9000 ppm (0, 3092, 10307, 30921 mg/m^3) CH for 6 hours/day, 5 days/week for 2 years. Mean body weights and body weight gains in the exposed animals were not statistically different from control values in the male mice. In the females however, at 9000 ppm, body weight gain was significantly reduced.

Macroscopic examinations found an apparent treatment-related increase in liver masses and nodules among the females in the 9000 ppm group but not among the males. Microscopic examinations found a treatment-related increase in hepatocellular neoplasms (adenoma and carcinoma) among females in the high exposure group. For females, the incidence of benign tumors was statistically significant for trend at 0.04 level. There were no significant pairwise differences. The incidence of malignant tumors was not significant for trend or pairwise comparisons. When benign and malignant tumors were combined there was a statistically significant trend at 0.01 level and a statistically significant difference between the high dose group and the control group. Liver tumors among males were not treatment-related. There was an increase in the incidence of pituitary proliferative changes (hyperplasia, adenoma and adenocarcinoma) among all treated groups of females but not among males. There was also a treatment-related decrease in the severity and a slight decrease in the incidence of cystic endometrial hyperplasia of the uterus among the females in 9000 ppm group. The authors concluded that commercial hexane was an oncogen in female mice.

In the previously described API (1995, Part I) rat study, the nasoturbinal tissues were examined and were severely affected by CH. These target tissues were not examined in mice in the API (1995, Part II) study.

Table 4. Microscopic Findings in Rat Respiratory Tract Tissues after Chronic Inhalation Exposure to Commercial Hexane (API, 1995 Part I)

			Number of animals affected							
			Male				Female			
Organ Examined	Tissue Examined	Group*:	1	2	3	4	1	2	3	4
		# / group:	48	50	50	50	50	49	49	50
		#examined:	48	50	50	50	50	49	49	50
Nose/Turbinates	• nasal mucosa (respiratory): goblet cell hypertrophy/hyperplasia		29	37	43	41	33	43	43	46
	• nasal mucosa (respiratory): epithelium-hyperplasia. intracytoplasmic eosinophilic material		2	19	36	43	6	34	38	42
	• nasal mucosa (respiratory/olfactory): epithelium-intracytoplasmic eosinophilic material		21	49	46	46	41	47	48	49
	• nasal mucosa (respiratory/olfactory): submucosal glands. epithelium-intracytoplasmic material		10	41	41	43	20	47	47	37
	• nasal mucosa (respiratory/olfactory): subacute (chronic active)/chronic inflammation		9	8	10	23	8	6	4	13
	• nasal lumen inflammatory cells/cell debris		13	16	13	23	9	5	10	6
		Number Examined:	49	19	18	50	48	10	14	48
Larynx	pseudostratified columnar epithelium: squamous/squamoid metaplasia (with hyperplasia)		4	0	2	11	1	0	2	7

* group 1 = control, and group 2, group 3, group 4, were exposed to 900, 3000, and 9016 ppm commercial hexane respectively.

The TPHCWG used the API-sponsored chronic studies on commercial hexane in mice and rats to derive a representative oral RfD for the C_5 - C_8 aliphatic fraction by first deriving an inhalation RfC from the inhalation exposure studies. From all of the studies, the most appropriate NOAEL identified for either the rat or mice chronic bioassay was 3000 ppm (10,307 mg/m^3). The exposure duration-adjusted NOAEL (NOAEL x 6/24 x 5/7) was estimated to be 1841 mg/m^3. By applying an uncertainty factor of 100 (10 for human variability, 10 for animal to human extrapolation), a chronic inhalation RfC of 18.4 mg/m^3 was estimated for the C_5 - C_8 aliphatic hydrocarbon fraction. An oral RfD of 5 mg/kg/day was then calculated from the inhalation RfC by assuming that the inhalation rate for a 70 kg human is 20 m^3 /day and absorption is 100%. Given the level of this RfD compared to that of pure n-hexane, the TPHCWG concluded that n-hexane toxicity can be influenced by the presence of other petroleum components.

The TPHCWG then proposed three alternative RfDs for the C_5 - C_8 aliphatic fraction:

1. Apply the n-hexane RfD of 0.06 mg/kg/day for the n-hexane portion of the fraction and the n-heptane RfD of 2 mg/kg/day for the remaining mass.
2. Evaluate the n-hexane concentration separately. If the n-hexane concentration is less than 53%, the RfD applied should be 5 mg/kg/day. If the n-hexane concentration is greater than 53%, the RfD used should be 0.06 mg/kg/day for the n-hexane portion and 2.0 mg/kg/day for the remaining mass since only n-heptane has well documented toxicity values.
3. Use a single RfD value of 5 mg/kg/day for all situations with the exception of the rare release of high purity n-hexane.

They choose option #3 (5 mg/kg/day, as a fractional RfD). The rationales for choosing this value were that:

- The composition of n-hexane in petroleum products ranges only from 0.05% to 15.7%.
- The presence of other petroleum products influences the toxicity of n-hexane.
- Mixtures' data are better representative of the toxicity of petroleum components and when available should be used to evaluate the human health risks from exposures to petroleum hydrocarbon mixtures.

2.1.1.2. Discussion and Recommendation. There are several issues associated with the TPHCWG's use of the commercial hexane rat study to derive an oral RfD for the C_5 – C_8 aliphatic fraction. These issues have a bearing upon the suitability of that RfD to represent the toxicity of that hydrocarbon range.

(1) The RfD for the C_5 - C_8 aliphatic fraction was derived by the TPHCWG from inhalation studies using direct route-to-route extrapolation. Although n-hexane appears to target the peripheral nerves when ingested or inhaled, estimating equivalent dose-response relationships from one route of exposure to another introduces an additional uncertainty in the derivation of an oral RfD.

(2) One of the commercial hexane animal studies designed to study neurotoxicity (API, 1990a) and reviewed by the TPHCWG in the surrogate RfD derivation process for the C_5 – C_8 fraction demonstrated negative neurological effects. However, there are human and animal studies on commercial hexane demonstrating peripheral neurotoxicity.

n-Hexane was originally selected by MA DEP as the indicator for this range because its toxicity has been well investigated and also because of some evidence demonstrating that the other alkanes in the group may have similar neurotoxic capacities. The peripheral neurotoxicity of n-hexane is of particular human health concern. Several epidemiological and animal studies have demonstrated that humans and animals exposed to n-hexane suffered from motor and sensory deficits that were associated with axonal degeneration in the peripheral nervous system. In many of the epidemiological studies, exposure was to mixtures containing commercial grade hexane or other aliphatic mixtures within the specified carbon ranges for this fraction. The mixtures contained n-hexane with levels ranging from 12.3 to 64%. Although none of the epidemiological studies permit the estimation of reference toxicity values because of data inadequacy (such as lack of control population and exact exposure estimation), they strongly suggest that commercial hexane or other mixtures within the group containing low levels of n-hexane may cause peripheral neurotoxicity.

Yamada (1972) investigated the cases of 17 workers who had reported symptoms of polyneuropathy (with subsequent development of muscular atrophy and paresthesia in the distal extremeties) while exposed to hexane vapors for 2 years. Six of the employees were exposed to hexane levels ranging between 1000 and 2500 ppm. The hexane solvent used in the plants where the six subjects worked contained 16% methyl pentane, 20% methyl cyclopentane, and 64% n-hexane; a characteristic composition of commercial grade hexane. Eleven of the 17 employees worked in a different plant where the solvent used contained 95% n-hexane. Exposure levels ranged between 500 and 1000 ppm. The n-hexane concentrations that failed to produce peripheral neurotoxicity in rats in the API (1990a) study were estimated to be 477, 1590 and 4770 ppm, based upon n-hexane being 53% of the exposure concentrations (900, 3000, 9000 ppm) that were used in the API studies. Gaultier et al. (1973) also reported peripheral neurotoxicity in people occupationally exposed to solvent mixtures. The solvent used in the workplace contained only 5% n-hexane, 14% heptane and 80% pentane. Yamamura (1969) reported an outbreak of peripheral neurotoxicity resulting from

exposure to hexane that was used as a glue solvent in a sandal factory in Japan. Inoue et al. (1970) reported that the hexane solvent in the glue used by the sandal makers who were studied by Yamamura (1969) contained 2-methylpentane, 3-methylpentane, methylcyclopentane, and n-hexane. Although the concentrations of the individual constituents were not given, the authors related that most commercial hexane solvents contained these four compounds with n-hexane constituting about 60% of the total.

A solvent that caused five cases of peripheral neurotoxicity in a workshop cleaning silk brocade sash contained C_5 – C_9 hydrocarbons and their isomers. n-Hexane accounted for only 12.3 % of the total (Takeuchi et al, 1975). Peripheral neurotoxicity was also reported in Italian workers in shoe manufacturing plants. Analyses of the solvents and glues in the shoe factories in which the workers developed peripheral neurotoxicity indicated that the vapors contained alkanes including, isopentane, n-pentane, 2-methylpentane, 3-methylpentane, n-hexane, isoheptane and n-heptane (Abbritti et al., 1976). After screening 654 employees in several shoe factories, 98 verified cases of peripheral neurotoxicity were detected. Analysis of the vaporized constituents of the glues and solvents demonstrated the presence of pentane, 2-methylpentane, 3-methylpentane, n-hexane, heptane, cyclohexane, and methy-cyclopentane. The individual solvent levels were not reported (Passero et al, 1983).

In summary, the epidemiological studies demonstrated that inhalation exposure to n-hexane, commercial grade hexane, or other mixtures in the group containing 12.3 – 60% n-hexane resulted in peripheral neurotoxicity. The data do not allow comparison of the severity of the neuropathy induced by pure n-hexane or the aliphatic mixtures in the series.

There are also some inhalation and oral animal studies on hexane mixtures that demonstrated peripheral neurotoxicity. Chronic and continuous exposure of mice to commercial hexane containing 65 – 70 % n-hexane caused peripheral neurotoxicity (Miyagaki, 1967). Male mice (10 per test group) were exposed to 0, 100, 250, 500, 1000, or 2000 ppm (0, 353, 881, 1762, 3520 or 7050 mg/m^3) of commercial hexane 24 hours/day, 6 days/week for one year. Monitored parameters included: electromyography, strength duration curves, electrical reaction time and flexor/extensor chronaxy ratio, gait posture, and grade of muscular atrophy. Electromyographic analysis showed increased complexity in neuromuscular unit voltages in 0/6 control, 1/6 animals examined in the 100 ppm group, 3/6 animals examined in the 250 ppm group, 5/6 animals examined in the 500 ppm group, 3/3 animals examined in the 1000 ppm group and 4/4 animals examined in the 2000 ppm group.

Electromyography also showed a similar dose-related increase in both incidence and severity of reduced interference voltages from muscles in animals exposed to 500 ppm and higher but not in controls and the low exposure concentrations. Dose-related increases in abnormalities of strength-duration curves were also detected. Electromyographs also showed dose-related fibrillation. Abnormal posture and muscle atrophy were noted in a dose-related manner in animals exposed to 250 ppm and higher. The NOAEL identified in this study was 100 ppm. The flaw in the study was that only the data from 3 to 6 of the 10 animals were presented. Also, mice are reported to be less susceptible to n-hexane peripheral neurotoxicity than rats (see ATSDR,1999). This observation suggests that more pronounced effects could have been detected if rats were used in this chronic study.

Rats were exposed to a mixture containing the n-hexane isomers 2-methylpentane, 3-methylpentane, cyclohexane, methylcyclohexane, methylcyclopentane, and 2,3-dimethybutane with about 1% n-hexane (494 ppm), or n-hexane (99%) alone (100 ppm) or n-hexane plus mixed hexanes (992 ppm). Gait disturbances and peripheral nerve atrophy were observed in the n-hexane (494 ppm) alone group and in the groups treated with n-hexane plus hexane mixture (992 ppm).

The frequency of peripheral nerve atrophy was higher in the group receiving n-hexane alone than the group receiving the n-hexane plus hexane mixture. However it was not possible from the data to quantitate the difference in severity between mixture treated and pure n-hexane treated groups. This study demonstrated that hexane mixtures containing about 51% n-hexane caused peripheral nerve damage (IRDC, 1981).

Krasavage et al. (1980) gavaged COBS rats with practical grade hexane (4000 mg/kg/day), n-hexane (570, 1140 or 4000 mg/kg/day), 2-hexanol (675 mg/kg/day), 2,5-hexanedione (755 mg/kg/day), 2,5-hexanediol (780mg/kg/day), 5-hydroxy-2-hexanone (765 mg/kg/day), or methyl n-butylketone (MnBK) (660 mg/kg/day) once daily, 5 days/week over a 90 - 120-day period. The practical grade hexane contained 40% n-hexane, 24% 3-methylpentane, 24% dimethylbutane, 9% cyclopentane, 2.5% cyclohexane and 1.2% 2-methylpentane. The highest dose of n-hexane, MnBK, and all hexane metabolites demonstrated clinical signs of polyneuropathy. No clinical signs of neuropathy were observed in rats treated with practical grade hexane. However, histologic examination of nerve tissues collected at termination revealed that all test compounds except the two lowest doses of n-hexane caused morphologic changes indicative of "giant axonal" neuropathy, which included multifocal axonal swellings, axonal myelin infolding and paranodal myelin retraction. The histologic anomaly occurred with equal frequency in rats treated with MnBK and n-hexane metabolites and with lowest frequency in rats treated with practical grade hexane.

For 2,5-hexanedione, 5-hydroxy-2-hexanol, 2,5-hexanediol, MnBK, 2-hexanol and n-hexane (4000 mg/kg/day) the severity of the neurotoxic indices was directly related to the peak 2,5-hexanedione concentration which is a metabolic product the above listed chemicals except 2,5-hexandione itself. However, n-hexane (570 or 1140 mg/kg/day) that did not produce any clinical or histological signs of peripheral neurotoxicity had higher levels of peak serum 2,5 hexanedione (24 ± 1.6 and 44 ± 2.7 μg/l respectively) than practical grade hexane (14 ± 2.7 μg/l). Practical grade hexane demonstrated histological signs of peripheral neurotoxicity. This result suggests that the other mixtures (3-methylpentane, dimethylbutane, cyclopentane, cyclohexane and 2-methylpentane) or their metabolites may have contributed to the peripheral neurotoxicity of n-hexane in the mixture.

In the above study, the authors reported that 3 out of 5 rats treated with 4000 mg/kg/day practical grade hexane, 1 out of 5 rats treated with 4000 mg/kg/day n-hexane 2 out of 5 rats treated with 1140 mg/kg/day n-hexane, and died due to chemical pneumonitis immediately following intubation and these rats were not included in the determination of the neurotoxicity. Only two rats were evaluated for practical grade hexane neurotoxicity that would make a significant difference in the outcome and interpretation of the results.

There is an oral study suggesting that some of the individual hexane isomers may be toxic to peripheral nerves. Rats were treated with oral doses of n-hexane, methylcyclopentane, 2-methylpentane or 3-methylpentane. n-Hexane, 2-methylpentane and 3-methylcyclopentane decreased motor nerve conduction velocities. The effect occurred sooner in the n-hexane treated animals than in the animals treated with the other isomers (Ono et al., 1981).

Saturated hydrocarbons in the C_5 - C_8 fraction other than n-hexane and its isomers include n-pentane, n-heptane, n-octane and their structural (branched chain and cyclic) isomers. Unlike n-hexane, few human and animal toxicity studies are available on these compounds.

As previously described, the TPHCWG evaluated only the negative animal studies on n-heptane. Trauhaut et al. (1973) reported that rats exposed to 1500 ppm technical grade heptane for five or six months demonstrated a reduced nerve conduction velocity, an increased refractory period, and decreased excitability of the sciatic and saphenous nerves as effectively as 2000 ppm technical grade hexane. The heptane used in the experiment contained 52.4% of n-heptane, 16.2% of 3-methylhexane, 9.8% of other heptane isomers, and 21.5% of octane isomers, but did not contain n-hexane. The same level of pure n-heptane exposure (1500 ppm, 9 hours/day, 5 days/week, for 7-14 weeks) did not cause peripheral neuropathy in rats (Frontali et al. 1981). The Trauhaut

et al. (1973) and the Frontali et al. (1981) studies suggest that mixtures containing the heptane isomers may be more neurotoxic than pure n-heptane alone.

Humans exposed for an extended period of time to the petroleum fraction with the boiling range 70°C to 100°C developed peripheral neuropathy (Cavigneaux, 1972). This fraction would normally contain various isomers of heptane as major ingredients. Eighteen individuals who had been exposed to 95% n-heptane for periods ranging 1 to 9 years were investigated for peripheral neurotoxicity. Electrophysiological examinations were performed on 12 of the test subjects. Mild peripheral neurotoxicity was demonstrated in the tested people (Crespi et al. 1979). This study did not specify the exposure concentrations of n-heptane in the workplace. Data on exposure of humans to technical grade heptane were unavailable. The data suggest that n-heptane which failed to produce peripheral neuropathy in animals may cause this disease in humans but to a lesser extent than n-hexane, practical grade hexane or practical grade heptane.

When male rats were exposed to n-heptane vapor (100, 500 or 1000 ppm) for up to two weeks, reduced RNA concentration, and increased NADPH-diaphorase activity were observed in the brain at the lowest exposure level. Increased proteolysis was detected in the cerebral samples in the second week at all exposure concentrations. All biochemical effects were abolished after two weeks of withdrawal from exposure with the exception of reduced amount of glutathione at the lowest dose. None of the rats demonstrated clinical signs of peripheral neuropathy (Savolainen and Pfaffli, 1980) after two weeks of exposure.

In vitro studies were conducted to investigate the effects of various neurotoxic compounds and n-heptane on primary neural cell cultures from fetal rats. The responses of the neural cells to the neurotoxic compounds were evaluated three and seven days after the first dosing by determining cell viability, and amounts of glial fibrillary acid protein (GFAP), and neuron-specific enolases (NSE) and neurofilaments in primary cortical cell cultures from rats. GFAP is an indicator of astrocyte proliferation (gliosis) that results from toxic or mechanical injury to neurons, and NSE is a cellular marker of neurons (Schmuck and Schluter, 1996).

n-Heptane demonstrated both acute and delayed cytotoxicity while 2,5-hexanedione, the metabolite of n-hexane, demonstrated only delayed cytotoxicity. n-Hexane did not cause cytotoxicity, and the authors attributed the lack of effect of n-hexane on cell viability to its more rapid evaporation rate from the culture dishes when compared to n-heptane. However, n-hexane caused other toxicities in the neural cell cultures suggesting that evaporation may not be a factor in n-hexane's lack of cytotoxicity. The no effect concentrations (NOECs) of n-heptane for GFAP, NSE and neurofilament at day 7 were lower than the NOEC for cytotoxicity at the same time point indicating that n-heptane's effect on these parameters started to occur prior to cell death. The concentrations of n-

heptane required to produce effect in all the described parameters are lower than n-hexane and 2,5-hexanedione (see Table 5). However, n-heptane should be studied at much lower concentrations that are not cytotoxic in order to accurately determine its effect on neuronal cell cultures.

With regards to n-hexane, the neurotoxic agent has been identified as a γ-diketone metabolite, 2,5-hexanedione. The knowledge that a γ-diketone metabolite of n-hexane is responsible for peripheral neuropathy led to structure activity relationship studies of other short and long chain diketones including 2,4-pentanedione and 2,5-heptanedione. The 2 carbon spacing between the carbonyl groups (Figure 1) is essential for the induction of peripheral neurotoxicity. The metabolism of only n-hexane and n-heptane was extensively studied and γ-diketone metabolites had been identified for these compounds (Filser et al., 1996). However, there are several studies on the toxicities of other aliphatic diketones containing 5, 6, 7, and 8 carbon atoms that could be possible metabolites of aliphatic solvents containing the respective carbon atoms.

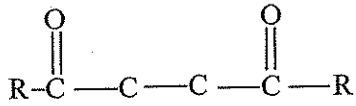

Figure 1. A γ-Diketone Structure

Table 5. Determination of the Cell (a) Viability, by Calcein-AM, (b) Intracellular Amount of Glial Fibrillary Acid Protein (GFAP), (c) Neuron-Specific Enolase (NSE) and (d) Neurofilaments in Primary Cortical Cell Cultures From Rat.

	(a) Viability				(b) GFAP			
Compound	Day 3 NOEC (µmol/L)	EC50 (µmol/L)	Day 7 NOEC (µmol/L)	EC50 (µmol/L)	Day 3 NOEC (µmol/L)	EC50 (µmol/L	Day 7 NOEC (µmol/L)	EC50 (µmol/L)
n-Hexane	>1.2	>1.2	>1.2	>1.2	>1.2	>1.2	0.12**	>1.2
2,5-hexanedione	>0.88	>0.88	0.09**	>0.88	>0.88	>0.88	0.44**	>0.88
n-Heptane	0.1**	0.49**	0.10**	.0.27**	0.1**	1**	0.01**	0.22**

	(c) NSE				(d) Neurofilament			
Compound	Day 3 NOEC (µmol/L)	EC50 (µmol/L)	Day 7 NOEC (µmol/L)	EC50 (µmol/L)	Day 3 NOEC (µmol/L)	EC50 (µmol/L)	Day 7 NOEC (µmol/)	EC50 (µmol/L)
n-Hexane	0.58**	>1.2	0.58**	>100	0.12**	>1.2	5**	100**
2,5-hexanedione	>0.88	>0.88	>0.88	>100	>0.88	>0.88	<1**	75**
n-Heptane	0.10**	>1	0.01**	0.40**	0.05**	1*	0.01*	0.24**

Note: evaluations were made three and seven days after first application and, for comparison, the no effect concentrations (NOEC) and effective concentrations (EC50) were documented. Statistical evaluations of between compound differences were made by ANOVA followed by a t-test (** = $p<0.001$). Table is modified and adopted from Schmuck and Schluter, (1996).

O'Donoghue and Krasavage (1979) have tested a series of diketones (2,3-, 2,4-, and 2,5-hexanedione, 2,5-heptanedione, and 3,6-octanedione in the rat, and demonstrated that only γ-diketones (2,5-hexanedione, 2,5-heptanedione, and 3,6-octanedione caused peripheral neuropathy. A study using various ketones including the diketones 2,4-pentanedione and 2,5-hexanedione was performed in rats (Misumi and Nagano, 1984). The diketone 2,5-hexandione showed disturbances in gait and severe paralysis in the

hind limbs of the treated animals. In the 2,4-pentanedione group, increased salivation was observed on the 15th day of treatment and those animals demonstrated disturbances in gait on the 45th day. Thereafter, all the animals developed a spastic paralysis of the hind limbs but were not flaccid as were the animals receiving 2,5-hexanedione.

The authors reported that it was difficult to compare the neurotoxic potency of 2,4-pentanedione with that of 2,5-hexanedione, but considering only the peripheral nerves, the neurotoxicity of 2,4-pentanedione seemed to be less than that of 2,5-hexanedione. However, its neurotoxic activity in the central nervous system was greater than that of 2,5-hexanedione. Moreover, animals treated with daily doses of 200 mg/kg of 2,4-pentanedione exhibited clinical and neurophysiological evidence of central nervous system toxicity, but repeated subcutaneous injections of 400 mg/kg/day of the compound caused increased salivation, convulsions, and ataxia followed by death in all tested animals. No animals died as a result of repeated injections of equivalent amounts of 2,5-hexanedione. The study suggests that 2,4-pentanedione may be more toxic to the central nervous system and to the whole animal while 2,5-hexanedione may be more toxic to the peripheral nerves.

Several γ-diketones and related compounds that produce peripheral nerve degeneration characterized by multifocal axonal swellings, often referred to as "giant axonal neuropathy, are presented in Table 6. All the C_5, C_6, C_7, and C_8 diketones caused peripheral neurotoxicity. The 2,4-pentanedione, unlike the other toxic diketones which induce mainly peripheral nerve damage, caused severe central nervous system toxicity (Topping et al., 1994). The γ-diketone, 3,4-dimethyl-2,5-hexanedione, is 30 times more potent than the prototype 2,5-hexanedione (Anthony et al., 1983). A potential precursor of this toxic diketone, 3,4-dimethyhexane has been identified in various petroleum fractions (TPHCWG, 1997b). The data support MA DEP's view that, while lacking direct evidence for peripheral neuropathy in humans associated with exposures to n-alkanes other than n-hexane and n-heptane, numerous compounds which could be metabolites of these n-alkanes have the same structural features which have been associated with peripheral neuropathy.

The toxicological information can be summarized as:

- Commercial hexane and practical grade heptane may cause peripheral nerve damage in humans similar to that observed for n-hexane;
- The peripheral neurotoxicity of mixtures containing various components of the C_5 – C_8 aliphatic fraction with very little n-hexane or no n-hexane content at all suggest that aliphatic mixtures containing very little or no n-hexane concentration may cause peripheral nerve damage;

- Other aliphatic hydrocarbons containing 5, 7, 8, and 9 carbon atoms may be metabolized to ketones and γ-diketones that may cause central and peripheral nerve damage;

- The sensitive endpoint for n-pentane may be the central nervous systems based on the data on 2,4-pentanedione. The data do not permit a calculation of an RfD for this compound based on central nervous system effects. This diketone could be a potential metabolite of n-pentane and may affect both the central and peripheral nervous systems;

- There may be more toxic compounds in the series other than n-hexane because some γ-diketones like 3,4-dimethyl-2,5-hexanedione are reported to be more potent than 2,5-hexanedione.

The oral toxicity surrogate for the C_5 - C_8 fraction derived by the TPHCWG has a number of shortcomings outlined above with regard to the potential for peripheral neuropathy and may underestimate human risk from oral exposure to the aliphatic compounds in the C_5 - C_8 carbon range. Although there are data gaps on the toxicity of the individual compounds in the C_5 – C_8 aliphatic fraction, the available data suggest that aliphatic compounds other than n-hexane may cause peripheral neurotoxicity. Until data for individual compounds or studies of mixtures in sensitive species are found, **MA DEP continues to recommend n-hexane as a representative compound for C_5 - C_8 fraction. An oral RfD of 0.06 mg/kg/day was derived from the results of an oral study on n-hexane by Krasavage et al. (1980).** This value was used as a surrogate toxicity number for the C_5 -C_8 aliphatic subgroup by the MA DEP in the draft of this document and based on the data presented above is the currently recommended toxicity value for this fraction.

Table 6. Observations on Peripheral Neuropathies of Ketones and Related Substances (from Topping et al., 1994)

# Carbon Atoms in Compound	Chemical	Structure	Peripheral Neuropathy Observed (y - +; n - -)
Five	2,4-pentanedione	$CH_3COCH_2COCH_2$	+[a]
Six	n-hexane	$CH_3(CH_2)_4CH_3$	+
	practical grade hexanes	Mixed hexanes	+
	methyl n-butyl ketone	$CH_3CO(CH_2)_3CH_3$	+
		$CH_3CO(CH_2)_2CHOHCH_3$	+
	5-hydroxy-2-hexanone	$CH_3CO(CH_2)_2COCH_3$	+
	2,5-hexanedione		
Seven	ethyl n-butyl ketone	$CH_3CH_2CO(CH_2)_3CH_3$	+
	2,5-heptanedione	$CH_3CO(CH_2)_3CH_2CH_3$	+
	3-methyl-2,5-hexanedione	$CH_3COCHCH_3CH_2COCH_3$	+
Eight	3,6-octanedione	$CH_3CH_2CO(CH_2)_2COCH_2CH_3$	+
	5-methyl-3-heptanone	$CH_3CH_2COCH_2CHCH_3CH_2CH_3$	+
	3,4-dimethyl-2,5-hexanedione	$CH_3COCHCH_3CHCH_3COCH_3$	+

[a] 2,4-pentanedione produces CNS damage that is clinically, anatomically, and morphologically different from "giant" axonal neuropathy

2.1.2 C_5 – C_8 Aliphatic Fraction - Inhalation RfC

Of the chemicals within this subgroup, inhalation toxicity values exist only for n-hexane (US EPA value of 0.2 mg/m^3 and ATSDR MRL of 2.0 mg/m^3). Adequate data were not identified to develop RfCs for any of the other individual compounds in this carbon range. However, various American Petroleum Institute-sponsored chronic exposure studies on commercial hexane exist, and these data were used by the TPHCWG to derive inhalation RfCs for the C_5 - C_8 mixtures. They chose the toxicity value of 18.4 mg/m^3 to represent the C_5 - C_8 aliphatic hydrocarbon fraction. These studies were discussed in Section 2.1.1.1.

While MA DEP supports the use of data on mixtures to derive fraction-specific toxicity values, the fractional RfC estimated using the commercial hexane studies seems inappropriate for the following reasons:

(i) the TPHCWG did not consider the serious respiratory effects that occurred at much lower exposure concentrations than the highest exposure level where no neurotoxicity was detected in the study;

(ii) as described previously, occupational exposure of humans to commercial hexane vapor caused peripheral neuropathy (Yamada, 1972; Gaultier et al. 1973; Yamura, 1969);

(iii) other aliphatic mixtures such as commercial grade heptane, C_5 – C_7, and C_5 – C_9 aliphatic mixtures containing very little n-hexane could cause peripheral neuropathy (Trauhaut et al., 1973; Gaultier et al., 1973; Takeuchi et al., 1975).

Neurotoxicity was not observed in the API (1990a)-sponsored studies in rats that were exposed to up to 9000 ppm commercial hexane. However, commercial hexane produced microscopic morphologic abnormalities that were considered to be treatment-related in the nasal turbinates and the larynx of rats exposed to up to 9000 ppm commercial hexane. These effects were not reported in mice treated chronically with commercial hexane (API 1995 Part I). The authors of the rat study (API, 1995 Part I) acknowledged that no NOAEL could be identified for the effects in the nasal turbinates.

In humans, exposure to 1400 - 1500 ppm hexane caused eye and throat irritation (Drinker et al., 1943). Sandmeyer (1981), and Von Oettingen (1940) have summarized the available toxicological information on paraffins showing that one of the chief effects of alkane vapor inhalation is irritation of the respiratory passages. Pentane, hexane, and heptane were at one time investigated for use as anaesthetics (Fuhner, 1921) but they produced undesirable side effects such as respiratory irritation and central nervous system inhibition leading to respiratory arrest (Fuhner, 1921; Drinker et al., 1943).

The TPHCWG toxicity value for this fraction could be improved by consideration of the noted respiratory effects. Use of this type of endpoint in developing of RfCs is not without precedent. The U S. EPA has considered such severe respiratory tract effects in the derivation of inhalation RfCs for other compounds such as acetaldehyde, acrylonitrile, 1,2-dichloropropanol, epichlorohydrin, ammonia and many others (see the compounds' in the respective IRIS database listings). The TPHCWG did not consider this frank upper respiratory toxicity observed in chronically treated rats (Table 4) in the derivation of an RfC for commercial hexane. The LOAEL for respiratory effects was 900 ppm (3092 mg/m^3) while the NOAEL for other systemic effects in the same study was reported to be 3000 ppm (10307 mg/m^3). Since the study demonstrated respiratory effects at a much lower exposure concentration than any other effects observed, the inhalation RfC should be estimated for this endpoint.

For gases and vapors that are very reactive and that have their toxic effect in the respiratory tract, the US EPA has an approach for deriving a human equivalent concentrations (US EPA, 1990) as outlined below. This methodology will be used to estimate a toxicity value for commercial hexane based on nasoturbinal effects. The RfC based on the respiratory endpoint is estimated for gas: respiratory effect in the extrathoracic region as follows:

The LOAEL identified for nasoturbinal effects is 3092 mg/m^3

LOAEL adj. = E (mg/m^3) x (exposure hours/day / 24 hours) x (exposure day/week/7 days)

$LOAEL_{HEC} = LOAEL_{adj}$ (mg/m^3) x RDGRET

$RDGRET = [VR/SR_{et}] / [VH/SH_{et}]$

where,

E	=	Exposure concentrations
$LOAEL_{adj}$	=	LOAEL adjusted for duration
$LOAEL_{HEC}$	=	LOAEL human equivalent concentration
RDGRET	=	Regionally deposited gas ratio, extrathoracic region
VR	=	Rat ventilation rate(0.33 m^3/day) (1)
SR_{et}	=	Surface area of the extrathoracic region for rat (11.6 cm^2)
VH	=	Human ventilation rate 20 m^3/day
SH_{et}	=	Surface area of the extrathoracic region in man (177 cm^2)
RDGRET	=	0.33 m^3/day/11.6 cm^2 /20 m^3/day /177 cm^2 = 0.25

$LOAEL_{adj}$ = 3092 x 6/24 x 5/7 = 552 mg/m^3

$LOAEL_{HEC}$ = 552 mg/m^3 x 0.25 = 138mg/m^3

RfC = $LOAEL_{HEC}$ = 138 $mg/m^3/300^* \approx$ **0.5 mg/m^3**

An uncertainty factor of 300 was applied (10 for human variability, 10 for LOAEL to NOAEL extrapolation, 3 for animal to human extrapolation). 3 instead of 10 was used for animal to human exposure since dosimetric adjustment was made using the regionally deposited gas ratio for the appropriate respiratory region.

Based on the nasoturbinal effects, an RfC of 0.5 mg/m^3 was estimated. It should be noted that this RfC is close to the US EPA RfC of 0.2 mg/m^3 derived for n-hexane based on neurotoxicity. As discussed previously, the human data suggest that the more serious health effect observed in people occupationally exposed to n-hexane or commercial hexane is peripheral neuropathy as opposed to respiratory toxicity.

In conclusion, the available data suggest there may be compounds in this hydrocarbon fraction in addition to n-hexane that may cause peripheral or central nervous system effects. However, the data do not permit estimation of toxicity values for the individual compounds or mixtures. Until appropriate human or animal data are available on the C_5 - C_8 mixtures or on the individual components of the fraction, **MA DEP recommends the U.S.EPA derived RfC of 0.2 mg/m^3 for n-hexane, which is based on a neurotoxic endpoint, as a representative surrogate for the C_5-C_8 fraction. This RfC would be protective of the respiratory effects also.**

2.1.3 C_9 - C_{18} (MA DEP) or $C_{>8}$ - C_{16} (TPHCWG) Aliphatic Fractions Oral RfD

2.1.3.1 Basis for Existing Toxicity Values. The MA DEP previously assigned the toxicity value estimated for n-nonane to all C_9 through C_{18} hydrocarbons. This RfD (0.6 mg/kg/day) is ten times that developed for n-hexane. The n-nonane RfD was derived by MA DEP based on the relative potencies of n-hexane and n-nonane described below:

- Subchronic inhalation studies using n-nonane (Carpenter et al., 1978) showed that n-hexane (Dunnick et al., 1989) is ten times more potent than n-nonane;
- Review of threshold limit values (TLVs) and recommended exposure limits (RELs) established by the American Conference of Governmental and Industrial Hygienists (ACGIH) and the National Institute for occupational Safety and Health (NIOSH) respectively indicated that the exposure limits TLV for n-nonane are approximately an order of magnitude greater than that those for n-hexane.

The TPHCWG used results from studies of rodent exposures to dearomatized streams which together cover the entire range of the fraction to derive a representative RfD for the $C_{>8}$ - C_{16} fraction. A study on JP-8 was also evaluated (Matti et al., 1995), but JP-8 has up to 20% aromatic content versus the petroleum streams which have maximally 1.5%, and in most cases less than 0.1% aromatics. The data on petroleum streams were given more weight for the derivation of an oral RfD for the $C_{>8}$ - C_{16} fraction because of their low aromatic content. Their recommended oral RfD for this fraction is 0.1 mg/kg/day.

2.1.3.2 Summaries of Petroleum Stream Toxicity Studies. The studies on petroleum streams are unpublished but were provided to MA DEP for review. The data are briefly summarized below.

- C_9 - C_{12} Isoparaffins/n-Alkanes/Naphthenes: Typical Aromatic Content 0.1% (Anon., 1991a)

  Rats were orally dosed with 0, 500, 2500 or 5000 mg/kg/day of C_9 - C_{12} aliphatic petroleum hydrocarbon fraction for 90 days. A high dose recovery group was also included. The mean body weights decreased in the male rats in the mid and high dose group when compared to controls. Hematological studies revealed dose-related significant increases in platelet counts in both male and female animals. Other hematological changes observed in male rats included increases in white blood cell, hematocrit and hemoglobin counts.

  Significant increases in serum chemistry values (urea nitrogen, gamma glutamyl transpeptidase (males), cholesterol (males and females), and triglycerides (females) were observed in the mid and high dose groups. Significant increases in alanine aminotransferase were observed in the mid and high dose male rats. High and low dose groups of both sexes showed decreased serum glucose levels. Other significant alterations in the serum included increases in bilirubin, creatinine, chloride and triglyceride levels.

  Significant increases in liver weights were observed in the mid and high dose males and in all dose groups in female rats. Kidney weights were significantly increased in all treated males. Adrenal weights were also significantly increased in both males (high dose) and females (mid and high dose) groups. Treatment-related microscopic changes were observed in the kidney of male rats in all dose groups; the liver of male/female rats in all dose groups and stomach and/or anus of males/females in the mid and high dose group.

The TPHCWG believed that the ill effects observed (except male rat nephropathy) could not be dismissed and therefore a NOAEL could not be determined. The LOAEL was estimated to be 500 mg/kg/day. The TPHCWG applied an uncertainty factor of 5000 (10 for animal to human extrapolation, 10 to account for human variability, 10 for subchronic to chronic and 5 for LOAEL to NOAEL extrapolation) to convert the LOAEL to an RfD. A value of 5 was chosen for conversion of the LOAEL to a NOAEL, since the effects observed were all reversible within 28 days. An RfD of 0.1 mg/kg/day was estimated for the C_9 - C_{12} hydrocarbon fraction.

- C_{10} - C_{13} Isoparaffins/Naphthenes/n-Alkanes: Typical Aromatic Content 0.1% (Anon., 1991b)

  Rats were orally treated with 0, 100, 500, or 1000 mg/kg/day with a C_{10} - C_{13} aliphatic petroleum hydrocarbon fraction for 13 weeks. Hematological studies revealed a significant increase in platelet count in the high dose male rats. Serum chemistry results demonstrated a significant decrease in aspartate aminotransferase in the high dose females. Other serum chemistry changes included a significant decrease in glucose (males/females), dose-related increase in male creatinine, male phosphorous, male alanine aminotransferase, and female cholesterol with the respective high dose groups being significantly increased compared to controls. Linear dose-related increases in male kidney weights were observed in the mid and high dose groups. Liver weights were significantly increased in the high dose females. Microscopic examination showed treatment-related changes in male kidney which are characteristic of kidney changes produced in male rats. This effect is known as □2u-globulin nephropathy. This nephropathy is considered to be a male rat specific phenomenon without human significance. A NOAEL of 100 mg/kg/day was identified in this study based on the observed liver effects. The TPHCWG applied an uncertainty factor of 1000 (10 to account for sensitive individuals, 10 for animal to human extrapolation, and 10 for subchronic to chronic adjustment) to the NOAEL and derived an RfD of 0.1 mg/kg/day for the fraction.

- C_{11}- C_{17} Isoparaffinic Solvent; Typical Aromatic Content: $<0.05\%$ (Anon., 1990)

  Rats were orally treated with 0, 100, 500, or 1000 mg/kg/day of the C_{11} - C_{17} aliphatic petroleum hydrocarbon fraction for 13 weeks. A high dose recovery group was also included. In male rats, hematological studies

showed significant increases in hemoglobin and corpuscular hemoglobin levels following the 28 day recovery period. Serum chemistry analysis showed dose-related decreases in the male triglyceride levels in both the high and mid dose groups differing significantly from controls. Increased liver weights were observed in both mid and high dose male and female rats. No histopathological alterations were observed.

The TPHCWG identified 100 mg/kg/day as a NOAEL and applied an uncertainty factor of 1000 (10 to account for sensitive individuals, 10 for animal to human extrapolation, and 10 for subchronic to chronic adjustment) to the NOAEL and derived an RfD of 0.1 mg/kg/day for the fraction.

Equivalent RfDs (0.1 mg/kg/day) were also derived from the dearomatized petroleum stream studies representing the C_9 - C_{12}, and C_{10} - C_{13} fractions. An oral RfD of 0.1 mg/kg/day was therefore selected as a surrogate for the C_9 - C_{16} fraction based on the results of the oral toxicity studies covering overlapping fractions of the total C_9 - C_{16} carbon range.

- JP-8 Jet Fuel (Matti et al., 1995)

Male rats were orally gavaged with 0, 750, 1500 and 3,000 mg/kg/d of JP-8 for 90 days. Body weights were significantly reduced in both mid and high dose groups. Glucose, total bilirubin, AST, and ALT were significantly altered in the treated groups. Dose dependent irritation of the GI tract was also noted. Neutrophil (elevation) and lymphocyte (depression) counts were significantly different in all treated groups from controls. In the high dose group, organ/body weight ratios were significantly different for brain, liver, kidneys, spleen and testes. However, individual organ weights were not significantly altered in the treated group. The TPHCWG considered the hematological and enzymatic changes to be insignificant in the absence of organ weight change. Based on body weight changes, 750 mg/kg/d was considered to be a NOAEL by the work group despite the observed dose-dependent adverse effects such as GI irritation and blood chemistry changes in that treatment group. The NOAEL was then adjusted by an uncertainty factor of 1000 (10 for sensitive individuals, 10 for animal to human extrapolation, 10 subchronic to chronic extrapolation). The estimated RfD was 0.75 mg/kg/d.

2.1.3.3 Discussion and Recommendation. Compounds in this group were assigned an RfD of 0.6 mg/kg/d by MA DEP, based on relative potency evaluations (using inhalation data) between n-hexane and n-nonane.

The TPHCWG on the other hand used recent oral exposure studies to mixtures of compounds within the hydrocarbon fraction of interest described in Section 2.1.3.2 to derive a representative RfD for this fraction. After review of the original studies referenced by the TPHCWG, MA DEP has chosen these studies as the more appropriate ones on which to base an RfD for this fraction and recommends the adoption of the RfD (0.1 mg/kg/day) derived by the TPHCWG. This value is recommended over that previously supported because the exposures were oral rather than inhalation, they were with mixtures of compounds within the size range of carbon compounds of interest, they were more recent, and the three studies gave consistent results.

2.1.4 C_9 - C_{18} (MA DEP) or $C_{>8}$ - C_{16} (TPHCWG) Aliphatic Fractions Inhalation RfC

2.1.4.1 Summaries of Toxicity Studies. Various studies that were identified by the TPHCWG and the MA DEP are summarized in the following paragraphs.

- **Isoparaffinic Hydrocarbons (IPH): C_{10} - C_{11}.** Male and female rats were exposed to 0, 1910, 5620 mg/m^3(0, 300, 900 ppm) isoparaffinic hydrocarbon (IPH) vapors (typical aromatic content 0.1%) for 6 hours/day, 5 days/week for 12 weeks (Phillips and Egan, 1984). Phillips and Egan (1984) presented the concentrations of IPH vapor as described above, whereas the TPHCWG reported different vapor concentrations (1742 and 5226 mg/m^3)] for the same study. Study animals were examined at 4, 8 and 12 weeks of exposure. Significant weight reduction was observed in male rats exposed to IPH at low and high exposure concentrations. In male rats exposed to IPH there was a significant decrease in erythrocytes after 12 weeks of exposure in both low and high exposure groups. No such effects were observed in female rats. Relative kidney weights were significantly increased in male rats exposed to 1742 and 5226 mg/m^3 IPH. In female rats transient increases in absolute and relative kidney weights were observed at 5226 mg/m^3 at 8 weeks of exposure. At 5226 mg/m^3, relative liver weights were significantly increased at 12 weeks of exposure and absolute and relative liver weights were increased at 4 weeks of exposure in male rats. According to the authors, the only treatment-related effects were the tubular nephrotoxicity in male rats. It was stated in the paper that the observed effects in the

kidney are consistent with a mechanism that appears to be unique to male rats and not relevant to humans.

The TPHCWG identified the high exposure concentration as the NOAEL. By converting the NOAEL to continuous exposure (NOAEL x 6 hours/24 hours x 5 days /7 days) and using an uncertainty factor of 1000 (10 for human sensitivity, 10 for animal to human extrapolation and 10 for subchronic to chronic adjustment), an RfC of 0.9 mg/m^3 was calculated. The RfC based on the originally reported NOAEL would be 1.0 mg/m^3.

- **Dearomatized White Spirit (DAWS): C_7 - C_{11}.** Male and female rats were exposed to 0, 1970 and 5610 mg/m^3 (0, 300, or 900 ppm) DAWS vapors (typical aromatic content 0.1%) for 6 hours/day, 5 days/week for 12 weeks (Phillips and Egan, 1984). Mean body weights in male rats were significantly reduced in the high exposure group. Significant reductions in erythrocyte counts were observed in male and female rats in the low exposure group. This result was difficult to interpret since no such effects were observed in the high exposure group. Relative kidney and liver weights were significantly increased in male rats in the high exposure group. In female rats, significant increases in relative liver weights were observed at 5610 mg/m^3.

  The TPHCWG chose the high exposure concentration (inexplicably noted as 5485 mg/m^3 in TPHCWG materials) as the NOAEL. The high exposure concentration in the original paper which is also the source for the TPHCWG derived RfC, is 5610 mg/m^3. The NOAEL was adjusted for continuous exposure as described above, and using an uncertainty factor of 1000 (10 for sensitive individuals, 10 for animal to human extrapolation and 10 for subchronic to chronic adjustment) an RfC of 1.0 mg/m^3 was determined.

  In another study identified by MA DEP, rats were exposed to 0, 2620, 5253 mg/m^3 (0, 400 or 800 ppm) DAWS for 6 hours/day, 5 days/ week for 6 months (Lund et al., 1995). After an exposure-free period of 2-6 months duration, neurophysiological, neurobehavioral, and microscopic pathologic examinations were performed. The study demonstrated exposure-related changes in sensory evoked potentials, and a decrease in motor activity during dark periods. No changes in learning and memory functions were observed. The measurements of the flash evoked potential (FEP), somatosensory evoked potential (SEP), and auditory brain stem responses (ABR) all revealed changes in the later latency peaks, which reflect the more associative aspects of sensory processing. According to the authors, the

results demonstrated that 6 months of exposure to DAWS induced long-lasting and possibly irreversible effects in the nervous system of the rat. No NOAEL was observed in this study. The LOAEL is determined by MA DEP to be 2620 mg/m^3 (400 ppm). Adjusting this LOAEL to continuous exposure and applying an uncertainty factor of 3,000 (10 for human variability, 10 for animal to human extrapolation and 10 for adjusting for LOAEL to NOAEL, and 3 to adjust for less than lifetime exposure) resulted in an RfC of 0.2 mg/m^3. This RfC is lower than the RfC (1.0 mg/m^3) derived by the TPHCWG for the C_9 - C_{16} aliphatic fraction.

In acute exposure animal studies, white spirit with low aromatic content produced significant response reductions of learned performances (Kulig, 1990). Increased levels in brain noradrenaline, dopamine, and 5-hydroxytryptamine were observed in rats exposed to various levels of white spirit (Lam et al., 1992). Changes in indices of oxidative stress were reported in animals exposed to this compound for 3 weeks (Lam et al., 1994).

The TPHCWG reported that no developmental effects were detected in rats exposed to 0, 1742 or 5226 mg/m^3 of isoparaffinic hydrocarbon vapors during gestation day 6-15. The maternal and developmental NOAEL was 5226 mg/m^3. These data, however, were not published and were not available for review by MA DEP. No other developmental/reproductive studies were identified.

2.1.4.2. Discussion and Recommendation The TPHCWG used the study of Phillips and Egan (1984) to derive an RfC of 0.9 mg/m^3 for the $C_{>8}$ – C_{16} aliphatic fraction. The TPHCWG considered the high exposure concentration as the NOAEL, although significant weight reductions and significant increases in liver and kidney weights were observed in the high exposure group animals. The high exposure concentration should be considered as a LOAEL and an uncertainty factor of at least 3 should be applied for extrapolating from a LOAEL to a NOAEL. A factor of 3 instead of 10 is recommended because the effects were not considered to be very serious. If such an adjustment is made, the estimated RfC is 0.3 mg/m^3.

Also, as discussed above, a recent neurotoxicity study (Lund et al., 1995) revealed that exposure of rats to DAWS for six months induced long-lasting and possibly irreversible effects in the nervous system. The test system used in that study was an improvement over the subjective studies normally used to measure neurobehavioral effects of toxicants. The tests reflect the functions of the nervous system directly. The measures have been shown to be highly reproducible both within and between individuals and almost equivalent among different species. Long lasting functional impairments of the nervous

system are generally found at lower exposure concentrations than those causing morphological changes. For instance, exposure of painters to white spirit caused early disability pension due to neuropsychological disorders. In most of the studies, workers were exposed to mixtures of organic solvents with the principal component being white spirit. The effects were mainly functional disturbances in the central nervous system including memory and learning impairments (see Lund et al. (1995) and references therein). Functional impairments of the nervous system are suggested as a criterion for neurotoxicity (Lund et al., 1995). Taken together, the data suggest that neurotoxicity may be a more sensitive endpoint than other effects observed in animals exposed to DAWS and IPH. **Based on the Lund et al. (1995) study, the MA DEP derived an RfC of 0.2 mg/m^3**, which is close to the above adjusted TPHCWG RfC of 0.3 mg/m^3. **The MA DEP recommended toxicity value for the C_9 – C_{18} aliphatic fraction is therefore 0.2 mg/m^3 based on neurotoxicity.**

2.1.5 C_{19} - C_{32} (MA DEP) or $C_{>16}$ - C_{35} (TPHCWG) Aliphatic Fraction. Oral RfD

2.1.5.1 Basis for Existing Toxicity Values. The MA DEP grouped together alkanes C_{19} and longer and used eicosane as a reference compound for the range. The toxicity value was derived from a lifetime dietary feeding study (API, 1992) of white mineral oil, a complex mixture of C_{15} - C_{50} saturated hydrocarbons with low toxicity. A NOAEL of up to 6000 mg/kg day was reported in that study. By applying an uncertainty factor of 1000 to this NOAEL (10 for subchronic exposure, 10 to account for animal to human extrapolation, and 10 to protect sensitive individuals), an RfD of 6.0 mg/kg/day was derived by MA DEP.

The TPHCWG used 90-day feeding studies of white mineral oils representing different molecular weight (MW) fractions to derive their toxicity values. White mineral oils are a complex mixture of highly refined mineral hydrocarbons consisting primarily of saturated paraffinic hydrocarbons (predominantly branched chain alkanes) and naphthenic hydrocarbons (alkanes containing one or more saturated cyclic structures). These oils are pure aliphatic hydrocarbons with no aromatic components and other contaminants. They are approved by the US Food and Drug Administration as direct food additives and also used in cosmetics and pharmaceutical products.

Male and female F/344 rats were administered a range of white mineral oils mixed in the diet at doses of 20, 200, 2000 and 20,000 ppm for 13 weeks (Smith et al., 1996). The daily intake of white mineral oils was approximated to be equal to 2, 20, 200 and 2000 mg/kg/day. Mesenteric lymph node histocytosis and liver granulomas were observed with the lower molecular weight (C_{17} - C_{34}) mineral oils, (average MW 240-280). The higher MW white mineral oil ($C_{>34}$, average MW >480) was without effect. Mesenteric lymph node histocytosis was noted at doses of 20 mg/kg/d or higher, whereas liver granulomas were only noted at 2000 mg/kg/d dose level in rats exposed

to lower molecular weight mineral oils. The critical effect used to determine RfDs for TPH aliphatic fractions $C_{\geq 17}$ was liver granuloma formation, although mesenteric lymph node histocytosis was noted at lower doses. The latter effect was not considered to be an adverse effect because it is a normal adaptive response to the ingestion of foreign material (Shuurman et al., 1994).

The NOAEL for the low molecular weight oils was determined to be 200 mg/kg/day. A factor of 100 (3 for animal to human extrapolation, 10 for human variability, and 3 for subchronic to chronic extrapolation) was applied to the NOAEL to derive an RfD of 2 mg/kg/day for the lower molecular weight (C_{17} - C_{34}) fraction. The NOAEL identified for the high molecular weight oils ($C_{>34}$) was 2000 mg/kg/day. An RfD of 20 mg/kg/day was derived by applying an uncertainty factor of 100 (3 for animal to human extrapolation, 10 for human variability, and 3 for subchronic to chronic extrapolation) to this value.

The justification presented by the TPHCWG for using uncertainty factors less than 10 for animal to human and subchronic to chronic extrapolation was based on the fact that exposures of humans to both natural dietary oils and white mineral hydrocarbons (MHC) are not associated with any clinical effects. MHC-induced lipid granulomas found in human tissues are characterized as being benign, circumscribed lesions containing mineral oils in the center, as opposed to lesions detected in F/344 rats which are reactive and associated with inflammation and occasional parenchymal cell necrosis. F/344 rats are more sensitive than many other species for the observed inflammatory effects of mineral oils. Although F/344 rats are sensitive for the inflammatory response, these effects did not appear to progress to tumors.

2.1.5.2 Discussion and Recommendation. The TPHCWG recommended an RfD of 2 mg/kg/day for the $C_{>16}$ - C_{35} aliphatic fraction. The toxicity value recommended by the TPHCWG for this fraction is lower than the value recommended by the MA DEP (6 mg/kg/day). The differences between the two values stem from the data sets used to derive the numbers.

The MA DEP RfD value for this fraction was based on a lifetime feeding study in rats reported in an API (1992) document which identified NOAELs ranging from 1200 to 6000 mg/kg/d. The types and purities of the oils used were not described.

The study selected by the TPHCWG appears to be a reasonable, preferable choice over the study originally selected by MA DEP because:

(i) the study used seven highly refined mineral oils representing a full range of these types of products (C_{15}-C_{45});

(ii) the effects of the mineral oils appeared to be inversely related to molecular weight. The lower molecular weight (C_{17}-C_{34}) mineral oils demonstrated effects in the liver and mesenteric lymph nodes. Essentially no effects were observed with the higher molecular weight ($C_{>34}$) mineral oils at the highest dose tested;

(iii) the lack of effect with the higher molecular weight mineral oils is consistent with studies showing no absorption for alkanes above C_{32} (Albro and Fishbein, 1970);

In summary, the TPHCWG selected well designed studies using highly refined fractions of mineral oils with carbon numbers ranging from C_{17} to C_{34} which demonstrated effects in rats. The NOAEL identified for these studies was 200 mg/kg/d. Higher molecular weight mineral oils containing carbon numbers greater than 34 were without effects with a NOAEL of 2000 mg/kg/d, the highest dose tested. The study used by MA DEP identified a NOAEL of 6000 mg/kg/d which is close to the NOAEL identified by the TPHCWG for the higher molecular weight mineral oils ($C_{>34}$). Since no description of the oils was available, it appears that NOAEL may be for the high molecular weight oils. MA DEP supports the RfD (2 mg/kg/day) derived by the TPHCWG for C_{19} – C_{32} aliphatic fraction.

2.1.6 C_{19} - C_{32} Aliphatic Fraction Inhalation RfC

No appropriate inhalation toxicity data were identified for individual components or fractions in C_{19} - C_{32} aliphatic carbon range. This may be because hydrocarbon constituents in this fraction are not volatile and inhalation is not a likely exposure pathway. However, as in the high molecular weight aromatic hydrocarbons, aliphatic compounds in C_{17} - C_{32} carbon range can bind to soil particles. Inhalation exposure to respirable particulates containing high molecular weight PHCs is possible; but there are no data to estimate inhalation toxicity to particulate-bound hydrocarbons.

2.2 AROMATIC FRACTION TOXICITY VALUES

2.2.1 C_6 - C_8 Aromatic Compounds Oral RfDs.

In the MA DEP fractions approach (MA DEP, 1994), aromatic hydrocarbons with fewer than nine carbon atoms (benzene, toluene, ethylbenzene, styrene, xylenes) are evaluated on a compound-specific basis. This is because each of the aromatic hydrocarbons in this carbon range has extensive databases and most have toxicity

values. No toxicity data were identified on mixtures in the carbon range specified above.

US EPA derived RfDs were identified by the TPHCWG for styrene, ethylbenzene and xylenes. The TPHCWG considered the available toxicity data and compositional information for this fraction and selected an oral RfD of 0.2 mg/kg/day as a representative toxicity value for all these compounds in the C_7 to C_8 range. They suggest that toxicity of the C_6 aromatic, benzene, be evaluated independently. **MA DEP continues to recommend not including these compounds with less than nine carbons in the carbon range approach, but rather evaluating them individually.**

2.2.2 C_6 - C_8 Aromatic Compounds Inhalation RfC.

MA DEP delineates this group as the C_6 - C_8 range while the TPHCWG delineated it as the $C_{>7}$-C_8 range: excluding benzene. The compounds identified in this group include benzene, ethylbenzene, styrene, toluene and xylene (*o-, m-, p-*). US EPA derived RfCs are available for all but xylenes and benzene. ATSDR has also developed inhalation minimal risk levels (MRLs) for toluene and xylenes. A fraction-specific inhalation RfC has been assigned to the group representing carbon ranges $C_{>7}$ - C_8 by the TPHCWG (Table 7).

2.2.2.1 Summaries of Toxicity Studies. The rationales for the development of the toxicity values by the different groups are briefly discussed below.

Ethylbenzene. The ATSDR (1990a) and US EPA (1995) have summarized the inhalation toxicity of ethylbenzene. It, like many other organic solvents, affects the central nervous system (CNS) and it is a mucous membrane irritant upon acute high level exposures. Genotoxicity tests are generally negative. It has however caused mutagenic effects in mouse lymphoma cells and a significant increase in sister chromatid exchange in human lymphocytes. These studies indicate that ethylbenzene may have the potential to be genotoxic in humans. A chronic oral carcinogenicity study on ethylbenzene produced inconclusive results.

One of the main human health concerns for inhaled ethylbenzene is its suspected developmental and reproductive effects (ATSDR, 1990a). This end point was the basis of the U. S. EPA's inhalation RfC for this compound (US EPA, 1995). They evaluated two inhalation studies conducted with rats and rabbits, exposed 6-7 hours/day, 7 days/week during days 1-19 and 1-24 of gestation, respectively to 434 or 4342 mg/m^3 (100 or 1000 ppm) of ethylbenzene. A separate group of rats

was also exposed pregestationally for 3 weeks prior to mating and exposure was continued into the gestational period (US EPA, 1995).

Table 7 . Aromatic TPH Components and Fractions with Inhalation Toxicity Values.

Carbon Range	Compounds	US EPA RfC mg/m^3	ATSDR MRL mg/m^3	TPHCWG Fractional RfC mg/m^3
C_6 - C_8 (MA DEP) $C_{>7}$-C_8 (TPHCWG)	Benzene	NA	NA	} 0.4
	Toluene	0.4	1.0 (0.3)*	
	Ethylbenzene	1.0	NA	
	Styrene	0.2	NA	
	Xylene (o-, p-, m-)	NA	0.4 (0.1)*	
C_9 – C_{18} (MA DEP) $C_{>8}$ - C_{16} (TPHCWG)	Isopropylbenzene	0.4	NA	NA
	Naphthalene	NA	0.01	NA
	Acenaphthene	NA	NA	NA
	Biphenyl	NA	NA	NA
	Fluorene	NA	NA	NA
	Anthracene	NA	NA	NA
	Fluoranthene	NA	NA	NA
	Pyrene	NA	NA	NA
	C_9 aromatic mixtures**	NA	NA	0.2***
	C_9 aromatic mixtures**	NA	NA	1.3
C_9 - C_{32} (MA DP) $C_{>16}$ – C_{35} (TPHCWG)	NA	NA	NA	NA

* adjusted for continuous exposure by MA DEP

** based on C_9 hydrocarbon mixture studies

***also selected as the surrogate RfC for the $C_{>8}$ - C_{16} aromatic fraction by MA DEP

In rabbits, the only adverse effect noted was that the number of live kits per litter was significantly reduced at the high exposure concentration. The NOAEL for this study was 434 mg/m^3 (US EPA, 1995).

In rats exposed during gestation, a significantly increased incidence of abnormal ribs was observed in the high exposure group and an elevated incidence of extra ribs occurred in both the high and low exposure groups. Both absolute and relative liver, kidney, and spleen weights were significantly increased in the high exposure group pregnant rats. In the rats exposed for 3 weeks pregestationally, there was an increased incidence of extra ribs in the high exposure group. Only relative kidney weights were significantly increased in this group. In the rat study, as in the rabbit study, 434 mg/m^3 (100 ppm) was considered a NOAEL (US EPA, 1995).

The US EPA derived an RfC of 1 mg/m^3 based on these NOAELs using an uncertainty factor of 300 (10 to account for sensitive individuals, 10 to adjust for the absence of multigenerational reproductive and chronic studies and 3 for animal to human extrapolation) (US EPA, 1995).

Styrene. Styrene causes CNS effects and mucous membrane irritation at high exposure concentrations in people who breathe large amounts of styrene for a short time. The CNS effects include depression, concentration problems, muscle weakness, tiredness, and nausea. Styrene is also a suspected human and animal carcinogen (ATSDR, 1990b).

The U.S EPA (1993) used an occupational study which examined neuropsychological functions in 50 workers whose mean duration of styrene exposure was 8.6 years (SD of 4.5). The air concentration of styrene was estimated to be 43 - 1282 mg/m^3 (10-300 ppm). Workers with absence of metabolic and neurologic disorders, smoking habits of 20 cigarettes/day and alcohol intake of 80 ml ethanol/day were chosen. These same eligibility criteria were used to select a control group of 50 workers that were matched for age , sex, and educational level. The exposed workers were further segregated with 4 subgroups (n=9-14) according to increasing styrene exposure.

The critical endpoints considered were neuropsychological effects such as visuo-motor speed, memory and intellectual function. Correlation analysis of the test results and styrene exposure levels showed clear concentration response in at least three of the eight tests (memory, intellectual function, and visuo-motor speed). When the results were analyzed using duration of exposure as a covariate, increases in reaction times and decreases in memory and concentration were apparent. A NOAEL of 94 mg/m^3 (22 ppm) was determined from this study and an RfC of 1 mg/m^3 was estimated by adjusting the occupational exposure to continuous exposure and by applying an uncertainty factor of 30 (3 for data inadequacy, 3 to account for sensitive individuals and 3 to account for lack of chronic study).

Toluene. Toluene inhalation primarily affects the CNS and mucous membranes. Acute CNS effects include CNS depression, neurological dysfunction, and narcosis. Chronic exposures have resulted in permanent effects such as ataxia, tremors, and impaired speech, vision and hearing. Cardiac arrhythmia and hepatic effects have been reported. Developmental and reproductive effects were produced in toluene exposed animals. *In vitro* and *in vivo* tests demonstrated that toluene is not genotoxic (ATSDR, 1994).

Neurologic disorders are the main human health concerns from chronic exposure to toluene. The USEPA (1997b) has derived an inhalation RfC of 0.4 mg/m^3 based on a chronic occupational study of Foo et al. (1990). The exposed workers scored lower in 6 of 8 of the tests administered when compared to controls from the same workplace that were not exposed to toluene. The toluene exposure concentrations were 49 mg/m^3 (13 ppm) in controls and 332 mg/m^3 (88 ppm) and in exposed workers. The occupational LOAEL used to derive the RfC was 332 mg/m^3. The duration-adjusted LOAEL was estimated to be 119 mg/m^3. An uncertainty factor of 300 (10 for human variability, 10 for use of a LOAEL and 3 for database deficiencies) was applied to the LOAEL to estimate an RfC of 0.4 mg/m^3.

The ATSDR (1994) has also developed a minimal risk level (MRL) of 0.4 ppm ($\approx$ 1.0 mg/m^3) based on a chronic duration occupational study of Orbaek and Nise (1989). Exposed workers had more neurasthenic complaints than control subjects. Workers with many neurasthenic complaints did not perform as well. The occupational exposure LOAEL used to estimate the MRL was 43 mg/m^3 (11.6 ppm). An uncertainty factor of 30 (3 for using minimally adverse LOAEL and 10 for human variability) was applied to the occupational LOAEL to derive the MRL.

Both the US EPA and the ATSDR used chronic occupational exposure studies to derive inhalation toxicity values. Although the occupational LOAEL used by the US EPA (332 mg/m^3) was higher than the occupational LOAEL used by the ATSDR (43 mg/m^3), the inhalation toxicity value derived by ASTDR was equivalent to that estimated by the U. S. EPA. This is mainly because the ATSDR did not adjust the occupational LOAEL for a continuous exposure scenario. It is not clear why the above adjustment was not made. If such an adjustment were made to the occupational LOAEL, the adjusted MRL would be about 0.3 mg/m^3.

Xylenes. The major effects of xylenes are on the central nervous system. High vapor exposures cause CNS effects including headache, nausea, mental confusion,

dizziness, tremors, unconsciousness and coma. Other reported adverse effects include hepatic, renal, cardiac, respiratory and developmental abnormalities. Genotoxicity tests for xylenes have been negative (ATSDR, 1995a).

The ATSDR (1995a) derived a chronic duration MRL of 0.6 mg/m^3 using an occupational study. Workers (175) were exposed to TWA of 61 mg/m^3 (14 ppm) time weighted average (TWA) concentration of xylenes for an average of 7 years. Mixed xylene exposures accounted for 70% or more of the total exposure. No hematological, hepatic or renal effects were observed. The occupational NOAEL was 61 mg/m^3 and was used to derive the chronic duration MRL. The ATSDR did not adjust the occupational LOAEL for continuous exposure. If such an adjustment were made to the NOAEL, the adjusted MRL becomes about 0.1 mg/m^3.

2.2.2.2 Discussion and Recommendation. The TPHCWG selected 0.4 mg/m^3 as a representative inhalation RfC for the $C_{>7}$ - C_8 aromatic TPH subset since the existing inhalation toxicity values developed by the US EPA for each of the compounds in the C_7 through C_8 fraction (Table 7) are not very different from each other. This approach is consistent with the evaluation employed for the higher molecular weight aromatic (C_9 - C_{18}) and all of the aliphatic fractions. Until data on mixtures are available, MA DEP defines this fraction to include benzene and continues to recommend evaluating the chemicals in this group individually because of the availability of good compound-specific toxicity information.

2.2.3 C_9 - C_{32} (MA DEP) $C_{>8}$ - C_{35} (TPHCWG) Aromatic Fraction Oral RfD

The MA DEP grouped the entire range of C_9 through C_{32} aromatic hydrocarbon compounds as a single fraction. Alkenes with the same carbon range were also evaluated similarly to aromatics in this fraction (MA DEP, 1994). The TPHCWG extended the higher end of the range to C_{35} and further subdivided compounds in the C_9 - C_{35} carbon range into C_9 - C_{16} and $C_{>16}$ - C_{35} subsets. It is not clear how alkenes in the same carbon range were evaluated.

The TPHCWG identified 77 individual compounds in this carbon range. US EPA derived RfDs were available only for 8 (acenaphthene, biphenyl, fluorene, anthracene, fluoranthene, naphthalene, and pyrene) of these compounds. The RfDs range from 0.03 to 3 mg/kg/day. The TPHCWG also derived an additional oral RfD of 0.03 mg/kg/day based on a naphthalene/methylnaphthalene mixture study. The work group determined an RfD of 0.04 mg/kg/day for the $C_{>8}$ -C_{16} and an RfD of 0.03 mg/kg/day for the $C_{>17}$ - C_{35} fraction.

For the C_9 through C_{16} fraction, which includes naphthalene, 2-methylnaphthalene and fluoranthene, it would be more health protective to select the lowest RfD (0.03 mg/kg/day) because of emerging data on the toxicities of naphthalene, 2-methylnaphthalene and fluoranthene.

Inhalation exposure to naphthalene produced severe pulmonary damage and adenoma in mice (NTP, 1992). A recent oral study of a structurally related compound, 2-methylnaphthalene, suggested that the target site for inhaled and ingested naphthalene might be the pulmonary tissues. An oral administration of 1-methylnaphthalene demonstrated chronic pulmonary effects and a significant increase in lung adenoma (Murata et al., 1993). Serious fluoranthene toxicity has been demonstrated in animals (Busby et al., 1984; Wang and Busby, 1993; Lavoie et al., 1994). The potential toxicities of compounds in the C_9 - C_{35} fraction is thus best represented by a single RfD value of 0.03 mg/kg/day which is the same as that originally put forth by the MA DEP. Further division, without additional toxicological information, would imply a greater degree of certainty than is suggested by the available data.

2.2.4 C_9 – C_{16} Aromatic Fraction Inhalation RfCs

The fate and transport section of the TPHCWG report series (TPHCWG, 1997a) identified 77 individual hydrocarbons within the C_9 - C_{16} carbon range. Of these compounds, a US EPA derived RfC was identified for only isopropylbenzene (C_9) (0.4 mg/m^3), commonly known as cumene (US EPA, 1997a). Naphthalene (C_{10}) is another compound in the C_9 - C_{16} carbon range that has a chronic inhalation toxicity value of 0.01 mg/m^3 derived by the ATSDR (Table 7).

2.2.4.1 Summaries of Toxicity Studies. Recent inhalation studies on trimethylbenzene isomers were identified. No other data on any of the other individual hydrocarbon components of the C_9 - C_{16} fraction were found. Three published inhalation studies on C_9 aromatic mixtures were discussed by the TPHCWG. The data on isopropylbenzene, naphthalene, trimethylbenzenes and the C_9 aromatic mixtures are briefly summarized below:

- **Isopropylbenzene.** Isopropylbenzene (cumene) is a potent narcotic, skin and mucous membrane irritant. It is absorbed through the intact skin more rapidly than toluene, xylene or ethylbenzene. In some short term, high dose experiments, animals exhibited damage to the spleen and fatty changes to the liver, but no renal or pulmonary irritancy (Sandmeyer, 1981). Two successive subchronic inhalation toxicity studies on isopropylbenzene were evaluated by the US EPA for the RfC derivation (EPA, 1997a). In the first study, groups of rats were exposed to 0, 492, 2438 or 5909 mg/m^3 (0, 199, 496, or 1202 ppm) isopropylbenzene vapor for 6 hours/day, 5 days/week for 13 weeks. In the second study, the group size was reduced and an additional group (246 mg/m^3) was added to incorporate a 4-week post exposure group.

  The critical treatment-related effects were increased relative and absolute kidney weights in female rats, and increased relative and absolute adrenal weights in both sexes at the highest concentrations (5909 mg/m^3) tested. A NOAEL of 492 mg/m^3 was used to derive the RfC of 0.4 mg/m^3. The NOAEL was adjusted for continuous exposure and an uncertainty factor of 1000 (10 for subchronic to chronic extrapolation, 10 for animal to human extrapolation, 3 for sensitive individuals and 3 for database deficiency in reproductive effects) was applied to the NOAEL to derive the inhalation RfC.

- **Naphthalene.** Naphthalene is a hematopoietic and pulmonary toxicant. Male and female mice were exposed to 0, 52, or 157 mg/m^3 (0, 10, or 30 ppm) of naphthalene, for 6 hours/day, 5 days/week for two years (NTP, 1992). Both sex groups demonstrated chronic inflammation and metaplasia of the olfactory epithelium, hyperplasia of the respiratory epithelium and dose-related increases in inflammatory lesions of the lungs. Female mice exposed to 157 μg/m^3 of naphthalene showed a significant increase in pulmonary alveolar bronchiolar adenoma. The ATSDR used 52 mg/m^3 as a LOAEL and derived a chronic inhalation minimal risk level (MRL) of 0.01 mg/m^3 (ATSDR, 1995b).

- **Trimethylbenzene Isomers.** Rats were exposed to 0, 123, 491, and 1227 mg/m^3 (0, 25, 100, or 200 ppm) 1,2,4-trimethylbenzene (TMB) 6 hours/day, 5 days/week for 4 weeks (Gralewicz et al., 1997). Behavioral tests such as radial maze performance, open field activity, passive avoidance and shock-induced changes in the pain sensitivity were conducted between days 14 and 54 after exposure.

No change in body weight gain was observed in any of the treated groups. Significant changes in CNS function as demonstrated by the behavioral tests were observed in the groups treated with 491 and 1227 mg/m^3 of TMB. The NOAEL in this study was 123 mg/m^3. The authors concluded that exposure to 1,2,4-trimethybenzene might lead to long-lasting changes in the functional state of the CNS. They further discussed that behavioral effects observed between days 21 and 54 after the last exposure may not be due to the presence of TMB or its metabolites in the rat CNS since TMB is metabolized and eliminated quickly.

Another observation discussed in the paper was that the lower concentration (492 mg/m^3) was more potent in the neurobehavioral effects assessment than the higher concentration (1227 mg/m3). This phenomenon was not an experimental artifact since it was also observed in another study conducted in the same laboratory using 1,2,3-trimethylbenzene. Although no mechanism was proposed for the pronounced toxicity at the lower exposure concentrations, further studies were recommended to elucidate the mechanism. Understanding the mechanism of the low exposure level toxicties to these chemicals is important since it is relevant to environmental exposure.

The suggested mechanism for the neurobehavioral toxicity is alterations in the utilization and turnover of biogenic amines in the brain. This hypothesis is inferred from such effects observed in animals exposed to other methylated benzenes (toluene and xylenes). The dopaminergic system is particularly vulnerable to methylbenzenes.

In another experiment, subchronic exposure of rats to 1,2,4-TMB or 1,2,3-TMB at concentrations of 0, 123, 491, and 1227 mg/m^3 (0, 25, 100, and 200 ppm) caused the same concentration dependent behavioral effects. The neurotoxic effects of 1,2,3-TMB were more pronounced than the effects observed with 1,2,4-TMB (Korsak and Rydzynski, 1996). The NOAEL in this study was also 123 mg/m^3.

An RfC 0.02 mg/m^3 can be derived from the above identified NOAEL of 123 mg/m^3 by adjusting for continuous exposure and by applying an uncertainty factor of 1000 (10 for subchronic to chronic extrapolation, 10 for animal to human extrapolation, and 10 to account for sensitive individuals).

- **Aromatic Mixtures.** Naphthenes are catalytically converted to aromatic compounds to make high-octane gasoline blending components. A portion of this wide-boiling range hydrocarbon stream can be separated by distillation and used for other purposes. One such distillate is a mixture containing primarily 9-carbon aromatic compounds usually consisting of isomers of ethyltoluene (28%) and trimethylbenzene (40 - 55%). Other C_9 minor components include isopropylbenzene (3%), n-propylbenzene (4%), and other aromatics containing more than 10 carbon atoms (6%). The percentages of the components may differ slightly from one distillate to another. These C_9 aromatic mixtures are commonly known as high flash aromatic naphtha (HFAN) and are used mainly as solvents (Douglas et al., 1993). The various studies on HFAN are summarized below:

  Neurotoxicity of C_9 Mixtures. Male rats were exposed by inhalation to HFAN for 90 days at concentrations of 0, 490, 2544 or 7362 mg/m^3 (0, 100, 500 or 1500 ppm) for 6 hours/day, 5 days/week to investigate the neurotoxicity of the solvent (Douglas et al., 1993). During the testing period, animals were examined monthly for motor activity and a functional observation battery of tests was applied which consisted of tests for hind limb grip strength, audio startle response, thermal response, and hind foot splay. Selected nervous system tissues were examined histopathologically.

  Significant weight reduction was observed in animals exposed to the highest concentrations (7362 mg/m^3). No histopathologic effects on the nervous tissues and no neurobehavioral abnormalities were observed in any of the treated groups.

  The TPHCWG determined a NOAEL of 7362 mg/m^3 from the above study. However, in the study, this concentration produced significant weight reductions. The same level of exposure caused high mortality rates and CNS effects in pregnant mice (McKee et al., 1990). By adjusting the NOAEL for continuous exposure (NOAEL x 6/24 x 5/7) and using an uncertainty factor of 1000 (10 to account for human variability, 10 for subchronic to chronic extrapolation and 10 for animal to human extrapolation), an RfC of 1.3 mg/m^3 was estimated by the TPHCWG .

Systemic Toxicity. Clark et. al. (1989) exposed male rats to high flash aromatic naphtha vapors at 0, 450, 900 or 1800 mg/m^3, 6 hours/day, 5 days/week for 12 months. Transient reduction in body weight gain was observed in male and female rats that did not last through the duration of the study. Hematological and clinical chemistry tests did not show any consistent dose-related effects. A possible increase in male "aggression" at the highest concentration was believed to be related to treatment. There was also a significant increase in male liver and kidney weights in the high exposure group.

The TPHCWG (1997b) determined 900 mg/m^3 as a NOAEL for hepatic effects in male rats. By adjusting the NOAEL for continuous exposure (NOAEL x 6/24 x 5/7) and by applying an uncertainty factor of 1000 (10 for animal to human extrapolation, 10 for human variability and 10 for subchronic to chronic extrapolation), an RfC of 0.2 mg/m^3 was estimated. The TPHCWG recommended that this RfC value (0.2 mg/m^3) be a surrogate for the entire C_9 - C_{16} fraction.

Developmental/Reproductive Toxicity. Mice were exposed by inhalation to high flash aromatic naphtha (HFAN) vapors at 0, 100, 500 or 1500 ppm (0, 491, 2544, or 7362 mg/m^3 for 6 hours/day during gestational days 6-15 (McKee et al., 1990). A three generation reproductive study was also conducted in rats exposed to 0, 100, 500, 1500 ppm (0, 491, 2544 or 7362 mg/m^3) of high flash aromatic naphtha.

The highest exposure concentration (7362 mg/m^3) caused 44% mortality in pregnant mice. Other clinical observations in pregnant mice included significantly reduced weight gain, ataxia, labored breathing, hunched posture, weakness, inadequate grooming, and circling. Maternal body weight gain was also significantly reduced at the medium exposure concentration (2544 mg/m^3). At the lowest exposure concentration (491 mg/m^3), maternal body weight was reduced, but not significantly. A marked decrease in hematocrit was observed in the dams exposed to the highest concentrations.

There was also evidence of developmental toxicity at the highest exposure concentration. The number of live fetuses per litter and the mean fetal body weight were significantly reduced. Post implantation loss was markedly elevated, ossification was delayed and the number of fetuses with cleft palate was increased. At the medium (2544 mg/m^3) exposure level, maternal and fetal body weights were significantly reduced. Minimal maternal weight reduction was observed at the low (491 mg/m^3) exposure level. This

concentration was determined to be a NOAEL for maternal and developmental toxicity. This mouse developmental NOAEL of 491 mg/m^3 is lower than the rat NOAEL (7362 mg/m^3) described previously. The mouse developmental NOAEL is also lower than the NOAEL (900 mg/m^3) for other systemic effects of HFAN. The TPHCWG used the NOAEL of 900 mg/m^3 to derive a fractional RfC of 0.2 mg/m^3.

In a three-generation reproductive study, rats were exposed to 0, 490, 2544 or 7362 mg/m^3 (0, 100, 500 or 1500 ppm) HFAN (McKee et al., 1990). All the F0 males survived to the scheduled sacrifice with significant weight reduction in both the 2544 and 7362 mg/m^3 exposure groups. Within the highest exposure group there was 23% mortality in female rats (about 12% prior to mating and about 12% during gestation and lactation). Body weight gain was also significantly reduced in both the medium and high exposure groups. No other significant effects were observed.

In the F1 generation, birth weights were not significantly different from controls at any exposure level. However, mean body weights were significantly reduced in pups in the high exposure group when maternal exposure was continued through the lactational period. No other reproductive effects were observed.

In the F2 generation, CNS effects manifested as ataxia and reduced motor activity were observed in the high exposure group. Also, 20% of the exposed females died (10% during gestation, 5% during delivery and 5% during lactation). The fraction of live-born offspring was slightly but significantly reduced in the high exposure group.

In the F3 generation, the F2 pups used to produce the F3 generation were exposed at an earlier age than pups exposed in the previous studies and most of the animals (36/40 males and 34/40 females) exposed to the highest concentration died in the first week of exposure. Body weights of pups from surviving dams exposed to the high exposure concentration were significantly reduced at birth, but were not significantly reduced at lactation day 4. As in the previous generations, once maternal exposure was initiated, body weight gain of the pups in the high dose group was significantly less than controls. The concentration that did not produce adverse effects in the three generation reproductive study is 100 ppm (490 mg/m^3).

The developmental and the reproductive studies suggest that mice are the more sensitive species to the developmental effects of HFAN. At the highest concentration (7362 mg/m^3), there were 44% mortality, clinical signs of toxicity including CNS effects in pregnant mice, and severe developmental effects in the pups. This concentration caused only 23% mortality in female rats with only significant weight reduction in survivors.

The female animals are also more sensitive to HFAN toxicity. No mortalities were observed in male rats exposed to concentrations that were lethal to female rats under the same exposure conditions.

The reproductive effects in the three generation rat study are manifested as reduced weight gain in the offspring at the highest exposure concentrations. No other major reproductive effects were observed. Since mice appear to be the most sensitive species for the developmental toxicity of HFAN, reproductive studies using these species are recommended for any definitive conclusions about the reproductive toxicity of HFAN.

In another developmental/reproductive study, rats were exposed to Armatol (a branched chain product conforming to the specifications of high flash aromatic naphtha) vapor at 0, 589, 982 or 1963 mg/m^3 for 24 hours/day from day 7 to 15 of gestation (Ungvary et al., 1983). Maternal weight gain during gestation was slightly but significantly reduced at all exposure levels. Exposure of rats to 982 or 1963 mg/m^3 resulted in developmental delays. The developmental NOAEL in this study was 589 mg/m^3. Maternal body weight was significantly but slightly reduced at these exposure levels. No maternal NOAEL was identified in this study. The developmental NOAEL determined in this study is also lower than the NOAEL used to derive the representative RfC for the C_9 - C_{16} aromatic fraction (900 mg/m^3). The developmental studies indicate that the fractional RfC derived by the TPHCWG from the neurotoxicity study may not be protective of the very sensitive subpopulations like the pregnant woman and the fetus.

2.2.4.2 Discussion and Recommendation . The TPHCWG used the NOAEL of 900 mg/m^3 for systemic effects in rats to derive an RfC of 0.2 mg/m^3 for the C_9 aromatic mixture. This toxicity value was ultimately designated as a surrogate toxicity number for the entire C_9 - C_{16} aromatic range. The NOAEL of 900 mg/m^3 is higher than the NOAELs for other endpoints determined for the aromatic mixtures. The developmental and maternal NOAEL from the McKee et al. (1990) mouse study was 491 mg/m^3 and the developmental NOAEL from the Ungvary et al. (1983) rat study was 589 mg/m^3. No maternal NOAEL was identified in the Ungvary et al. study. The studies reviewed have

demonstrated that pregnant animals are more sensitive than their non-pregnant counterparts and the male animals tested. In male rats, reduced weight gain was the only anomaly observed at the highest exposure concentration (7362 mg/m^3) (API, 1990c), while this concentration was lethal to 22% of pregnant and non- pregnant female rats and 44% of pregnant female mice. A factor of 10 applied to the systemic NOAEL of 900 mg/m^3 to adjust for sensitive individuals may not be adequate to protect the most sensitive species, the pregnant mother and the fetus. It is, therefore, health protective to reduce the inhalation RfC (0.2 mg/m^3) derived by the TPHCWG by an additional factor of at least 3. A factor of 3, but not 10, is recommended based on the fact that:

- The NOAEL (900 mg/m^3) used to derive the RfC is only twice the concentration determined to be the developmental NOAEL (491 mg/m^3);
- Developmental toxicities were observed at maternally toxic exposure concentrations.

Another question regarding the surrogate RfC derived using C_9 aromatic mixtures is whether it is representative of all the components in the C_9 - C_{16} petroleum hydrocarbon aromatic subgroup. While the RfC derived by the TPHCWG may be a representative value for the volatile alkyl benzenes, the volatile aromatics possessing more than one ring in their structures may not be represented. This assumption is based on metabolic and toxicity considerations.

Polycyclic aromatic hydrocarbons (PAHs) having two to three rings (naphthalene, acenaphthene, anthracene, fluorene, pheneanthrene) are present in air predominantly in the vapor phase (ATSDR, 1995c). PAHs that have four rings (fluoranthene, and pyrene) exist both in the vapor and particulate phase (ATSDR, 1995c). Exposure to PAHs that exist in both the particulate and vapor phase via inhalation is possible. However, it is not within the scope of this report to address toxicity from particulate inhalation. The data indicate that inhalation could be a pathway for exposure to the volatile PAHs such as acenapthene, anthracene, fluorene, fluoranthene, naphthalene, 2-methylnaphthalene and phenanthrene and the semi-volatiles such as fluoranthene and pyrene. All these PAHs are included in the C_9 - C_{16} aromatic subgroup.

The most investigated alkylated benzenes such as toluene and xylenes are primarily metabolized through side chain oxidation (Philpot and Smith, 1984). The principal identified cytochrome P450 isozymes that metabolize these compounds are the phenobarbital inducible cytochrome *P*4502B family which oxidize substrates in conformationally unhindered positions giving products that are easily conjugated and eliminated (Philpot and Smith, 1984; Ionnides and Park, 1987). It is reasonable to assume that side chain oxidation of other alkylated benzenes may be mediated by the same enzyme system.

The polycyclic aromatic hydrocarbons on the other hand are mainly metabolized by the 3-methylcholanthrene inducible cytochrome *P*4501A family (Ionnides and Park, 1987). These isozymes metabolize chemical carcinogens at conformationally hindered positions resulting in reactive metabolites which are poor substrates for subsequent conjugation and detoxication. While these PAH metabolizing enzymes have been characterized using the carcinogenic PAHs like benzo(a)pyrene, such studies are lacking for the lower molecular weight PAHs. Recently, an enzyme inhibition study using naphthalene showed that one of the enzymes that may metabolize naphthalene was cytochrome *P*-4501A; the other being cytochrome *P*-450 3A (Tingle et al., 1993). Phenanthrene is also metabolized by cytochrome *P*-4501A (Shou et al., 1994).

Thus the methylbenzenes and the PAHs included in the C_9 - C_{16} carbon range may not compete for primary oxidation pathways in their metabolism and they also may have different toxicities. This differential toxicity is exemplified by the pulmonary cytotoxicity of naphthalene and the CNS toxicities of alkylbenzenes.

It is therefore health protective to apply an uncertainty factor of at least three to the RfC derived by the TPHCWG using the C_9 aromatic mixture data to account for a database deficiency. The deficiency is an absence of direct information on whether the data on C_9 aromatic mixtures are representative of all compounds in the C_9 - C_{16} aromatic group. The total uncertainty factor applied by MA DEP to the TPHCWG derived RfC of 0.2 mg/m^3 would be 10 (3 to account for developmental effects and 3 to adjust for database deficiency). The adjusted RfC is 0.02 (0.2/10) mg/m^3. This number is close to the toxicity value derived for naphthalene (0.01 mg/m^3) by the ATSDR (1995b) and similar to the value derived by the MADEP for methylbenzenes (0.02 mg/m^3) in Section 2.1.11. **Thus, MA DEP recommends an RfC value of 0.02 mg/m^3 as a surrogate toxicity number for the C_9 - C_{16} aromatic TPH fraction.**

2.2.5 C_{17} - C_{32} Aromatic Fraction – Inhalation RfC

No appropriate data were identified to support development of inhalation RfCs for the individual components or mixtures in this carbon range, although some of the PAHs in this group (chrysene and benzo(a)anthracene) can partially exist in the vapor phase in the ambient air. The high molecular weight PAHs like benzo(a)pyrene and dibenz(g,h,i)perylene exist primarily in the particulate phase in air (ATSDR, 1995c). The compounds in this carbon range are not very volatile and inhalation of gaseous compounds is not a likely route of exposure. However, it should be noted that the high molecular weight aromatic hydrocarbons can bind to soil particles because of their high K_{oc}, and inhalation exposure to these chemicals may depend on inhaled particulate matter. No data exist to estimate toxicity value for soil-bound and inhaled C_{17} - C_{35} PAHs.

3.0 CONCLUSIONS AND RECOMMENDATIONS

MA DEP in 1994 developed the first fractional approach to evaluate human health risks from oral exposures to mixtures of petroleum hydrocarbon compounds (PHC) and developed oral reference doses (RfDs) for various PHCs fractions. However, fraction-specific toxicity values for inhalation exposures were not derived. Subsequent to this effort, the national ad hoc workgroup known as the TPH Criteria Working Group (TPHCWG) introduced a modified version of the fractional approach and derived fraction-specific oral RfDs and inhalation reference concentrations (RfCs).

There are apparent methodological differences followed by the two groups in the segregation of the PHC fractions and in the derivation of the fractional toxicity values. The MA DEP grouped TPH fractions based on their chemical structure, number of carbons, the nature and degree of toxicity and structure activity relationship considerations. This methodology gave 3 subgroups for aliphatics and 1 subgroup for aromatics.

The TPHCWG on the other hand specified fractions based on fate and transport considerations. Aromatic or aliphatic petroleum hydrocarbon components having similar leaching factors and volatilization factors ranging over one order of magnitude were grouped as fractions having similar transport properties. As a result, 7 aliphatic and 6 aromatic fractions were specified.

The fractions based on chemical structure, number of carbons, and SAR and those based on fate and transport considerations with assigned toxicity values (TPHCWG) are similar.

The oral RfDs and inhalation RfCs derived for petroleum hydrocarbon subgroups by the MA DEP and the TPHCWG differ for all but the C_9 – C_{16} and C_{17} – C_{35} aliphatics oral toxicity values (Table 8 and Table 9). New data available after MA DEP's interim final report in 1994 and data not available to MA DEP at that time were used by the TPHCWG to develop their fraction-specific oral RfDs and inhalation RfCs. Inhalation RfCs were not developed by MADEP in 1994. MA DEP has used this newer information to derive inhalation RfCs for all volatile petroleum hydrocarbon fractions specified in 1994. In most cases, the data on which the MA DEP and the TPHCWG derived toxicity values are based are the same; but the differences in the final numbers stem from differing interpretations of the same underlying studies.

Based upon a review of the TPHCWG documentation, the literature sources cited, and consideration of the rationales for the MA DEP fraction specific toxicity values, MA DEP's recommends the following oral and inhalation toxicity for the fractions.

Table 8. MA DEP and TPHCWG Derived Oral Toxicity Values

Carbon Range*	2002 MA DEP Recommend Values (mg/kg/day)	TPHCWG* (1997b) (mg/kg/day)	Critical Effect (MA DEP)	Critical Effect (TPHCWG)
Aliphatic				
C_5 - C_8	0.06	5	Neurotoxicity	Neurotoxicity
C_9-C_{18}	0.1	0.1	Hepatic and hematological	Hepatic and hematological
C_{19} - C_{32}	2.0	2.0	Liver granuloma	Liver granuloma
$C_{>16}$-C_{35}	-	2.0		
Aromatic				
C_6 - C_8	Evaluate each chemical in the series separately	Benzene alone, 0.2 (C_7 – C_8)		Neurotoxicity
C_9-C_{16}		0.04		
C_9-C_{32}	Determined	0.03	Nephrotoxicity	Nephrotoxicity
$C_{>8}$-C_{35}	0.03 mg/kg/day as surrogate value for the C_9 – C_{32} fraction	0.03		

Table 9. MA DEP and TPHCWG Derived Inhalation Toxicity Values

Carbon Range*	2002 MA DEP Recommend Values (mg/m^3)	TPHCWG* (1997b) (mg/m^3)	Critical Effect (MA DEP)	Critical Effect (TPHCWG)
Aliphatic				
C_5 - C_8	0.2	18.4	Neurotoxicity	Neurotoxicity
C_9-C_{18}	0.2	1.0	Neurotoxicity	Hepatic changes
C_{19} - C_{32}	NA**	NA	NA	NA
Aromatic				
C_6 - C_8	Use individual RfCs for compounds in this range	Benzene alone 0.4 (C_7-C_8)		Hepatotoxicity Nephrotoxicity
C_9-C_{16}	0.02	0.2	Body weight reduction, hepatic, renal, and developmental effects	Body weight reduction, hepatic, and renal effects
C_{17}-C_{32}	NA	NA		

*TPHCWG defined their carbon ranges on the basis of equivalent carbon number. The convention used here is to show the carbon range based on actual number of carbon atoms in the compounds.

** NA = Not applicable. Compounds in this size range not volatile.

1. Aliphatics C_5 - C_8: The TPHCWG derived an oral RfD of 5 mg/kg/day (Table 8) for this fraction based on American Petroleum Institute (API) sponsored inhalation studies on commercial hexane. They estimated an inhalation RfC of 18.4 mg/m^3 using neurotoxicity as an endpoint. The oral RfD was then derived by applying direct route-to-route extrapolation. Overall, the chronic commercial hexane studies used by the TPHCWG demonstrated that an inhalation exposure to a hexane mixture containing 53% n-hexane produced little overall toxicity in rats and mice. However, and most importantly, other chronic human and animal studies showed that commercial hexane causes peripheral neuropathy. In addition, many potential diketone metabolites of n-alkanes produce peripheral neurotoxicity. Thus, the oral toxicity value of 5 mg/kg/day for C_5 - C_8 alkanes derived by the TPHCWG has some shortcomings and may underestimate human risk. **Until data on individual components of the fraction or mixtures are found, MA DEP will continue to use its original toxicity surrogate (0.06 mg/kg/day) for this fraction. This number is based on a well-designed oral toxicity study on n-hexane.**

As described above, an inhalation RfC of 18.4 mg/m^3 was derived from chronic inhalation studies on commercial hexane by the TPHCWG. The end point evaluated was neurotoxicity. However, respiratory effects appeared to be the most sensitive endpoint in the study. Moreover, other studies demonstrated that commercial hexane and other aliphatic mixtures in the series caused neurotoxicity in humans and animals. **Until data on mixtures or individual compounds are found, MA DEP recommends using the US EPA derived RfC for n-hexane (0.2 mg/m^3) as a surrogate toxicity value for this fraction.**

2. Aliphatic C_9 - C_{18}: New oral gavage studies on various petroleum streams covering C_9 - C_{17} carbon ranges were used by the TPHCWG to derive an oral RfD of 0.1 mg/kg/day. The observed adverse effects in the treated animals included body weight, organ weight, and blood chemistry changes. These newer, well designed and executed studies are a better and more defensible choice for use in derivation of the RfD for this fraction than that which was previously presented by MA DEP in the 1994 Interim report. **MA DEP therefore recommends adoption of the fractional toxicity value of 0.1 mg/kg/day derived by the TPHCWG for this fraction.**

The TPHCWG derived a surrogate RfC of 1 mg/m^3 for its C_9 -C_{16} aliphatic fraction using various studies on dearomatized petroleum streams. The TPHCWG considered exposure concentrations which produced significant weight reduction and significant increases in liver and kidney weights in rodents as a NOAEL. This exposure concentration should be considered as a LOAEL and an uncertainty factor of at least 3 (based on the severity of the adverse effects observed) should be applied to the LOAEL to extrapolate from

LOAEL to NOAEL. If such an adjustment were made, the estimated RfC would be 0.3 mg/m^3.

As previously discussed, a recent neurotoxicity study revealed that exposure of rats to dearomatized white spirit for six months induced long-lasting and possibly irreversible effects in the nervous system. The MA DEP determined RfC from this study was 0.2 mg/m^3, which is close to the above adjusted TPHCWG RfC of 0.3 mg/m^3.

MA DEP recommends use of an RfC based on neurotoxic responses in rats exposed to dearomatized white spirits because of emerging neurotoxicicty data on white petroleum spirits. Exposure of painters to white spirit resulted in early disability pension due to neuropsychological disorders. In most of the studies, workers were exposed to mixtures of organic solvents, the principal component being white spirit. The effects were mainly functional disturbances in the central nervous system including memory and learning impairments.

In acute animal studies, white spirit with low aromatic content produced significant reductions in animal response to learned performances. Increased levels in brain noradrenaline, dopamine, and 5-hydroxytryptamine were observed in rats exposed to various levels of white spirit. Changes in indices of oxidative stress in the synaptosomes were also reported in animals exposed to white spirit for 3 weeks.

Since the rat study on which the RfC is based is a well-conducted study, **MA DEP's recommended toxicity value for the C_9 -C_{18} aliphatic fraction is 0.2 mg/m^3.**

3. Aliphatics C_{19}-C_{32}: The TPHCWG derived an oral RfD of 2.0 mg/kg/day for this fraction ($C_{>16}$-C_{35}) based on a subchronic feeding study of several different highly refined white mineral oil samples representing various mineral hydrocarbon (MHC) sizes. The low molecular weight (average molecular weight 320-420) MHC caused mesenteric lymph node histocytosis and liver granulomas while the high molecular weight MHC were without effect. This study was more recent and a more defensible choice for derivation of the RfD for this fraction than that presented by MA DEP in 1994. **MA DEP therefore recommends the adoption of the RfD of 2.0 mg/kg/day derived by the TPHCWG for the aliphatic fractions containing 19 through 32 carbon atoms.**

4. Aromatics C_6 - C_8: Until data on mixtures constituting C_6 – C_8 aromatic fraction are available, MA DEP recommends that chemical specific RfDs and RfCs continue to be used for each of the compounds in the C_6 - C_8 aromatic range. This is because the toxicity values for each are well supported and these compounds have a wide range of toxicity. To use one surrogate value would not allow for recognition of the potential toxicological contributions of the most toxic compounds in the group.

5. Aromatics C_9 - C_{32}: The TPHCWG identified 77 individual compounds in this carbon range. US EPA derived RfDs were available only for 8 (acenaphthene, biphenyl, fluorene, anthracene, fluoranthene, naphthalene, and pyrene) of these compounds. The RfDs range from 0.03 to 3 mg/kg/day. The TPHCWG also derived an additional oral RfD of 0.03 mg/kg/day based on a naphthalene/methylnaphthalene mixture study. The TPHCWG determined an RfD of 0.04 mg/kg/day for the $C_{>8}$ -C_{16} range and an RfD of 0.03 mg/kg/day for the $C_{>17}$ - C_{35} fraction. **MA DEP recommends that an RfD of 0.03 mg/kg/day for the aromatic hydrocarbons containing 9 through 32 carbon continue to be used to represent the toxicities of all compounds in this fraction**. As previously concluded by MA DEP (1994), use of other RfDs for subdivisions of this fraction may convey more certainty in the data than is warranted.

6. C_9 - C_{16} Aromatic Fraction. Although the C_9 - C_{32} compounds are grouped together and an oral surrogate value is assigned representing all compounds in the fraction, the more volatile compounds containing 9 to 16 carbons are subdivided for inhalation toxicity evaluation. Compounds containing carbon atoms ranging between 17 and 32 were considered to be not volatile and toxicity values were not estimated for this subgroup. The rationale used to derive an inhalation RfC for this fraction by MA DEP was similar to that used by the TPHCWG. The RfC derived by the TPHCWG was 0.2 mg/m^3. However, the MA DEP considered the NOAEL chosen by the TPHCWG as a LOAEL and applied a safety factor of 3 to account for LOAEL to NOAEL extrapolation. Further, an additional safety factor of 3 was applied to protect sensitive individuals like the fetus and the pregnant mother who may react to the C_9 – C_{16} aromatic mixtures at low exposure concentrations. **The MA DEP adjusted RfC is 0.02 mg/m^3 (0.2 mg/m^3/10) and this value is recommended for MA DEP use for the fraction**.

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U.S. Environmental Protection Agency

Integrated Risk Information System

Benzene (CASRN 71-43-2)

Toxicological Review (PDF) Available

Support Documents Available

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Health assessment information on a chemical substance is included in IRIS only after a comprehensive review of toxicity data by U.S. EPA health scientists from several Program Offices, Regional Offices, and the Office of Research and Development.

Disclaimer: This QuickView represents a snapshot of key information. We suggest that you read the Full IRIS Summary to put this information into complete context.

For definitions of terms in the IRIS Web site, refer to the IRIS Glossary.

Status of Data for Benzene

File First On-Line: 03/01/1988
Last Significant Revision: 04/17/2003

Category	Status	Last Revised
Oral RfD Assessment	On-line	04/17/2003
Inhalation RfC Assessment	On-line	04/17/2003
Carcinogenicity Assessment	On-line	01/09/2000

Chronic Health Hazard Assessments for Noncarcinogenic Effects

Reference Dose for Chronic Oral Exposure (RfD)

Critical Effect	Experimental Dose	UF	MF	RfD
Decreased lymphocyte count	BMDL : 1.2 mg/kg-day	300	1	4.0×10^{-3} mg/kg-day

The Experimental Dose listed serves as a basis from which the Oral RfD was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Human occupational inhalation study, Rothman et. al., 1996

Confidence in the Oral RfD
Study -- Medium
Database -- Medium
RfD -- Medium

Reference Concentration for Chronic Inhalation Exposure (RfC)

Critical Effect	Experimental Dose	UF	MF	RfC
Decreased lymphocyte count	BMCL : 8.2 mg/m3	300	1	$3x10^{-2}$ mg/m3

The Experimental Dose listed serves as a basis from which the Inhalation RfC was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Human occupational inhalation study, Rothman et. al., 1996

Confidence in the Inhalation RfC
Study -- Medium
Database -- Medium
RfC -- Medium

Carcinogenicity Assessment for Lifetime Exposure

Weight of Evidence Characterization

Weight of Evidence (1986 US EPA Guidelines):
A (Human carcinogen)

Weight of Evidence Narrative:
Under the proposed revised Carcinogen Risk Assessment Guidelines (U.S. EPA, 1996), benzene is characterized as a known human carcinogen for all routes of exposure based upon convincing human evidence as well as supporting evidence from animal studies. (U.S. EPA, 1979, 1985, 1998; ATSDR, 1997).

This may be a synopsis of the full weight-of-evidence narrative. See Full IRIS Summary.

Quantitative Estimate of Carcinogenic Risk from Oral Exposure

Oral Slope Factor(s)	Extrapolation Method
$1.5x10^{-2}$ per mg/kg-day[1]	Linear extrapolation of human occupational data
$5.5x10^{-2}$ per mg/kg-day[1]	Linear extrapolation of human occupational data

[1] This is one endpoint in a range of oral slope factors/drinking water unit risks. See Additional Comments (Carcinogenicity, Oral Exposure).

Drinking Water Unit Risk(s):
$4.4x10^{-7}$ per ug/L[1]
$1.6x10^{-6}$ per ug/L[1]

Drinking Water Concentrations at Specified Risk Levels

Risk Level	Concentration
E-4 (1 in 10,000)	$1x10^{2}$ ug/L[1]
E-5 (1 in 100,000)	$1x10^{1}$ ug/L[1]
E-6 (1 in 1,000,000)	1 ug/L[1]
E-4 (1 in 10,000)	$1x10^{3}$ ug/L[1]
E-5 (1 in 100,000)	$1x10^{2}$ ug/L[1]
E-6 (1 in 1,000,000)	$1x10^{1}$ ug/L[1]

[1] This is one endpoint in a range of oral slope factors/drinking water unit risks. See Additional Comments (Carcinogenicity, Oral Exposure).

Dose-Response Data (Carcinogenicity, Oral Exposure)

Tumor Type: Leukemia
Test Species: Human
Route: Inhalation, Occupational exposure
Reference: Rinsky et al., 1981, 1987; Paustenbach et al., 1993; Crump, 1994; U. S. EPA, 1998; U.S. EPA, 1999

Quantitative Estimate of Carcinogenic Risk from Inhalation Exposure

Air Unit Risk(s)	Extrapolation Method
$2.2x10^{-6}$ per ug/m3[1]	Low-dose linearity utilizing maximum likelihood estimates
$7.8x10^{-6}$ per ug/m3[1]	Low-dose linearity utilizing maximum likelihood estimates

Air Concentrations at Specified Risk Levels

Risk Level	Concentration
E-4 (1 in 10,000)	$1.3x10^{1}$ ug/m3[1]
E-5 (1 in 100,000)	1.3 ug/m3[1]
E-6 (1 in 1,000,000)	$1.3x10^{-1}$ ug/m3[1]
E-4 (1 in 10,000)	$4.5x10^{1}$ ug/m3[1]
E-5 (1 in 100,000)	4.5 ug/m3[1]
E-6 (1 in 1,000,000)	$4.5x10^{-1}$ ug/m3[1]

[1] This is one endpoint in a range of air unit risks. See Additional Comments (Carcinogenicity, Inhalation Exposure).

Dose-Response Data (Carcinogenicity, Inhalation Exposure)
Tumor Type: Leukemia
Test Species: Human
Route: Inhalation
Reference: Rinsky et al., 1981, 1987; Paustenbach et al., 1993; Crump and Allen, 1984; Crump, 1992, 1994; U.S. EPA, 1998

Revision History

Review Full IRIS Summary for complete Revision History.

Synonyms

Benzene
Coal naphtha
Phene
Phenyl hydride
Polystream
71-43-2
Benzol
Cyclohexatriene
Pyrobenzol

U.S. Environmental Protection Agency

Integrated Risk Information System

Ethylbenzene (CASRN 100-41-4)

Health assessment information on a chemical substance is included in IRIS only after a comprehensive review of toxicity data by U.S. EPA health scientists from several Program Offices, Regional Offices, and the Office of Research and Development.

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Status of Data for Ethylbenzene

File First On-Line: 01/31/1987
Last Significant Revision: 03/01/1991

Category	Status	Last Revised
Oral RfD Assessment	On-line	06/01/1991
Inhalation RfC Assessment	On-line	03/01/1991
Carcinogenicity Assessment	On-line	08/01/1991

Chronic Health Hazard Assessments for Noncarcinogenic Effects

Reference Dose for Chronic Oral Exposure (RfD)

Critical Effect	Experimental Dose	UF	MF	RfD
Liver and kidney toxicity	NOEL : 97.1 mg/kg-day	1000	1	1×10^{-1} mg/kg-day

The Experimental Dose listed serves as a basis from which the Oral RfD was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Rat subchronic to chronic oral bioassay, Wolf et al., 1956

Confidence in the Oral RfD
Study -- Low
Database -- Low
RfD -- Low

Reference Concentration for Chronic Inhalation Exposure (RfC)

Critical Effect	Experimental Dose	UF	MF	RfC
Developmental toxicity	NOAEL (HEC): 434 mg/m3	300	1	1 mg/m3

The Experimental Dose listed serves as a basis from which the Inhalation RfC was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Rat and rabbit developmental inhalation studies, Andrew et al., 1981; Hardin et al., 1981

Confidence in the Inhalation RfC
Study -- Low
Database -- Low
RfC -- Low

Carcinogenicity Assessment for Lifetime Exposure

Weight of Evidence Characterization

Weight of Evidence (1986 US EPA Guidelines):
D (Not classifiable as to human carcinogenicity)

Weight of Evidence Narrative:
Nonclassifiable due to lack of animal bioassays and human studies.

This may be a synopsis of the full weight-of-evidence narrative. See Full IRIS Summary.

Quantitative Estimate of Carcinogenic Risk from Oral Exposure

Not Assessed under the IRIS Program.

Quantitative Estimate of Carcinogenic Risk from Inhalation Exposure

Not Assessed under the IRIS Program.

Revision History

Review Full IRIS Summary for complete Revision History.

Synonyms

100-41-4
Benzene, ethyl
EB
Ethylbenzeen
Ethylbenzol
Etilbenzene
Phenylethane
UN 1175
Aethylbenzol
Ethylbenzene
Etylobenzen
NCI-C56393

Methyl tert-butyl ether (MTBE) (CASRN 1634-04-4)

Health assessment information on a chemical substance is included in IRIS only after a comprehensive review of toxicity data by U.S. EPA health scientists from several Program Offices, Regional Offices, and the Office of Research and Development.

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Status of Data for Methyl tert-butyl ether (MTBE)

File First On-Line: 12/01/1991
Last Significant Revision: 09/01/1993

Category	Status	Last Revised
Oral RfD Assessment	No data	03/01/1993
Inhalation RfC Assessment	On-line	09/01/1993
Carcinogenicity Assessment	No data	

Chronic Health Hazard Assessments for Noncarcinogenic Effects

Reference Dose for Chronic Oral Exposure (RfD)

Not Assessed under the IRIS Program.

Reference Concentration for Chronic Inhalation Exposure (RfC)

Critical Effect	Experimental Dose	UF	MF	RfC
Increased absolute and relative liver and kidney weights and increased severity of spontaneous renal lesions (females), increased prostration (females), and swollen periocular tissue (males and females)	NOAEL (HEC): 259 mg/m3	100	1	3 mg/m3

The Experimental Dose listed serves as a basis from which the Inhalation RfC was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Chronic rat 24-month inhalation study, Chun et al., 1992

Confidence in the Inhalation RfC
Study -- Medium

Database -- Medium
RfC -- Medium

Carcinogenicity Assessment for Lifetime Exposure

Weight of Evidence Characterization

Not Assessed under the IRIS Program.

Quantitative Estimate of Carcinogenic Risk from Oral Exposure

Not Assessed under the IRIS Program.

Quantitative Estimate of Carcinogenic Risk from Inhalation Exposure

Not Assessed under the IRIS Program.

Revision History

Review Full IRIS Summary for complete Revision History.

Synonyms

1634-04-4
Propane, 2-methoxy-2-methyl-
Methyl tert-butyl ether
t-Butyl methyl ether
Ether methyl tert-butylique [french]
Ether, tert-butyl methyl
HSDB 5847
Methyl 1,1-dimethylethyl ether
Methyl-tert-butyl ether
Methyl-tert-butylether
Metil-terc-butileter [spanish]
tert-Butyl methyl ether
2-Methoxy-2-methylpropane
2-Methyl-2-methoxypropane
Methyl tert-butyl ether (MTBE)

Naphthalene (CASRN 91-20-3)

Toxicological Review (PDF) Available

Health assessment information on a chemical substance is included in IRIS only after a comprehensive review of toxicity data by U.S. EPA health scientists from several Program Offices, Regional Offices, and the Office of Research and Development.

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For definitions of terms in the IRIS Web site, refer to the IRIS Glossary.

Status of Data for Naphthalene

File First On-Line: 12/01/1990
Last Significant Revision: 09/17/1998

Category	Status	Last Revised
Oral RfD Assessment	On-line	09/17/1998
Inhalation RfC Assessment	On-line	09/17/1998
Carcinogenicity Assessment	On-line	09/17/1998

Chronic Health Hazard Assessments for Noncarcinogenic Effects

Reference Dose for Chronic Oral Exposure (RfD)

Critical Effect	Experimental Dose	UF	MF	RfD
Decreased mean terminal body weight in males	NOAEL (ADJ): 71 mg/kg-day	3000	1	2×10^{-2} mg/kg-day

The Experimental Dose listed serves as a basis from which the Oral RfD was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Subchronic oral rat study, BCL, 1980a

Confidence in the Oral RfD
Study -- High
Database -- Low
RfD -- Low

Reference Concentration for Chronic Inhalation Exposure (RfC)

Critical Effect	Experimental Dose	UF	MF	RfC

Nasal effects: hyperplasia and metaplasia in respiratory and olfactory epithelium, respectively	LOAEL (HEC): 9.3 mg/m3	3000	1	$3x10^{-3}$ mg/m3

The Experimental Dose listed serves as a basis from which the Inhalation RfC was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Chronic mouse inhalation study, NTP, 1992a

Confidence in the Inhalation RfC
Study -- Medium
Database -- Low/Medium
RfC -- Medium

Carcinogenicity Assessment for Lifetime Exposure

Weight of Evidence Characterization

Weight of Evidence (1986 US EPA Guidelines):
C (Possible human carcinogen)

Weight of Evidence Narrative:
Using the 1996 Proposed Guidelines for Carcinogen Risk Assessment, the human carcinogenic potential of naphthalene via the oral or inhalation routes "cannot be determined" at this time based on human and animal data; however, there is suggestive evidence (observations of benign respiratory tumors and one carcinoma in female mice only exposed to naphthalene by inhalation [NTP, 1992a]). Additional support includes increase in respiratory tumors associated with exposure to 1-methylnaphthalene.

This may be a synopsis of the full weight-of-evidence narrative. See Full IRIS Summary.

Quantitative Estimate of Carcinogenic Risk from Oral Exposure

Information reviewed but value not estimated. Refer to Full IRIS Summary.

Quantitative Estimate of Carcinogenic Risk from Inhalation Exposure

Information reviewed but value not estimated. Refer to Full IRIS Summary.

Revision History

Review Full IRIS Summary for complete Revision History.

Synonyms

91-20-3
Naphthalene
Albocarbon
caswell No. 587
Dezodorator
EPA Pesticide Chemical Code 055801
HSDB 184
Moth Balls
Moth Flakes
Naftalen [Polish]

Naftaleno [Spanish]
Naphtalene [French]
Naphthalene
Naphthalin
Naphthaline
Naphthene
Napthalene, molten
NCI-C52904
NSC 37565
RCRA Waste Number U165
Tar Camphor
UN 1334
UN 2304
White Tar

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Integrated Risk Information System

Toluene (CASRN 108-88-3)

Toxicological Review (PDF) Available

Health assessment information on a chemical substance is included in IRIS only after a comprehensive review of toxicity data by U.S. EPA health scientists from several Program Offices, Regional Offices, and the Office of Research and Development.

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Status of Data for Toluene

File First On-Line: 01/31/1987
Last Significant Revision: 09/23/2005

Category	Status	Last Revised
Oral RfD Assessment	On-line	09/23/2005
Inhalation RfC Assessment	On-line	09/23/2005
Carcinogenicity Assessment	On-line	09/23/2005

Chronic Health Hazard Assessments for Noncarcinogenic Effects

Reference Dose for Chronic Oral Exposure (RfD)

Critical Effect	Experimental Dose	UF	MF	RfD
Increased kidney weight	BMDL : 238 mg/kg-day	3000	1	.08 mg/kg-day

The Experimental Dose listed serves as a basis from which the Oral RfD was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
13-week gavage study in rats, NTP, 1990

Confidence in the Oral RfD
Study -- Medium
Database -- Medium
RfD -- Medium

Reference Concentration for Chronic Inhalation Exposure (RfC)

Critical Effect	Experimental Dose	UF	MF	RfC

Neurological effects in occupationally-exposed workers	NOAEL (ADJ): 46 mg/m3	10	1	5 mg/m3

The Experimental Dose listed serves as a basis from which the Inhalation RfC was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Multiple human studies, Abbate et al., 1993, Boey et al., 1997, Cavalleri et al., 2000, Eller et al., 1999, Foo et al., 1990, Murata et al., 1993, Nakatsuka et al., 1992, Neubert et al., 2001, Vrca et al., 1995, Zavalic et al., 1998a

Confidence in the Inhalation RfC
Study -- High
Database -- High
RfC -- High

Carcinogenicity Assessment for Lifetime Exposure

Weight of Evidence Characterization

Weight of Evidence (1986 US EPA Guidelines):
Not applicable. This substance was not assessed using the 1986 cancer guidelines (U.S. EPA, 1986).

Weight of Evidence Narrative:
Under the Guidelines for Carcinogen Risk Assessment (U.S. EPA, 2005), there is inadequate information to assess the carcinogenic potential of toluene because studies of humans chronically exposed to toluene are inconclusive, toluene was not carcinogenic in adequate inhalation cancer bioassays of rats and mice exposed for life (CIIT, 1980 NTP, 1990 Huff, 2003), and increased incidences of mammary cancer and leukemia were reported in a lifetime rat oral bioassay at a dose level of 500 mg/kg-day but not at 800 mg/kg-day (Maltoni et al., 1997).

This may be a synopsis of the full weight-of-evidence narrative. See Full IRIS Summary.

Quantitative Estimate of Carcinogenic Risk from Oral Exposure

Not Assessed under the IRIS Program.

Quantitative Estimate of Carcinogenic Risk from Inhalation Exposure

Not Assessed under the IRIS Program.

Revision History

Review Full IRIS Summary for complete Revision History.

Synonyms

108-88-3
Antisal 1a
Benzene, methyl
Methacide
Methylbenzene
Methylbenzol
NCI-C07272
Phenylmethane
RCRA Waste Number U220
Toluene

Toluen
Toluene
Toluol
Toluolo
Tolu-sol
UN 1294
Monomethylbenzene

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Last Updated on Wednesday, November 3, 2004
URL: http://cfpub.epa.gov/iris/quickview.cfm?substance_nmbr=0118

Xylenes (CASRN 1330-20-7)

Toxicological Review (PDF) Available

Health assessment information on a chemical substance is included in IRIS only after a comprehensive review of toxicity data by U.S. EPA health scientists from several Program Offices, Regional Offices, and the Office of Research and Development.

Disclaimer: This QuickView represents a snapshot of key information. We suggest that you read the Full IRIS Summary to put this information into complete context.

For definitions of terms in the IRIS Web site, refer to the IRIS Glossary.

Status of Data for Xylenes

File First On-Line: 09/30/1987
Last Significant Revision: 02/21/2003

Category	Status	Last Revised
Oral RfD Assessment	On-line	02/21/2003
Inhalation RfC Assessment	On-line	02/21/2003
Carcinogenicity Assessment	On-line	02/21/2003

Chronic Health Hazard Assessments for Noncarcinogenic Effects

Reference Dose for Chronic Oral Exposure (RfD)

Critical Effect	Experimental Dose	UF	MF	RfD
Decreased body weight, increased mortality	NOAEL : 179 mg/kg-day	1000	1	0.2 mg/kg-day

The Experimental Dose listed serves as a basis from which the Oral RfD was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Chronic F344/N rat study, Oral gavage exposure, NTP, 1986

Confidence in the Oral RfD
Study -- Medium
Database -- Medium
RfD -- Medium

Reference Concentration for Chronic Inhalation Exposure (RfC)

Critical Effect	Experimental Dose	UF	MF	RfC

Impaired motor coordination (decreased rotarod performance)	NOAEL (HEC): 39 mg/m3	300	1	0.1 mg/m3

The Experimental Dose listed serves as a basis from which the Inhalation RfC was derived. See Discussion of Conversion Factors and Assumptions for more details.

Principal Study
Subchronic inhalation study in male rats, Korsak et. al., 1994

Confidence in the Inhalation RfC
Study -- Medium
Database -- Medium
RfC -- Medium

Carcinogenicity Assessment for Lifetime Exposure

Weight of Evidence Characterization

Weight of Evidence (1986 US EPA Guidelines):
Not applicable. This substance was not assessed using the 1986 cancer guidelines (U.S. EPA, 1986).

Weight of Evidence Narrative:
Under the Draft Revised Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1999), data are inadequate for an assessment of the carcinogenic potential of xylenes. Adequate human data on the carcinogenicity of xylenes are not available, and the available animal data are inconclusive as to the ability of xylenes to cause a carcinogenic response. Evaluations of the genotoxic effects of xylenes have consistently given negative results.

This may be a synopsis of the full weight-of-evidence narrative. See Full IRIS Summary.

Quantitative Estimate of Carcinogenic Risk from Oral Exposure

Not Assessed under the IRIS Program.

Quantitative Estimate of Carcinogenic Risk from Inhalation Exposure

Not Assessed under the IRIS Program.

Revision History

Review Full IRIS Summary for complete Revision History.

Synonyms

1330-20-7
106-42-3
Dimethylbenzene
1,3-Dimethylbenzene
1,4-Dimethylbenzene
Mixed xylenes
meta-Xylene
o-Xylene
p-Xylene
para-Xylene
108-38-3
95-47-6

1,2-Dimethylbenzene
m-Xylene
ortho-Xylene
Xylenes

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ACENAPHTHENE

GENERAL BACKGROUND INFORMATION

Acenaphthene is a member of the polycyclic aromatic hydrocarbons (PAH). PAHs are a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. The database for acenaphthene is very limited.

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of acenaphthene.

HUMAN TOXICOLOGICAL PROFILE

No data were found regarding the human toxicology of acenaphthene.

MAMMALIAN TOXICOLOGICAL PROFILE

Adverse effects on the lungs, glands, and blood were observed in rats following aerosol administration of 12 mg/m^3 acenaphthene for 5 months (U.S. EPA, 1981).

GENOTOXICITY

Mutagenicity tests for acenaphthene were negative (U.S. EPA, 1981). Carcinogenicity tests were negative (IARC, 1983).

REFERENCES

International Agency for Research on Cancer (IARC) (1983) *Monograph on the evaluation of carcinogenic risk of chemicals to man: polynuclear aromatic hydrocarbons.* 32:33-43.

U.S. Environmental Protection Agency (U.S. EPA) (1981) An exposure and risk assessment for acenaphthalene. U.S. EPA Contract No. 68-01-6017. Office of Water Regulations and Standards, Washington, D.C.

ORIGINAL

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BENZENE

GENERAL BACKGROUND INFORMATION.

Benzene is a clear, volatile, highly flammable, aromatic hydrocarbon which exists naturally and is produced by volcanoes and forest fires. Benzene is also a very common industrial solvent, produced from petroleum. It is used as a solvent for fats, inks, paints, plastics, rubber, in the extraction of oils from seeds and nuts, in photogravure printing, as a chemical intermediate and in the manufacture of detergents, explosives, pharmaceuticals and dyestuffs. It is also a component of gasoline and other petroleum-based fuels. Exposure to benzene can occur via inhalation, ingestion, especially of contaminated drinking water, and dermal contact (as in contact with liquid benzene found in gasoline.) (Sittig, 1981; ATSDR, 1989)

PHARMACOKINETICS

Benzene is readily absorbed through ingestion, moderately absorbed through inhalation and poorly absorbed through intact skin (see section on Relative Absorption Factors). Once in the bloodstream, benzene is distributed throughout the body, with the concentration in any one compartment dependent on the degree of perfusion of tissues by blood. Since benzene is lipid-soluble, it accumulates in fat, but the rate of accumulation is slow since fat is poorly perfused. The metabolites of benzene are responsible for its toxic effects. These include phenol (which is either formed via an unstable benzene oxide precursor or directly from benzene), catechol, hydroquinone and conjugated phenolic compounds. The primary site of benzene metabolism is the liver via the cytochrome P450 mixed function oxidase system. Some benzene metabolism may also occurs in the bone marrow via the same enzyme system. Benzene is excreted either unchanged from the lungs or as metabolites in the urine (ATSDR, 1989).

HUMAN TOXICOLOGICAL PROFILE

Benzene targets its effects on the hemopoietic, immune and nervous systems (ATSDR, 1989). Exposure to benzene has produced irritation of the skin, eyes and upper respiratory tract. Acute exposure has produced central nervous system depression, headache, dizziness, nausea, convulsions, coma and death at extremely high concentrations (Sittig, 1981). Health effects in humans have been reported starting as low as 50 ppm via inhalation. Twenty-five ppm for 6 hrs had no obvious effects though benzene was detected in blood (Sandmeyer, 1981). Early autopsy reports found benzene-induced hemorrhages of the brain, pericardium, urinary tract, mucous membranes and skin (Sittig, 1981). Chronic exposure to benzene produces blood changes involving an initial increase in levels of erythrocytes, leukocytes and

thrombocytes, followed by aplastic anemia indicated by anemia, leukopenia and thrombocytopenia (Sittig, 1981).

MAMMALIAN TOXICOLOGICAL PROFILE

The following effects have been produced experimentally in laboratory animals, following exposure to benzene: decreased leukocyte and/or erythrocyte counts, reduction in cellular immunity and bone marrow depression (reduced number of granulopoietic stem cells). Animal studies do not indicate that benzene is teratogenic, but the following fetotoxic effects have been found: reduced fetal weight, altered fetal hematopoiesis, fetal skeletal variations and increased resorptions in pregnant exposed animals. In addition, benzene has produced histopathological changes in ovaries and testes of test animals (ATSDR, 1989).

GENOTOXICITY

Benzene and its metabolites have been shown to be mutagenic in a number of in vitro and in vivo studies. Genotoxic effects produced experimentally include structural and numerical chromosome aberrations in humans, animals and cell cultures, and sister chromatid exchanges and micronuclei in in vivo animal studies. Benzene exposure has been found to produce an increase in the number of chromosome aberrations associated with myelotoxicity (Sittig, 1981). In addition, sperm head abnormalities, inhibition of DNA and RNA synthesis, DNA binding and interference with cell cycle progression have been shown in in vitro studies (ATSDR, 1989). The epidemiologic data indicate that benzene is leukemogenic. The evidence is most convincing for acute myelogenous and acute erythroleukemia, although a correlation has also been found with chronic leukemia. Benzene has been designated a group A human carcinogen (leukemogen) by inhalation. Although data are insufficient to validate the carcinogenicity of benzene via ingestion, it would not be unreasonable that benzene is carcinogenic via this route as well if present in sufficient quantities. The carcinogenicity of benzene via dermal exposure is considered to be lower since benzene is absorbed poorly through the skin (ATSDR, 1989).

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1989) Toxicological profile for benzene. U.S. Public Health Service.

Sandmeyer, E.E. (1981) *Aromatic hydrocarbons.* In: Patty's Industrial Hygiene and Toxicology, Vol. 2, 3rd ed., Clayton G.D., Clayton F.E., eds. New York: Interscience Publishers. pp. 3253-3283.

Sittig, M. (1981) Handbook of Toxic and Hazardous Chemicals. Noyes Publications.

ETHYLBENZENE

GENERAL BACKGROUND INFORMATION

Ethylbenzene is a colorless liquid that smells like gasoline. It is volatile and flammable. Ethylbenzene occurs naturally in coal tar and petroleum, and is also manufactured for commercial uses in paints, inks, and insecticides (ATSDR, 1990). The two major uses of ethylbenzene are in the plastic and rubber industry, where it is used in the synthesis of styrene (U.S. EPA, 1980). Gasoline contains about 2% (by weight) ethylbenzene (ATSDR, 1990). Ethylbenzene has a wide environmental distribution due to its widespread use.

PHARMACOKINETICS

Ethylbenzene has been shown to be readily absorbed via inhalation, ingestion, and dermal exposure in humans as well as in laboratory animals (see section on Relative Absorption Factors). Following exposure, ethylbenzene is distributed throughout the body, with the highest levels detected in the kidney, lung, adipose tissue, digestive tract, and liver (Chin et al., 1980). There appears to be quantitative differences in metabolism of the chemical in humans and laboratory animals. However, in all species, ethylbenzene undergoes a variety of microsomally-mediated side-chain hydroxylations to yield the major metabolites, mandelic acid and phenylglyoxylic acid (Engstrom et al., 1984). The oxidation products are conjugated followed by urinary excretion which appears to be complete within 2 days of exposure (ATSDR, 1990).

HUMAN TOXICOLOGICAL PROFILE

Humans exposed to low levels of ethylbenzene in air for short periods of time experience eye and throat irritation. Exposure to higher levels may cause more severe effects such as central nervous system depression, decreased movement and dizziness, and more severe mucous membrane irritation. No studies have reported death in humans following exposure to ethylbenzene. No information was located to indicate that ethylbenzene produces toxicity in other organ systems upon short-term or prolonged exposure (ATSDR, 1990).

MAMMALIAN TOXICOLOGICAL PROFILE

Animal studies indicate that the primary symptoms resulting from acute exposure to ethylbenzene are manifested as neurological and respiratory depression. Other studies suggest that the liver, kidney and hematopoietic system may also be targets of ethylbenzene toxicity (ATSDR, 1990). Studies indicate that ethylbenzene exposure of pregnant rats can produce fetotoxic effects at doses that also induce maternal toxicity (Andrew et al., 1981).

Additionally, oral administration resulted in blockage of the estrus cycle in female rats (Ungvary, 1986).

GENOTOXICITY

Results of in vitro genotoxicity test generally indicate that ethylbenzene is not mutagenic in the presence or absence of metabolic activation (ATSDR, 1990). In one in vivo study, there was no dose-dependent increase in the frequency of micronucleated polychromic erythrocytes (Mohtashamipur et al., 1985). Ethylbenzene did cause a mutagenic effect in mouse lymphoma cells and has been shown to induce a marginal yet significant increase in SCE in human lymphocytes. Therefore, ethylbenzene may cause an increased potential for genotoxicity in humans (ATSDR, 1990). No association between increased cancer incidence in humans and exposure to ethylbenzene has been reported. In animal studies, the only chronic bioassay produced inconclusive results of the tumorigenicity of oral ethylbenzene (Maltoni et al., 1985). Ethylbenzene is classified as a Group D agent (not classified as to carcinogenicity) by the EPA.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicological profile for ethylbenzene. U.S. Public Health Service.

Andrew, F.D., Buschbom, R.L. and Cannon, W.C. (1981) Teratologic assessment of ethylbenzene and 2-ethoxyethanol. Richland, WA: Battelle Pacific Northwest Laboratory. PB83-208074.

Chin, B.J., McKelvey, J.A. and Tyler, T.R. (1980) *Absorption, distribution and excretion of ethylbenzene, ethylcyclohexane and methylethylbenzene isomers in rats.* Bull. Env. Contam. Toxicol. 24:477-483.

Engstrom, K., Riihimaki, V. and Laine, A. (1984) *Urinary disposition of ethylbenzene and m-xylene in man following separate and combined exposure.* Xenobiotica 15:281-286.

Maltoni, C., Conti, B. and Cotti, G. (1985) *Experimental studies on benzene carcinogenicity at the Bologna Institute of Oncology: Current results and ongoing research.* Am. J. Ind. Med. 7:415-446.

Mohtashamipur, E., Norpoth, K. and Woelke, U. (1985) *Effects of ethylbenzene, toluene, and xylene on the induction of micronuclei in bone marrow polychromatic erythrocytes of mice.* Arch. Toxicol. 58:106-109.

Ungvary, G. (1986) *Solvent effects on reproduction.* Exp. Toxicol. 220:169-177.

U.S. Environmental Protection Agency (U.S. EPA) (1980) Ambient water quality criteria for ethylbenzene. Washington, D.C. EPA-440/5-80-048.

FLUORANTHENE

GENERAL BACKGROUND INFORMATION

Fluoranthene is a member of the polyaromatic hydrocarbons (PAH). PAHs constitute a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. Fluoranthene has been detected in food, cigarette smoke, and smoke from industrial and natural burning.

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of fluoranthene.

HUMAN TOXICOLOGICAL PROFILE

The database for the toxicological effects of fluoranthene on humans, separate from other PAHs, is limited. Toxic effects attributable to mixtures of PAHs include a variety of skin lesions and non-cancer lung diseases such as bronchitis (IARC, 1973).

MAMMALIAN TOXICOLOGICAL PROFILE

The database on the toxicity of fluoranthene is limited. A 13 week subchronic study where CD-1 mice were gavaged with up to 500 mg/kg-day of fluoranthene indicated nephropathy, increased liver weights, hematological alterations and clinical effects (EPA, 1988). A developmental study in which fluoranthene was administered once via intraperitoneal injection to pregnant mice reported only an increased rate of embryo resorption (Irvin and Martin, 1987).

Chronic dermal application of up to 1 percent fluoranthene to the backs of mice did not induce skin tumors following lifetime application (Hoffman et al, 1972; Horton and Christian, 1974; and Wydner and Hoffman, 1959a). Fluoranthene is not a complete carcinogen (ATSDR, 1990) and does not exhibit iniation activity (Hoffman et al, 1972).

GENOTOXICITY

There is some evidence that fluoranthene is genotoxic (ATSDR, 1990). Genotoxic effects have been reported in human cells with exogenous metabolic activation, but negative results were recorded without metabolic activation.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicological profile for polycyclic aromatic hydrocarbons. U. S. Public Health Service.

Hoffman, D. et al. (1972) *Fluoranthenes: Quantitative determination in cigarette smoke, formation by pyrolsis and tumor initiating activity.* JNCI 49:1165-1175.

Horton, A.W. and Christian, G.M. (1974) *Cocarcinogenic versus incomplete carcinogenic activity among aromatic hydrocarbons: contrast between chrysenes and benzo(b)triphenylene.* J Natl Cancer Inst 53:1017-1020.

International Agency for Research on Cancer (IARC) (1983) Monograph on the evaluation of chemicals in man, fluoranthene. 32:355-364.

Irvin, T.R. and martin, J.E. (1987) *In vitro and in vivo embryotoxicity of fluoranthene, a major prenatal toxic component of diesel soot.* Teratology 35:65A.

U.S. Environmental Protection Agency (EPA) (1988) 13-week mouse oral subchronic toxicity study. Prepared by Toxicity Research Laboratories, Ltd. Muskegon, MI for the Office of Solid Waste, Washington, D.C.

Wydner. E.L. and Hoffman, D. (1959) *A study of tobacco carcinogenesis. VII. The role of higher polycyclic hydrocarbons.* Cancer 12:1079-1086.

2-METHYLNAPHTHALENE

GENERAL BACKGROUND INFORMATION

2-Methylnaphthalene is a member of the polycyclic aromatic hydrocarbons (PAH). PAHs are a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. This compound is used in the synthesis of organic chemicals and pesticides. The database for toxicological information is very limited.

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of 2-methylnaphthalene.

HUMAN TOXICOLOGICAL PROFILE

No data were found regarding the human toxicity of 2-methylnaphthalene.

MAMMALIAN TOXICOLOGICAL PROFILE

No data were found regarding the mammalian toxicology of 2-methylnaphthalene.

GENOTOXICITY

No data were found regarding the genotoxicity of 2-methylnaphthalene.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicity profile for naphthalene and 2-methylnaphthalene. U.S. Public Health Service.

METHYL TERT BUTYL ETHER

GENERAL BACKGROUND INFORMATION

Methyl tert butyl ether (MTBE) is an volatile organic ether with extensive water solubility and lipophilicity. It is used clinically in the nonsurgical treatment of gallstones (Hofmann, 1990), as an industrial solvent and as a gasoline oxygenated octane enhancer. At normal temperature and pressure, it exists as a clear liquid with a disagreeable odor. MTBE is highly flammable and may pose a fire hazard if improperly handled (U.S. EPA, 1987).

PHARMACOKINETICS

Due to its lipophilicity, MTBE is well absorbed by all routes of exposure. It is readily soluble in blood and rapidly distributes to all organ systems, including fetal tissue, with highest concentrations occuring in organs with high lipid content such as adipose tissue and brain (U.S. EPA, 1987). Most of an administered dose is excreted unchanged in expired air (Biodynamics, 1984). The remainder undergoes oxidative metabolism mediated by the P-450 mixed function oxidase enzyme system to yield either tertiary butanol or formaldehyde which are ultimately eliminated from the body as either exhaled CO_2 or formic acid in urine and feces (Brady et al., 1990; Savolainen et al., 1985).

HUMAN TOXICOLOGICAL PROFILE

The only information concerning the human toxicity of MTBE involves its use as a therapeutic agent to dissolve gallstones. The procedure entails catheterization of the gallbladder through the abdominal cavity and subsequent perfusion with MTBE until the stones are dissolved. More than 400 patients have been treated worldwide with a high degree of success and few complications reported (Hofmann, 1990). Nausea, vomiting, sedation, local pain and mild hemolysis are possible side effects. The only major complication induced by MTBE has been a case of reversible renal failure in a patient during treatment (Ponchon, 1988).

MAMMALIAN TOXICOLOGICAL PROFILE

MTBE is considered to have a relatively low order of acute toxicity, evident from reported LD_{50} values of 2962-3866 mg/kg and LC_{50} values of 33,427-39,461 ppm (U.S. EPA, 1987). MTBE, in air, produces local irritation of the upper respiratory tract and mucous membranes. By all routes of exposure, it produces central nervous system depression evidenced as sedation, slowed reflexes, tremors, incoordination and altered behavior. Mild changes in

hematological parameters, neurobehavioral indices and organ weights were evident upon prolonged exposure (API, 1985).

Inhalation teratology and reproduction studies have failed to show any treatment related effects (Biodynamics, 1984).

GENOTOXICITY

Limited in vivo and in vitro cytogenetic results are available. In vivo, clastogenic effects were not observed in rats following subchronic exposure to MTBE (Bushy Run, 1989). In vitro tests similarly failed to show any correlation between MTBE exposure and cytogenetic abnormalities. MTBE did yield a dose-related positive response when tested in the mouse lymphoma forward mutation assay in the presence of metabolic activation. Negative results were obtained in the absence of metabolic activation (ARCO, 1987). No information on the carcinogenicity of MTBE was located. However, structure-activity analysis predicts MTBE to be neither a genotoxicant nor a carcinogen (Rosenkranz and Klopman, 1991).

REFERENCES

API (1985) Unpublished information on the production, use, occupational exposure, release and toxicity of MTBE. Submitted by W.F. O'Keefe, American Petroleum Institute.

ARCO (1987) Acute tox study on methyl t-butyl ether. NTIS/OTS0513481.

Biodynamics, Inc. (1984) Methyl t-butyl ether (MTBE) composite report. Final report Vols. I and II. 80-7452: A nine-day inhalation toxicity study of MTBE in the rat; 80-2515: An inhalation teratology study in rats with MTBE; 800-2516: An inhalation teratology study in mice with MTBE; 80-7453: A single generation inhalation reproduction/fertility study in rats with MTBE; 80-089: The metabolic fate of methyl-t-butyl ether (MTBE) following an acute intraperitoneal injection. March 30. Submitted to American Petroleum Institute.

Brady, J.F., Xiao, F., Ning, S.M. and Yang, C.S. (1990) *Metabolism of methyl tertiary-butyl ether by rat hepatic microsomes*. Arch. Toxicol. 64:157-160.

Bushy Run Research Center (1989) Methyl tertiary butyl ether repeated exposure vapor inhalation study in rats: In vivo cytogenetic evaluation. Report No. 51-635.

Hofmann, A.F. (1990) *Nonsurgical treatment of gallstone disease*. Ann. Rev. Med. 41:401-415.

Ponchon, T., Baroud, J., Pujol, B. Valette, P.J. and Perrot, D. (1988) *Renal failure during dissolution of gallstones by methyl-tert-butyl-ether*. Lancet 2:276-77.

Rosenkranz, H.S. and Klopman, G. (1991) *Predictions of the lack of genotoxicity and carcinogenicity in rodents of two gasoline additives: Methyl-tert-butyl and ethyl-tert-butyl ethers*. In Vitro Toxicol. 4:49-54.

Savolainen, H., Pfaffli, P. and Elovaara, E. (1985) *Biochemical effects of methyl tertiary-butyl ether in extended vapour exposure of rats*. Arch. Toxicol. 57:285-288.

U.S. Environmental Protection Agency (U.S. EPA) (1987) Technical support document - MTBE. Prepared for Test Rules Development Branch, Existing Chemicals Assessment Division, Office of Toxic Substances. Publication SRC TR-86-394.

NAPHTHALENE

GENERAL BACKGROUND INFORMATION

Naphthalene is a white solid substance at room temperature. It has a distinct odor of mothballs or tar. Humidity and sunshine cause evaporation into the air within a few hours. When placed in water or soil, bacteria will destroy naphthalene, or will render it airborne within a few hours (ATSDR, 1990). Tobacco smoke is known to release 3 ug of naphthalene per cigarette (U.S. EPA, 1982). The compound is used in the production of dyes, solvents, lubricants, motor fuels (U.S. EPA, 1980) and is a major component of many moth ball preparations.

PHARMACOKINETICS

Humans can absorb naphthalene by dermal, inhalation and oral routes (see section on Relative Absorption Factors). Metabolism occurs via the P450 mixed function oxidase enzyme system to yield multiple intermediates which are then conjugated. Key metabolites are responsible for each toxicity endpoint following intraperitoneal administration: 2-naphthoquinones --> hemolysis; 1,2-naphthoquinones --> cataracts; 3-GSH adducts --> pulmonary toxicity (Buckpitt et al., 1984). Excretion of metabolites occurs via urine and feces (ATSDR, 1990).

HUMAN TOXICOLOGICAL PROFILE

Adults and children exposed to airborne naphthalene experience vomiting, abdominal pain and anemia (ATSDR, 1990). Most of the data is for inhalation of naphthalene from mothballs. The primary site of toxicity is the erythrocyte resulting in hemolytic crisis (hemolytic anemia). Jaundice is seen upon dermal, inhalation, and oral exposures, as are kidney effects (ATSDR, 1990). Near-blindness resulted in male and female subjects with 5 gram ingestion (ATSDR, 1990).

MAMMALIAN TOXICOLOGY PROFILE

Oral doses in rats have hepatic effects. Dogs (1800 mg/kg) for 5 days of exposure showed signs of lethargy and ataxia, and decreased hemoglobin levels (ATSDR, 1990)

GENOTOXICITY

No studies of genotoxic effects in humans or laboratory animals were located. No human epidemiological evidence for cancer.

Inconclusive evidence for cancer in rats and mice were found (ATSDR, 1990).

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicological profile for naphthalene 2-methylnaphthalene. U.S. Public Health Service.

Buckpitt, A. and Richieri, P. (1984) Comparative biochemistry and metabolism: Part 2. Naphthalene lung toxicity. Wright-Patterson Air Force Base, OH: Air Force Systems Command, Aerospace Medical Division. Air Force Aerospace Medical Research Laboratory. AFAMRL-TR-84-058.

U.S. Environmental Protection Agency (U.S. EPA) (1980) Ambient water quality criteria for polycyclic aromatic hydrocarbons. Office of Emergency and Remedial Response. Washington, DC.

XYLENES

GENERAL BACKGROUND INFORMATION

Xylenes are colorless liquid organic molecules with a sweet odor and a high degree of lipid solubility. There are three isomers of xylene: meta- ortho- and para-xylene (m-, o- and p-xylene, respectively). The term "total xylenes" is used to designate a mixture of the three possible isomers, in any proportions. They are commonly used as industrial solvents, as components of paints, varnishes, cleaners, degreasers and gasoline and as chemical intermediates in the manufacture of other chemicals, plastics and synthetic fibers. Xylenes are volatile molecules and therefore, evaporate quickly. They are also flammable and may pose a fire hazard if handled improperly (ATSDR, 1990).

PHARMACOKINETICS

Xylenes are readily absorbed by all routes of exposure (see section on Relative Absorption Factors). Xylenes are very soluble in blood and therefore are absorbed easily into the systemic circulation during exposure (Astrand, 1982). Following absorption, distribution occurs rapidly to all organs, including fetal tissue, with greatest distribution occuring to organs having a high lipid content, such as adipose tissue, bone marrow and brain (Astrand, 1982; Engstron and Bjurstrom, 1978; Riihimaki et al., 1979). In humans, xylenes are primarily metabolized by the mixed function oxidase enzyme system to methylbenzyl alcohols which are further oxidized by alcohol and aldehyde dehydrogenase to yield methyl benzoic acids. The acids are readily conjugated and excreted in urine (Fishbein, 1985). In addition, a small percentage (3-6%) is exhaled unchanged due to the volatile nature of these compounds.

HUMAN TOXICOLOGICAL PROFILE

Human data suggests that the three xylene isomers all produce qualitatively similar effects, although the individual isomers are not necessarily equal in potency with regard to a given effect (ATSDR, 1990). Exposure, by any route, results in primarily central nervous system effects that may include headaches, nausea, mental confusion, narcosis, impaired learning and memory, dizziness, tremors, unconscienceness and coma, depending on dose and length of exposure. High doses may result in death. The respiratory system may also be a target of xylene toxicity in humans, producing respiratory tract irritation, pulmonary edema and inflammation after inhalation. Ocular irritation may result following exposure to xylene vapors. Skin irritation, dryness and scaling may result following dermal exposure. Limited data are available concerning effects of exposure on the hepatic, renal, cardiovascular,

musculoskeletal or hematological system. Insufficient information is available regarding the developmental and reproductive toxicity of xylenes in humans.

MAMMALIAN TOXICOLOGICAL PROFILE

Exposure to xylenes produces similar effects in humans and laboratory animals. The central nervous system is the primary target for both short-term and long-term exposures. Respiratory effects are observed following inhalation exposure. Data from animal studies provide limited evidence that xylene may produce cardiovascular effects (arrhythmias, atrial fibrillation and alterations in blood vessels and blood flow) (Morvai et al., 1976, 1987), hepatic effects (enzyme induction, increased liver weight, ultrastructural alterations) (Condie et al., 1988; Elovaara et al., 1980; Elovaara, 1982) and renal effects (enzyme induction, renal atrophy, tubular alterations) (Condie et al., 1988; Elovaara, 1982; Toftgard and Nilsen, 1982). These results suggest that humans might be at increased risk of developing such effects following exposure. Findings in animal studies suggest that xylenes may produce developmental defects including increased fetal death, decreased fetal weight, delayed skeletal development and gross anomalies (Marks et al., 1982; Ungvary et al., 1980). No animal data exists suggesting effects on reproductive organs, the musculoskeletal system or hematological system.

GENOTOXICITY

Xylenes have been tested for genotoxicity in a variety of in vitro and in vivo assays. Results of the various assays indicate that xylenes are nongenotoxic following in vitro and in vivo exposure (ATSDR, 1990). No evidence of carcinogenicity exists in humans or laboratory animals (ATSDR, 1990).

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicological profile for total xylenes. U.S. Public Health Service.

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ACENAPHTHYLENE

GENERAL BACKGROUND INFORMATION

Acenaphthylene is a member of the polycyclic aromatic hydrocarbons (PAH). PAHs are a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. The data on acenaphthylene are limited.

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of acenaphthylene.

HUMAN TOXICOLOGICAL PROFILE

No data were found regarding the human toxicity of acenaphthylene.

MAMMALIAN TOXICOLOGICAL PROFILE

No data were found regarding the mammalian toxicity of acenaphthylene.

GENOTOXICITY

Data from a single mutagenicity assay using acenaphthylene were positive (U.S. EPA, 1982).

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ANTHRACENE

GENERAL BACKGROUND INFORMATION

Anthracene is a polycyclic aromatic hydrocarbon (PAH). PAHs are a class of compounds which are non-polar and contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. As a PAH, anthracene is found in tobacco smoke, certain foods, and the emissions from industrial or natural burning.

PHARMACOKINETICS

Little data were found regarding the pharmacokinetics of anthracene. The intestinal absorption of anthracene is less dependent on the presence of bile in the stomach than is the absorption of larger PAHs such as benzo(a)pyrene (Rahman et al, 1986).

HUMAN TOXICOLOGICAL PROFILE

Anthracene is a skin irritant and allergen (Sax, 1984). Humans exposed to anthracene in an occupational setting may demonstrate skin disorders (Clement, 1985). Anthracene has been associated with gastrointestinal tract toxicity in humans (Badiali et al, 1985). However, the usefulness of this study is limited due to confounding factors. Hematopoietic toxicity has also been observed in cancer patients who have been treated with anthracene-containing chemotherapeutics (Falkson et al, 1985). No control groups and concomitant exposure to other ingredients in the therapeutic agents prevents any definitive conclusions.

MAMMALIAN TOXICOLOGICAL PROFILE

A subchronic study where anthracene was administered to mice by gavage for at least 90 days found no treatment-related effects at doses up to 1000 mg/kg-day (USEPA, 1989).

The data on the carcinogenicity of anthracene are considered inadequate by EPA (IRIS, 1991).

GENOTOXICITY

Tests for DNA damage, mutation, chromosome effects and cell transformation in a variety of eukaryotic cell preparations have shown negative results. The majority of tests using anthracene in prokaryotes are negative, but positive results are reported in one or two tests (ATSDR, 1990; IRIS, 1991).

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BENZO[a]ANTHRACENE

GENERAL BACKGROUND INFORMATION

Benzo[a]anthracene (BaA) is a member of the polycyclic aromatic hydrocarbons (PAH). PAHs are a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. The overall database for benzo[a]anthracene is limited. Human exposures to BaA can come from the oral, inhalation or dermal routes. BaA is produced when gasoline or other organic material is burned. It is also found in cigarette smoke and cooked food. People most at risk from exposure to BaA are those in the coal tar and asphalt production industries, cooking plants, coal gasification plants, smoke houses and industrial plants that burn wood, trash, coal or oil.

PHARMACOKINETICS

BaA is absorbed by the dermal and oral routes. There is no information on absorption by inhalation. Biotransformation to reactive intermediates is necessary for toxicity (ATSDR, 1990). BaA accumulates in adipose tissue. The metabolism of BaA is similar to the metabolism of benzo[a]pyrene (Cooper et al., 1983). In brief, the aromatic ring is oxidized by arene oxides to form reactive intermediates. The reactive intermediates are subsequently hydrolyzed to diols (Sims and Grover, 1974). The diols are conjugated with glutathione and excreted.

HUMAN TOXICOLOGICAL PROFILE

There are no reports directly correlating human exposure to BaA with the development of excess tumors.

MAMMALIAN TOXICOLOGICAL PROFILE

The only toxicity endpoint that has been adequately studied for BaA is dermal carcinogenicity. There is some evidence that benz[a]anthracene is carcinogenic in laboratory animals by the oral route (Klein, 1963; Bock and King, 1959) and also by subcutaneous injection (IARC, 1973). BaA has been shown to cause skin tumors after dermal application (Bingham and Falk, 1969). Tumorigenicity of the diol epoxide metabolite has been shown (Levin et al., 1978) as well as the mutagenicity of the diol epoxide (Wood et al., 1977).

GENOTOXICITY

The metabolism of BaA is an essential event in producing genotoxic effects in both *in vitro* and *in vivo* biological test systems (ATSDR, 1990). The intermediates formed by BaA metabolism are reactive electrophiles which are capable of interacting with DNA.

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BENZO[a]PYRENE

GENERAL BACKGROUND INFORMATION

Benzo[a]pyrene (BaP) is a member of the class of compounds generally referred to as polyaromatic hydrocarbons (PAH).
PAHs contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. BaP is a component of fossil fuels and is produced from the incomplete combustion of organic compounds. BaP and other PAHs are found in coal tar, creosote oils and pitches formed from the distillation of coal tars (ATSDR, 1990).

PHARMACOKINETICS

BaP is readily absorbed by dermal, inhalation and oral routes (see section on Relative Absorption Factors). Distribution of BaP is rapid among several tissues. Following inhalation exposure to ^{3}H labeled BaP, maximum levels of radioactivity were found in the liver, esophagus, small intestine and blood after 30 minutes. After 12 hours, maximum levels were found in the cecum, stomach and large intestine (Sun et al., 1982). This and other studies provide evidence for the enterohepatic circulation of BaP metabolites.

Mammalian metabolism of BaP follows the mechanism established for smaller aromatic compounds (Williams, 1959). There is an initial oxidation of a double bond on one of the rings to an arene oxide. The oxide is then hydrolyzed to the diol. Oxidations may occur at multiple sites on the BaP molecule. Phase II metabolism is considered the detoxication pathway and involves the conjugation of the activated Phase I metabolites with easily eliminated substrates such as glutathione, glucuronide or sulfate (Cooper et al., 1983). In addition to being conjugated, the diol intermediate can undergo (1) further oxidation to several uncharacterized metabolites via the P-450 monooxygenase system, (2) spontaneous rearrangement to the phenol or (3) hydration to the trans-diols through a reaction catalyzed by epoxide hydrolase (Cooper et al., 1983). BaP 7,8-diol-9,10-epoxide has been established as an ultimate carcinogen (ATSDR, 1990). The primary route of excretion of BaP is through the feces. BaP undergoes first-pass metabolism and is reabsorbed via enterohepatic circulation (Chipman et al., 1982). Rats exposed by gavage to ^{14}C labeled BaP in peanut oil excreted up to 85% in the feces. Excretion in the urine was 1 to 3% of the administered dose (Hecht et al., 1979).

HUMAN TOXICOLOGICAL PROFILE

The database for the toxicological effects of BaP on humans, separate from PAHs, is limited. Toxic effects attributable to mixtures of PAHs include a variety of skin lesions and non-cancer lung diseases such as bronchitis (IARC, 1973).

MAMMALIAN TOXICOLOGICAL PROFILE

BaP is a moderately potent experimental carcinogen in numerous species by many routes of exposure (IARC, 1983). Mice exposed to doses of BaP ranging from 1.5 to 400 mg/kg/d developed benign and malignant tumors of the forestomach (Hartwell, 1951; Thompson, 1971). Acute intragastric doses of 50 to 67 mg/kg of BaP have been shown to elicit pulmonary adenomas and forestomach papillomas in mice (Sparnins et al., 1986; Wattenberg and Beuding, 1986). Intermittent gavage exposure of mice to 50 to 67 mg/kg BaP resulted in 100% forestomach and pulmonary tumor incidences at 30 weeks of age (Sparnins et al., 1986; Wattenberg and Leong, 1970). Mice fed BaP at concentrations equivalent to 33.3 mg/kg/d exhibited gastric neoplasms following two or more days of consumption. However, lower concentrations of BaP (equivalent to 13.3 mg/kg/d) administered for up to 7 days did not produce any forestomach tumors (Neal and Rigdon, 1967). Hamsters have developed papillomas and carcinomas of the alimentary tract following gavage or dietary exposure to BaP (Chu and Malmgrem, 1965). A single oral dose of 100 mg BaP (200mg/kg) produced mammary tumors in 88% of female Sprague-Dawley rats (Huggins and Yang, 1962). A 77% mammary tumor incidence was observed 90 weeks after a single oral dose of BaP of 50 mg (100mg/kg) was administered to rats (McCormick, 1981).

GENOTOXICITY

There are no studies relating exposure to BaP in humans to genotoxicity. In short-term *in vitro* and *in vivo* genetic toxicology tests, BaP has been shown to be a potent genotoxic agent when metabolically activated. In mice, oral exposure to 10 mg/kg BaP produced gene mutations in the mouse coat color spot test (Davidson and Dawson, 1976,1977). BaP shows positive mutagenic activity, in vitro, in several strains of *Salmonella typhimurium* in the presence of either rodent microsomes or hepatocytes for exogenous metabolic activation (ATSDR, 1990). Epidemiological studies have shown increased incidences of lung cancer in humans exposed via inhalation to mixtures of PAHs which include BaP (ATSDR, 1990).

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BENZO[b]FLUORANTHENE

GENERAL BACKGROUND INFORMATION

Benzo[b]fluoranthene (BbF) is a member of the class of compounds referred to as polycyclic aromatic hydrocarbons (PAHs). PAHs contain two or more aromatic rings. PAHs are ubiquitous in nature and are both naturally occurring and man-made. Exposure to BbF can come from air, water, or soil. As a PAH, BbF is present in the emissions from industrial plants that produce coal tar, cooking plants, asphalt production plants, and home heating with wood and coal. BbF is also present in charcoal-broiled foods and cigarette smoke (ATSDR, 1990).

PHARMACOKINETICS

No data on the absorption, distribution or excretion of BbF were identified. BbF is metabolized under *in vitro* incubation conditions to phenol and dihydrodiol metabolites (Amin et al., 1982). The general metabolic pathways elucidated for benzo(a)pyrene are also active on BbF (Cooper et al., 1983; Levin et al., 1982; Grover et al., 1986). The reactive metabolites associated with the tumorigenic effects of BbF may not be the diol epoxides (Amin et al., 1982; Amin et al., 1985). As for the other PAHs, the material excreted is expected to consist primarily of dihydrodiol and phenol conjugates (Grover et al., 1986).

HUMAN TOXICOLOGICAL PROFILE

The database for human toxicity is very limited. There are no studies correlating exposure to BbF and cancer or systemic toxicity. The only data implicating BbF as a carcinogen come from carcinogenicity studies using a mixture of PAHs.

MAMMALIAN TOXICOLOGICAL PROFILE

The database on the toxicity of BbF is limited. Intratracheal administration of BbF to rats resulted in an increase in respiratory tract tumors (Deutsch-Wenzel et al., 1983). BbF has caused skin tumors in mice following dermal application (Wynder and Hoffman, 1959). The skin tumor initiating ability of BbF has been demonstrated in mice using a standard initiation/promotion protocol with either croton oil or phorbol myristate acetate as a tumor promotor (Amin et al., 1985; LaVoie et al., 1979, 1982).

GENOTOXICITY

The genotoxicity of BbF has been shown equivocally in three *in vitro* studies. BbF has been shown to be mutagenic in *Salmonella typhimurium* in the presence of an exogenous rat-liver preparation (LaVoie et al., 1979). Mutagenic activity has been reported in another similar study (Hermann, 1981). Negative results were reported by Mossanda (1979). The results cannot support an unequivocal determination regarding the genotoxicity of BbF at this time.

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BENZO[g,h,i]PERYLENE

GENERAL BACKGROUND INFORMATION

Benzo[g,h,i]perylene is a member of the polyaromatic hydrocarbons (PAH). PAHs constitute a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. The data regarding benzo[g,h,i]perylene are limited. As a PAH, it is found in food (charcoal broiled meats), vegetables, tobacco smoke and soot (U.S. EPA, 1980). Exposure occurs by inhalation, ingestion and by dermal contact.

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of benzo[g,h,i]perylene.

HUMAN TOXICOLOGICAL PROFILE

No data were found regarding the human toxicology of benzo[g,h,i]perylene.

MAMMALIAN TOXICOLOGICAL PROFILE

No data were found regarding the mammalian toxicity of benzo[g,h,i]perylene.

GENOTOXICITY

No data were found regarding the genotoxicity of benzo[g,h,i]perylene.

REFERENCES

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BENZO[k]FLUORANTHENE

GENERAL BACKGROUND INFORMATION

Benzo[k]fluoranthene (BkF) is a member of the class of compounds referred to as polycyclic aromatic hydrocarbons (PAHs). PAHs contain two or more aromatic rings. PAHs are ubiquitous in nature and are both naturally occurring and man-made. Exposure to BkF can come from air, water, or soil. As a PAH, BkF is present in the emissions from industrial plants that produce coal tar, cooking plants, asphalt production plants, and home heating with wood and coal. BkF is also present in charcoal-broiled foods and cigarette smoke (ATSDR, 1990).

PHARMACOKINETICS

No data on the absorption, distribution or excretion of BkF were identified. BkF is believed to be metabolized to phenol and dihydrodiol metabolites (ATSDR, 1990). The general metabolic pathways elucidated for benzo[a]pyrene are believed to be active on BkF. As for the other PAHs, the material excreted is expected to consist primarily of dihydrodiol and phenol conjugates (Levin et al., 1982; Cooper et al., 1983; Grover et al., 1986).

HUMAN TOXICOLOGICAL PROFILE

The database for human toxicity is very limited. There are no studies correlating exposure to BkF and cancer or systemic toxicity. The only data implicating BkF as a carcinogen come from carcinogenicity studies using a mixture of PAHs.

MAMMALIAN TOXICOLOGICAL PROFILE

The database on the toxicity of BkF is limited. The skin tumor initiating ability of BkF has been demonstrated in mice using a standard initiation/promotion protocol with either croton resin or phorbol myristate acetate as tumor promotors (Van Duuren et al., 1966; LaVoie et al., 1982). Chronic dermal application of benzo[k]fluoranthene to mice resulted in no skin tumors, suggesting that BkF alone is not a complete carcinogen (Wynder and Hoffman, 1959).

GENOTOXICITY

The genotoxicity of BkF has not been documented in *in vitro* studies. In vivo, a single topical application of BkF was reported to bind to DNA in CD-1 mouse skin (Weyland et al., 1987). Covalent binding of chemicals to DNA can result in strand breaks and DNA damage, ultimately leading to mutations (ATSDR, 1990).

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CHRYSENE

GENERAL BACKGROUND INFORMATION

Chrysene is one of the polycyclic aromatic hydrocarbon (PAH) compounds which are formed during the combustion of organic material. Chrysene often exists in particulate form, adsorbing to existing particulate material in air. Human exposure can occur in the workplace (coal and asphalt production plants, cooking plants, smoke houses) or in the environment due to chrysene contamination of air, food, soil and water (ATSDR, 1990).

PHARMACOKINETICS

Chrysene can be absorbed by all routes of exposure (see section on Relative Absorption Factors). Its absorption is believed to be qualitatively similar to benzo[a]pyrene (ATSDR, 1990). Following absorption, chrysene distributes to all organs, reaching the highest concentration in tissues with large fat content (adipose tissue, mammary tissue, brain) (Modica et al., 1983). Chrysene undergoes metabolic biotransformation mediated by the mixed function oxidase enzyme system to form reactive intermediates hypothesized to be responsible for its toxicity. The major metabolites include trans-dihydrodiols, phenols, diol epoxides and triol epoxides (Thakker et al., 1985). The reactive metabolites are conjugated and excreted primarily in feces (Schlede et al., 1970).

HUMAN TOXICOLOGICAL PROFILE

There is no information available on threshold toxic effects of chrysene in humans. Since it is structurally similar to benzo[a]pyrene, it would be expected to produce effects similar to B[a]P following acute or chronic exposure (see Toxicity Profile on Benzo[a]pyrene).

MAMMALIAN TOXICOLOGICAL PROFILE

There is no information available on threshold toxic effects of chrysene in animals. Since it is structurally similar to benzo[a]pyrene, it would be expected to produce effects similar to B[a]P following acute or chronic exposure (see Toxicity Profile for Benzo[a]pyrene).

GENOTOXICITY

The genotoxicity of chrysene has been evaluated in in vivo and in vitro cytogenetic tests. Chrysene produced weak positive results in bacterial mutation assays, human epithelial mutation studies, cell transformation assays and in vivo cytogenetic studies (Waters et al., 1987). Metabolism of chrysene is essential to produce the observed positive responses. Chrysene is not genotoxic in all test systems, however, it is believed to be a weak mutagen (ATSDR, 1990). The carcinogenicity of chrysene has not been adequately studied. There are no reports directly correlating human chrysene exposure and tumor development. There is limited evidence that chryesene is a skin carcinogen in animals following long-term dermal application (Wynder and Hoffmann, 1959; Hecht et al., 1974).

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FLUORENE

GENERAL BACKGROUND INFORMATION

Fluorene is a member of the polyaromatic hydrocarbons (PAH). PAHs constitute a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. The data on fluorene are very limited. Low levels of (5 to 67 ug/kg) have been detected in smoked meats (U.S. EPA, 1982).

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of fluorene.

HUMAN TOXICOLOGICAL PROFILE

The database for the toxicological effects of fluoranthene on humans, separate from other PAHs, is limited. Toxic effects attributable to mixtures of PAHs include a variety of skin lesions and non-cancer lung diseases such as bronchitis (IARC, 1973).

MAMMALIAN TOXICOLOGICAL PROFILE

Limited information is available on the threshold effects of fluorene. An EPA study (EPA,1989) indicated that CD-1 mice exposed by gavage to up to 500 mg/kg-day of fluorene showed hypoactivity as well as a decrease in red blood cell count and packed cell volume and hemoglobin. Increases in absolute and relative liver, spleen and kidney weights was also observed. Gershbein (1975) reported that partially hepatectomized rats fed a diet of 180 mg/kg-day of fluorene for 10 days showed a statistically significant increase in liver regeneration, which is indicative of the ability to induce a proliferative response.

Fluorene is not reported to be a complete skin carcinogen (ATSDR, 1990). It was inactive as a tumor initiator when an estimated total dose of 1.0 mg was applied prior to the application of tetradecanoyl phorbol acetate (LaVoie et al, 1980).

GENOTOXICITY

There is no evidence that fluorene is genotoxic, but genotoxiciity has been studied only in a few in vitro assays (ATSDR, 1990).

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicological profile for polycyclic aromatic hydrocarbons. U. S. Public Health Service.

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INDENO[1,2,3-cd]PYRENE

GENERAL BACKGROUND INFORMATION

Indeno[1,2,3,-cd]pyrene is a member of the polyaromatic hydrocarbons (PAH). PAHs constitute a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. Indeno[1,2,3-cd]pyrene is present in cigarette smoke (IARC, 1983) as well as emissions from industrial stacks.

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of indeno[1,2,3-cd]pyrene. However, its metabolism should be similar to another non-alternant PAH, benzo(b)fluoranthene (ATSDR, 1990).

HUMAN TOXICOLOGICAL PROFILE

The database for the toxicological effects of indeno[1,2,3-cd]pyrene on humans, separate from other PAHs, is limited. Toxic effects attributable to mixtures of PAHs include a variety of skin lesions and non-cancer lung diseases such as bronchitis (IARC, 1973).

MAMMALIAN TOXICOLOGICAL PROFILE

Studies on laboratoyr animals have demonstrated that indeno[1,2,3-cd]pyrene can induce skin tumors (i.e. it is a complete carcinogen) following dermal exposure (ATSDR, 1990).
It has tumor initiating activity, but is not as potent as benzo(b)fluoranthene (Rice et al, 1985).

Carcinogenic PAHs as a group are immunosuppressant, with the degree of suppression correlated with the degree of potency (ATSDR, 1990)

GENOTOXICITY

In test systems using non-human cells, indeno[1,2,3-cd]pyrene was found to be genotoxic (ATSDR, 1990).

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicological profile for polycyclic aromatic hydrocarbons. U. S. Public Health Service.

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PHENANTHRENE

GENERAL BACKGROUND INFORMATION

Phenanthrene is a member of the polyaromatic hydrocarbons (PAH). PAHs constitute a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. The database on the potential health effects of phenanthrene is limited.

PHARMACOKINETICS

Little data are available regarding the pharmacokinetics of phenanthrene. The intestinal absorption of phenanthrene is less dependent on the presence of bile in the stomach than is the absorption of the larger PAHs (such as benzo(a)pyrene) (Rahman et al, 1986).

HUMAN TOXICOLOGICAL PROFILE

Phenanthrene has been shown to be a skin photosensitizer in humans (Sax, 1984).

MAMMALIAN TOXICOLOGICAL PROFILE

Phenanthrene has a reported LD 50 of 700 mg/kg in mice (Simmon et al., 1979). Rats injected intraperitoneally evidenced liver effects (Yoshikawa et al, 1987).

There is equivocal evidence for cancer from dermal application of phenanthrene in rats (IARC, 1983). Phenanthrene is not a complete skin carcinogen (ATSDR, 1990). It is neither an initiator (LaVoie et al, 1981; Roe, 1962) nor a promoter (Roe and Grant, 1964). Higgins and Yang (1962) reported no tumor production within two months after the ingestion of 200 mg of phenanthrene by rats.

GENOTOXICITY

There are limited data that suggest that phenanthrene is mutagenic (Wood et al., 1979). However, the majority of tests are negative (ATSDR, 1990).

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PYRENE

GENERAL BACKGROUND INFORMATION

Pyrene is a member of the polyaromatic hydrocarbons (PAH). PAHs constitute a class of non-polar compounds that contain two or more aromatic rings. They are ubiquitous in nature and are both naturally occurring and man-made. As with many of the other PAHs, pyrene has been detected in charbroiled meats and shellfish (U.S. EPA, 1982). It is found in tobacco smoke, industrial stack smoke, and smoke from forest fires.

PHARMACOKINETICS

No data were found regarding the pharmacokinetics of pyrene.

HUMAN TOXICOLOGICAL PROFILE

Pyrene is reported to be a skin irritant (Sax, 1984).

MAMMALIAN TOXICOLOGICAL PROFILE

Rats given 150 mg/kg of pyrene had changes in blood chemistry, liver and kidney damage (USEPA, 1982). A 1989 EPA study (EPA, 1989) reported nephropathy and decreased kidney weights in mice exposed to 125 mg/kg-day of pyrene by gavage for 13 weeks.

Mouse skin painting assays indicate that pyrene is neither a complete skin carcinogen, nor an initiating agent (ATSDR, 1990, IRIS, 1991).

GENOTOXICITY

The majority of genotoxic tests of pyrene are negative.
Positive results have been recorded in Salmonella typhimurium mutagenicity tests and in in vitro mammalian cell systems (ATSDR, 1990).

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) (1990) Toxicological profile for polycyclic aromatic hydrocarbons. U. S. Public Health Service.

Sax, N.I. (1984) Dangerous Properties of Industrial Materials. 6th Edition. Van Nostrand Reinhold Company. N.Y.

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TOLUENE

GENERAL BACKGROUND INFORMATION

Toluene is a clear, colorless organic liquid with a sweet smell and a high degree of lipid solubility. It is used as an industrial solvent/degreaser, as an intermediate in the manufacture of chemicals and pharmaceuticals, and is present as a component of gasoline and other fuels, paints, lacquers, adhesives, rubber and printing ink. Toluene is a volatile molecule with relatively low water solubility. It is flammable and may pose a fire hazard if handled improperly (ATSDR, 1989).

PHARMACOKINETICS

Toluene is readily absorbed by all routes of exposure (see section on Relative Absorption Factors). Once absorbed, it is rapidly distributed to all organ systems, including fetal tissue, with highest concentrations occuring in organs with high lipid content such as adipose tissue, brain and bone marrow. Toluene undergoes primarily oxidative metabolism to benzyl alcohol mediated by the mixed function oxidase enzyme system. Benzyl alcohol is further oxidized by alcohol and aldehyde dehydrogenase to produce benzoic acid which is primarily conjugated with glycine or glucuronic acid and excreted in urine as hippuric acids or benzoyl glucuronide. Toluene may also be excreted unchanged in exhaled air. Metabolism and excretion occurs rapidly, with the major portion occurring within 12 hours of exposure (Fishbein, 1985).

HUMAN TOXICOLOGICAL PROFILE

In humans, the most profound effects of toluene are on the central nervous system. Acute exposure results in reversible depression of the central nervous system, neurological dysfunction, impaired performance and narcosis. Chronic exposure has been reported to result in permanent central nervous system effects such as ataxia, tremors and impaired speech, hearing and vision (ATSDR, 1989). Toluene vapors cause irritation of the upper respiratory tract, mucous membranes and eyes, and may produce cardiac arrhythmias upon chronic exposure (Anderson et al., 1982). Reports of effects on the hematological system, liver, kidney, immune system, reproductive organs and the developing fetus are confounded by exposure to multiple solvents (ATSDR, 1989).

MAMMALIAN TOXICOLOGICAL PROFILE

Toluene has been demonstrated to produce similar effects in humans and animals. The major target organ following acute or chronic exposure is the central nervous system. Signs

of central nervous system damage include impaired motor abilities, narcosis, tremors, alterations in EEG activity, changes in the levels of brain neurotransmitters and morphological effects (ATSDR, 1989). High level inhalation exposure resulted in respiratory irritation and inflammation and pulmonary lesions (NTP, 1989). Toluene does not appear to be directly toxic to the cardiovascular system (Bruckner and Peterson, 1981). Decreased leukocyte counts were observed in dogs following exposure to toluene (Hobara et al., 1984). In addition, exposed mice exhibited increased susceptibility to respiratory infection (Aranyi et al., 1985). Hepatic effects appear to be relatively mild with reported increases in liver weight and minor ultrastructural changes (Ungvary et al., 1982). Renal toxicity has not been observed (NTP, 1989; Bruckner and Peterson, 1981). Studies with animals provide evidence that toluene may be a developmental toxicant. Exposure in utero resulted in skeletal anomalies, retarded skeletal growth and low fetal weights (Ungvary, 1985). No reproductive effects have been reported (API, 1985; NTP, 1989).

GENOTOXICITY

Available in vitro studies suggest that toluene is nongenotoxic (ATSDR, 1989). In vivo studies in animals provide additional supportive evidence (API, 1981). A small number of human studies have reported an increased incidence in chromosomal abnormalities, however, these studies are confounded by possible co-exposure to other chemicals (Schmid et al., 1985; Bauchinger et al., 1982). Other human studies have found no correlation between exposure to toluene and increased frequencies of chromosomal abnormalities (Haglund et al., 1980; Maki-Paakkanen et al., 1980).

REFERENCES

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APPENDIX C

Table 1
Method 2 Hydrodynamic Dispersion Model
88 South Maple Street
Westfield, MA

This modeling report has been prepared to evaluate potential future surface water impacts attributable to releases of OHM from the Site via groundwater transport.

Using a Method 2 approach, site-specific data, fate and transport factors, and/or predictive models may be used to modify GW-3 Method 1 standards using fractional fate and transport parameters provided in Section 4.6 (Table 4-14). of the document titled *Characterizing Risks posed by Petroleum Contaminated Sites: Implementation of the MADEP VPH/EPH Appproach* - Final Policy, October 21, 2002.

In lieu of site-specific modeling, the conservative dilution factors graphically illustrated in Figure 4-4 of the Final Policy document are used. Conservative dilution factors are used as part of this evaluation of groundwater to surface water impacts. The only attenuation mechanism considered is hydrodynamic dispersion.

The equations used to calculate dilution factors are based on the source area dimensions & following conditions:
1. Groundwater/contaminant flow is occurring only in an overburden aquifer;
2. The thickness of the impacted soil (source area) layer is equal to or less than 6 feet;
3. No "short circuiting" of groundwater/contaminants is occuring along preferred flow paths;
4. No fractional range is present at a concentration greater than 100,000 ug/L; and
5. The nearest downgradient surface water body is >100 feet from the impacted well/groundwater.

Using the formulas presented in the VPH/EPH Guidance document the following calculations are presented:

30'x30' source area
Dilution Factor DF=303*(distance in feet)$^{-1.365}$, r^2=0.99
distance 100 feet to Little River
DF= 0.564

An additional dilution factor of 10 is applied to account for the mixing of groundwater with surface water. Therefore, the adjusted dilution factor (DFa) is:
DFa= 0.0564

The Discharge Concentration at the unnamed river is calculated by multiplying the DFa times the maximum concentration detected in groundwater at the disposal site wi thin the past year (since Jan 2005).

The Method 2 GW-3 Standard was calculated by dividing the Surface Water Guideline by the DFa.

Analyte/COC	Max EPC (ug/L)	Discharge Conc @ Little River (ug/L)	DEP Surface Water Guideline/Ref. (ug/L)		Method 2 GW-3 Standard (ug/L)	Method 2 Standard or UCL (ug/L)
VPH						
C5-C8 Aliphatics	1,107	62	250	1	4,431	4,431
C9-C12 Aliphatics	2,012	114	1,800	1	31,903	31,903
C9-C10 Aromatics	2,000	113	430	1	7,621	7,621
VPH Target Analytes						
Benzene	14.9	0.8	460	1	8,153	8,153
Toluene	6.5	0.4	1,400	1	24,813	24,813
Ethylbenzene	32.0	1.8	181	1	3,208	3,208
Xylenes	256.0	14.4	200	1	3,545	3,545
MTBE	4130.0	233.0	7,000	1	124,067	100,000
Naphthalene	68.0	3.8	72	1	1,276	1,276

References:
1. Selected Ecological Benchmark from DEP's Development of Risk-Based Levels for Soil and Groundwater (1/2007)
2. Input concentration is the maximum site-wide EPC using data from August 2006 through June 2007

ATTACHMENT A

Table Aa
Subchronic Dose and Hazard Estimates - Soil Ingestion and Dermal Contact
Commercial Worker - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		RAF [a.]	ADD chronic [b.] (mg/kg/day)	RAF [a.]	ADD chronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	1.00	1.2E-03	1.00	2.4E-03	3.6E-03	4.0E-01	0.00888
C9-C12 Aliphatic	935	1.00	5.8E-04	0.50	6.0E-04	1.2E-03	1.0E+00	0.00118
C9-C10 Aromatic	1650	1.00	1.0E-03	0.50	1.1E-03	2.1E-03	3.0E-01	0.00692
VPH Target Analytes								
Benzene	5.76	1.00	3.5E-06	0.08	5.9E-07	4.1E-06	1.0E-02	0.00041
Toluene	291	1.00	1.8E-04	0.12	4.5E-05	2.2E-04	8.0E-01	0.00028
Ethylbenzene	132	1.00	8.1E-05	0.20	3.4E-05	1.2E-04	1.0E+00	0.00012
Xylenes	539	1.00	3.3E-04	0.12	8.3E-05	4.1E-04	2.0E-01	0.00207
MTBE	23.8	1.00	1.5E-05	0.10	3.1E-06	1.8E-05	1.0E+00	0.00002
Naphthalene	32.9	0.36	7.3E-06	0.10	4.2E-06	1.2E-05	2.0E-01	0.00006
PCBs								
PCBs	32.05	0.85	1.7E-05	0.16	6.6E-06	2.3E-05	5.0E-05	0.46725
					TOTAL CHRONIC INGESTION & ABSORPTION HI [g.] =			**0.49**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Subchronic } ADD_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Subchronic } ADD_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Subchronic } ADD_{Total} = ADD_{ingestion} + ADD_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD_{Total}/chronic RfD

g. Total Hazard Index = Sum of Hazard Indices

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	50	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(event/day)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	1	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	1	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	0.03	(mg/cm^2)

Table Ab
Chronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Commercial Worker - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total ADD [d.] (mg/kg/day)	Chronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		RAF [a.]	ADD $_{chronic}$ [b.] (mg/kg/day)	RAF [a.]	ADD $_{chronic}$ [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	1.00	1.2E-03	1.00	2.4E-03	3.6E-03	4.0E-02	0.08884
C9-C12 Aliphatic	935	1.00	5.8E-04	0.50	6.0E-04	1.2E-03	1.0E-01	0.01176
C9-C10 Aromatic	1650	1.00	1.0E-03	0.50	1.1E-03	2.1E-03	3.0E-02	0.06919
VPH Target Analytes								
Benzene	5.76	1.00	3.5E-06	0.08	5.9E-07	4.1E-06	4.0E-03	0.00103
Toluene	291	1.00	1.8E-04	0.12	4.5E-05	2.2E-04	8.0E-02	0.00280
Ethylbenzene	132	1.00	8.1E-05	0.20	3.4E-05	1.2E-04	1.0E-01	0.00115
Xylenes	539	1.00	3.3E-04	0.12	8.3E-05	4.1E-04	2.0E-01	0.00207
MTBE	23.8	1.00	1.5E-05	0.10	3.1E-06	1.8E-05	1.0E-01	0.00018
Naphthalene	32.9	0.36	7.3E-06	0.10	4.2E-06	1.2E-05	2.0E-02	0.00058
PCBs								
PCBs	32.05	0.85	1.7E-05	0.16	6.6E-06	2.3E-05	2.0E-05	1.16812
						TOTAL CHRONIC INGESTION & ABSORPTION HI [g.] =		**1.35**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

Chronic $ADD_{ingestion}$= {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

Chronic ADD_{dermal}= {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose

Chronic $ADD_{Total} = ADD_{ingestion} + ADD_{dermal\ absorption}$

e. Toxicity values

f. Hazard index = ADD $_{Total}$/chronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	50	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(event/day)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	30	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	30	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	0.03	(mg/cm^2)

Table Ac
Lifetime Daily Dose and Increased Cancer Risk Estimates
Soil Ingestion and Dermal Contact - Commercial Worker
Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total LADD [d.] (mg/kg/day)	Cancer Slope Factor [e.] 1/(mg/kg/d)	ELCR [f.]
		RAF [a.]	LADD [b.] (mg/kg/day)	RAF [a.]	LADD [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	935	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	1650	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes								
Benzene	5.76	1	1.52E-06	0.08	2.54E-07	1.77E-06	5.50E-02	9.8E-08
Toluene	291	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	132	NA	NA	NA	NA	NA	NA	NA
Xylenes	539	NA	NA	NA	NA	NA	NA	NA
MTBE	23.8	NA	NA	NA	NA	NA	NA	NA
Naphthalene	32.9	NA	NA	NA	NA	NA	NA	NA
PCBs								
PCBs	32.05	0.85	7.19E-06	0.16	2.82E-06	1.00E-05	2.00E+00	2.0E-05
						TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g.] =		**2.0E-05**

NOTES:

NC = Not a Class A or B Carcinogen

a. RAF = Relative Absorption Factor

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation:

LADD = {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation:

LADD = {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose

$LADD_{Total} = LADD_{dermal\ absorption} + LADD_{ingestion}$

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil}$ * SF

g. Total ELCR = Sum of OHM-Specific ELCR

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	50	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure	1	(day/event)
EP = Duration of Exposure Period	30	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	70	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed.	0.03	(mg/cm^2)

Table Aa1
Subchronic Dose and Hazard Estimates - Soil Ingestion and Dermal Contact
Commercial Worker - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		RAF [a.]	ADD chronic [b.] (mg/kg/day)	RAF [a.]	ADD chronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	1.00	9.2E-05	1.00	1.9E-04	2.8E-04	4.0E-01	0.00071
C9-C12 Aliphatic	96.83	1.00	6.0E-05	0.50	6.2E-05	1.2E-04	1.0E+00	0.00012
C9-C10 Aromatic	151.36	1.00	9.3E-05	0.50	9.7E-05	1.9E-04	3.0E-01	0.00063
VPH Target Analytes								
Benzene	0.41	1.00	2.5E-07	0.08	4.2E-08	2.9E-07	1.0E-02	0.00003
Toluene	17.07	1.00	1.1E-05	0.12	2.6E-06	1.3E-05	8.0E-01	0.00002
Ethylbenzene	10.11	1.00	6.2E-06	0.20	2.6E-06	8.8E-06	1.0E+00	0.00001
Xylenes	39.81	1.00	2.5E-05	0.12	6.1E-06	3.1E-05	2.0E-01	0.00015
MTBE	2.58	1.00	1.6E-06	0.10	3.3E-07	1.9E-06	1.0E+00	0.00000
Naphthalene	3.17	0.36	7.0E-07	0.10	4.1E-07	1.1E-06	2.0E-01	0.00001
PCBs								
PCBs	4.28	0.85	2.2E-06	0.16	8.8E-07	3.1E-06	5.0E-05	0.06237
					TOTAL CHRONIC INGESTION & ABSORPTION HI [g.] =			**0.06**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Subchronic } ADD_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Subchronic } ADD_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Subchronic } ADD_{Total} = ADD_{ingestion} + ADD_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD_{Total}/chronic RfD

g. Total Hazard Index = Sum of Hazard Indices

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	50	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(event/day)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	1	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	1	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	0.03	(mg/cm^2)

Table Ab1
Chronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Commercial Worker - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total ADD [d.] (mg/kg/day)	Chronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		RAF [a.]	ADD $_{chronic}$ [b.] (mg/kg/day)	RAF [a.]	ADD $_{chronic}$ [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	1.00	9.2E-05	1.00	1.9E-04	2.8E-04	4.0E-02	0.00712
C9-C12 Aliphatic	96.83	1.00	6.0E-05	0.50	6.2E-05	1.2E-04	1.0E-01	0.00122
C9-C10 Aromatic	151.36	1.00	9.3E-05	0.50	9.7E-05	1.9E-04	3.0E-02	0.00635
VPH Target Analytes								
Benzene	0.41	1.00	2.5E-07	0.08	4.2E-08	2.9E-07	4.0E-03	0.00007
Toluene	17.07	1.00	1.1E-05	0.12	2.6E-06	1.3E-05	8.0E-02	0.00016
Ethylbenzene	10.11	1.00	6.2E-06	0.20	2.6E-06	8.8E-06	1.0E-01	0.00009
Xylenes	39.81	1.00	2.5E-05	0.12	6.1E-06	3.1E-05	2.0E-01	0.00015
MTBE	2.58	1.00	1.6E-06	0.10	3.3E-07	1.9E-06	1.0E-01	0.00002
Naphthalene	3.17	0.36	7.0E-07	0.10	4.1E-07	1.1E-06	2.0E-02	0.00006
PCBs								
PCBs	4.28	0.85	2.2E-06	0.16	8.8E-07	3.1E-06	2.0E-05	0.15593
						TOTAL CHRONIC INGESTION & ABSORPTION HI [g.] =		**0.17**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

Chronic $ADD_{ingestion}$= {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

Chronic ADD_{dermal}= {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose

Chronic ADD_{Total} = $ADD_{ingestion}$ + $ADD_{dermal\ absorption}$

e. Toxicity values

f. Hazard index = ADD $_{Total}$/chronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	50	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(event/day)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	30	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	30	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	0.03	(mg/cm^2)

Table Ac1
Lifetime Daily Dose and Increased Cancer Risk Estimates
Soil Ingestion and Dermal Contact - Commercial Worker
Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total LADD [d.] (mg/kg/day)	Cancer Slope Factor [e.] 1/(mg/kg/d)	ELCR [f.]
		RAF [a.]	LADD [b.] (mg/kg/day)	RAF [a.]	LADD [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	96.83	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	151.36	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes								
Benzene	0.41	1	1.08E-07	0.08	1.80E-08	1.26E-07	5.50E-02	6.9E-09
Toluene	17.07	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	10.11	NA	NA	NA	NA	NA	NA	NA
Xylenes	39.81	NA	NA	NA	NA	NA	NA	NA
MTBE	2.58	NA	NA	NA	NA	NA	NA	NA
Naphthalene	3.17	NA	NA	NA	NA	NA	NA	NA
PCBs								
PCBs	4.28	0.85	9.60E-07	0.16	3.77E-07	1.34E-06	2.00E+00	2.7E-06
					TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g.] =			**2.7E-06**

NOTES:

NC = Not a Class A or B Carcinogen

a. RAF = Relative Absorption Factor

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation:

$$LADD = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation:

$$LADD = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$LADD_{Total} = LADD_{dermal\ absorption} + LADD_{ingestion}$$

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil} * SF$

g. Total ELCR = Sum of OHM-Specific ELCR

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	50	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure	1	(day/event)
EP = Duration of Exposure Period	30	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	70	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed.	0.03	(mg/cm^2)

ATTACHMENT B

Table Ba
Subchronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Construction Worker - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		RAF [a.]	ADD subchronic [b.] (mg/kg/day)	RAF [a.]	ADD subchronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	1.00	2.3E-03	1.00	8.0E-02	8.2E-02	4.0E-01	0.205942
C9-C12 Aliphatic	935	1.00	1.2E-03	0.50	2.0E-02	2.1E-02	1.0E+00	0.021170
C9-C10 Aromatic	1650	1.00	2.0E-03	0.50	3.5E-02	3.7E-02	3.0E-01	0.124529
VPH Target Analytes								
Benzene	5.76	1.00	7.1E-06	0.08	2.0E-05	2.7E-05	1.0E-02	0.002683
Toluene	291	1.00	3.6E-04	0.12	1.5E-03	1.9E-03	8.0E-01	0.002317
Ethylbenzene	132	1.00	1.6E-04	0.20	1.1E-03	1.3E-03	1.0E+00	0.001293
Xylenes	539	1.00	6.6E-04	0.12	2.8E-03	3.4E-03	2.0E-01	0.017167
MTBE	23.8	1.00	2.9E-05	0.10	1.0E-04	1.3E-04	1.0E+00	0.000131
Naphthalene	32.9	0.36	1.5E-05	0.10	1.4E-04	1.6E-04	2.0E-01	0.000777
PCBs								
PCBs	32.05	0.85	3.4E-05	0.16	2.2E-04	2.5E-04	5.0E-05	5.062637
							TOTAL SUBCHRONIC INGESTION & ABSORPTION HI [g.]=	**5.44**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

Subchronic $ADD_{Ingestion}$= {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

Subchronic ADD_{dermal}= {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose

Subchronic ADD_{Total} = $ADD_{ingestion}$ + $ADD_{dermal\ absorption}$

e. Toxicity values

f. Hazard index = ADD /subchronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	100	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	0.5	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	0.5	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	1.00	(mg/cm^2)

Table Bb
Subchronic Dose and Hazard Estimates-Dust Inhalation
Construction Worker - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	RAF [a.]	ADD_{Inh-GI} [b.] (mg/kg/day)	$ADD_{Inh-res}$ [c.] (mg/kg/day)	$ADE_{Inh-res}$ [d.] (mg/m^3)	Subchronic Oral RfD [e.] (mg/kg/day)	Subchronic RfC [e.] (ug/m3)	Hazard $Index_{DI}$ [f.]
VPH								
C5-C8 Aliphatic	1870	1.00	8.0E-05	2.0E-05	7.0E-05	4.0E-01	2.0E+02	5.5E-04
C9-C12 Aliphatic	935	1.00	4.0E-05	9.9E-06	3.5E-05	1.0E+00	2.0E+02	2.1E-04
C9-C10 Aromatic	1650	1.00	7.0E-05	1.8E-05	6.1E-05	3.0E-01	5.0E+01	1.5E-03
VPH Target Analytes								
Benzene	5.76	1.00	2.5E-07	6.1E-08	2.1E-07	1.0E-02	9.0E+01	2.7E-05
Toluene	291	1.00	1.2E-05	3.1E-06	1.1E-05	8.0E-01	4.0E+02	4.3E-05
Ethylbenzene	132	1.00	5.6E-06	1.4E-06	4.9E-06	1.0E+00	1.0E+03	1.1E-05
Xylenes	539	1.00	2.3E-05	5.7E-06	2.0E-05	2.0E-01	6.0E+01	4.5E-04
MTBE	23.8	1.00	1.0E-06	2.5E-07	8.9E-07	1.0E+00	3.0E+03	1.3E-06
Naphthalene	32.9	0.36	5.0E-07	1.3E-07	4.4E-07	2.0E-01	3.0E+00	1.5E-04
PCBs								
PCBs	32.05	0.85	1.2E-06	2.9E-07	1.0E-06	5.0E-05	2.0E-02	7.4E-02
						TOTAL DUST INHALATION HI [g.]=		**0.077**

NOTES:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for effects on the gastrointestinal (GI) system via inhalation using the following equation:

$$ADD_{Inh-GI} = [(OHM_{particulate})*2*PM_{10}*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

ADD_{Inh-GI} =	see above	mg/kg/day
$_{articulate}$(max. soil conc.)=	see above	mg/kg
PM_{10}=	60	ug/m^3
Inh=	60	L/min
RAF=	see above	unitless
EF=	1	event/day
ED=	8	hours/event
EP=	130	days
BW=	58	kg
AP=	182	days for non-cancer risk
C=	6.00E-11	conversion factor

c. The Average Daily Dose was calculated for effects on the respiratory system via inhalation using the following equation:

$$ADD_{Inh-Res} = [(OHM_{particulate})*0.5*(PM_{10})*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

$ADD_{Inh-Res}$=	see above	mg/kg/day

d. The Average Daily Dose was converted to an Average Daily Exposure for compatability with dose-response values using the following equation:

$$ADE_{Inh-res} = (ADD_{Inh-res}*BW_{RfC})/Inh_{day}$$

where,

$ADE_{Inh-res}$=	see above	mg/m^3	BW_{RfC} = BW of Receptor used to develop RfC = 70 Kg
Inh_{day}=	20	m^3/day	

e. Toxicity values

f. The Non-Cancer Risk Hazard Index for GI and respiratory systems is calculated using the following equation:

$$HI = (ADD_{Inh-GI}/RfD) + (ADE_{Inh-res}/(RfC/C))$$

where,

HI=	see above	unitless
RfD=	see above	mg/kg/day
RfC=	see above	ug/m^3
C =	1000	ug/mg (conversion of RfC to mg/m^3)

g. Total Hazard Index = Sum of Hazard Indexes

Table Bc
Lifetime Daily Dose and Increased Cancer Risk Estimates-Soil Ingestion and Dermal Contact
Construction Worker - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total LADD [d.] (mg/kg/day)	Slope Factor [e.] 1/(mg/kg/d)	ELCR [f.]
		RAF [a.]	LADD [b.] (mg/kg/day)	RAF [a.]	LADD [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	935	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	1650	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes								
Benzene	5.76	1.0E+00	5.1E-08	8.0E-02	1.4E-07	1.9E-07	5.5E-02	1.1E-08
Toluene	291	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	132	NA	NA	NA	NA	NA	NA	NA
Xylenes	539	NA	NA	NA	NA	NA	NA	NA
MTBE	23.8	NA	NA	NA	NA	NA	NA	NA
Naphthalene	32.9	NA	NA	NA	NA	NA	NA	NA
PCBs								
PCBs	32.05	8.5E-01	2.4E-07	1.6E-01	1.6E-06	1.8E-06	2.0E+00	3.6E-06
						TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g.] =		**3.6E-06**

Notes:

NC = Not a Class A or B Carcinogen; NA = Not Available or Not Applicable

a. RAF = Relative Absorption Factor

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation:

$$LADD = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation:

$$LADD = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$LADD_{Total} = LADD_{dermal\ absorption} + LADD_{ingestion}$$

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil}$ * SF

g. Total ELCR = Sum of OHM-Specific ELCR

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	100	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure	1	(day/event)
EP = Duration of Exposure Period	0.5	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	70	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	1.00	(mg/cm^2)

Table Bd
Lifetime Daily Dose and Increased Cancer Estimates-Dust Inhalation
Construction Worker - Exposure to SIte-Wide Max Soils (0-15')
88-980 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	RAF [a.]	ADD_{Inh-GI} [b.] (mg/kg/day)	$ADD_{Inh-res}$ [c.] (mg/kg/day)	$ADE_{Inh-res}$ [d.] (mg/m^3)	Cancer Slope Factor [e.] 1/(mg/kg/d)	Unit Risk Factor [e.] $1/(ug/m^3)$	$ELCR_{DI}$ [f.]
VPH								
C5-C8 Aliphatic	1870	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	935	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	1650	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes								
Benzene	5.76	1	1.7E-09	4.4E-10	1.5E-09	5.5E-02	7.8E-06	1.1E-10
Toluene	291	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	132	NA	NA	NA	NA	NA	NA	NA
Xylenes	539	NA	NA	NA	NA	NA	NA	NA
MTBE	23.8	NA	NA	NA	NA	NA	NA	NA
Naphthalene	32.9	NA	NA	NA	NA	NA	NA	NA
PCBs								
PCBs	32.05	0.85	8.3E-09	2.1E-09	7.2E-09	2.0E+00	1.0E-04	1.7E-08
							DUST INHALATION ELCR [g.]=	**1.7E-08**

NOTES:

b. The Average Daily Dose was calculated for effects on the gastrointestinal (GI) system via inhalation using the following equation:

$$ADD_{Inh-GI}=[(OHM_{particulate})*2*PM_{10}*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

ADD_{Inh-GI} =	see above	mg/kg/day
rticulate(max. soil conc.)=	see above	mg/kg
PM_{10}=	60	ug/m^3
Inh=	60	L/min
RAF=	see above	unitless
EF=	1	event/day
ED=	8	hours/event
EP=	130	days
BW=	58	kg
AP=	25550	days for cancer risk
C=	6.00E-11	conversion factor

a. RAF = Relative Absorption Factor

e. Toxicity values

g. Total ELCR = Sum of OHM specific ELCRs

NC = Not a Class A or B Carcinogen

NA = Not Available or Not Applicable

c. The Average Daily Dose was calculated for effects on the respiratory system via inhalation using the following equation:

$$ADD_{Inh-Res}=[(OHM_{particulate})*0.5*(PM_{10})*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

$ADD_{Inh-Res}$=	see above	mg/kg/day

d. The Average Daily Dose was converted to an Average Daily Exposure for compatability with dose-response values using the following equation:

$$ADE_{Inh-res}=(ADD_{Inh-res}*BW_{RfC})/Inh_{day}$$

where,

$ADE_{Inh-res}$=	see above	mg/m^3
Inh_{day}=	20	m^3/day

BW_{RfC} = BW of Receptor used to develop RfC = 70 Kg

f. The Estimated Lifetime Cancer Risk (ELCR) value was calculated using the following equation:

$$ELCR=(ADD_{Inh-GI}*CSF)+(ADE_{Inh-res}*(URF/C))$$

where,

ELCR=	see above	unitless
er Slope Factor (CSF)=	see above	1/(mg/kg/day)
Init Risk Factor (URF)=	see above	$1/(ug/m^3)$
C =	1000	1/ug/mg (conversion of URF to $1/mg/m^3$)

Table Ba1
Subchronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Construction Worker - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		RAF [a.]	ADD $_{subchronic}$ [b.] (mg/kg/day)	RAF [a.]	ADD $_{subchronic}$ [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	1.00	1.8E-04	1.00	6.4E-03	6.6E-03	4.0E-01	0.016508
C9-C12 Aliphatic	96.83	1.00	1.2E-04	0.50	2.1E-03	2.2E-03	1.0E+00	0.002192
C9-C10 Aromatic	151.36	1.00	1.9E-04	0.50	3.2E-03	3.4E-03	3.0E-01	0.011423
VPH Target Analytes								
Benzene	0.41	1.00	5.0E-07	0.08	1.4E-06	1.9E-06	1.0E-02	0.000190
Toluene	17.07	1.00	2.1E-05	0.12	8.8E-05	1.1E-04	8.0E-01	0.000136
Ethylbenzene	10.11	1.00	1.2E-05	0.20	8.7E-05	9.9E-05	1.0E+00	0.000099
Xylenes	39.81	1.00	4.9E-05	0.12	2.0E-04	2.5E-04	2.0E-01	0.001268
MTBE	2.58	1.00	3.2E-06	0.10	1.1E-05	1.4E-05	1.0E+00	0.000014
Naphthalene	3.17	0.36	1.4E-06	0.10	1.4E-05	1.5E-05	2.0E-01	0.000075
PCBs								
PCBs	4.28	0.85	4.5E-06	0.16	2.9E-05	3.4E-05	5.0E-05	0.675816
						TOTAL SUBCHRONIC INGESTION & ABSORPTION HI [g.]=		**0.71**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

Subchronic $ADD_{ingestion}$= {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

Subchronic ADD_{dermal}= {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose

Subchronic ADD_{Total} = $ADD_{ingestion}$ + $ADD_{dermal\ absorption}$

e. Toxicity values

f. Hazard Index = ADD /subchronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	100	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	0.5	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	0.5	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	1.00	(mg/cm^2)

Table Bb1
Subchronic Dose and Hazard Estimates-Dust Inhalation
Construction Worker - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	RAF [a.]	ADD_{Inh-GI} [b.] (mg/kg/day)	$ADD_{Inh-res}$ [c.] (mg/kg/day)	$ADE_{Inh-res}$ [d.] (mg/m^3)	Subchronic Oral RfD [e.] (mg/kg/day)	Subchronic RfC [e.] (ug/m3)	Hazard $Index_{DI}$ [f.]
VPH								
C5-C8 Aliphatic	149.89	1.00	6.4E-06	1.6E-06	5.6E-06	4.0E-01	2.0E+02	4.4E-05
C9-C12 Aliphatic	96.83	1.00	4.1E-06	1.0E-06	3.6E-06	1.0E+00	2.0E+02	2.2E-05
C9-C10 Aromatic	151.36	1.00	6.4E-06	1.6E-06	5.6E-06	3.0E-01	5.0E+01	1.3E-04
VPH Target Analytes								
Benzene	0.41	1.00	1.7E-08	4.3E-09	1.5E-08	1.0E-02	9.0E+01	1.9E-06
Toluene	17.07	1.00	7.3E-07	1.8E-07	6.4E-07	8.0E-01	4.0E+02	2.5E-06
Ethylbenzene	10.11	1.00	4.3E-07	1.1E-07	3.8E-07	1.0E+00	1.0E+03	8.1E-07
Xylenes	39.81	1.00	1.7E-06	4.2E-07	1.5E-06	2.0E-01	6.0E+01	3.3E-05
MTBE	2.58	1.00	1.1E-07	2.7E-08	9.6E-08	1.0E+00	3.0E+03	1.4E-07
Naphthalene	3.17	0.36	4.9E-08	1.2E-08	4.3E-08	2.0E-01	3.0E+00	1.4E-05
PCBs								
PCBs	4.28	0.85	1.5E-07	3.9E-08	1.4E-07	5.0E-05	2.0E-02	9.9E-03
							TOTAL DUST INHALATION HI [g.]=	**0.010**

NOTES:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for effects on the gastrointestinal (GI) system via inhalation using the following equation:

$$ADD_{Inh-GI} = [(OHM_{particulate})*2*PM_{10}*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

ADD_{Inh-GI} =	see above	mg/kg/day
$_{articulate}$(max. soil conc.)=	see above	mg/kg
PM_{10}=	60	ug/m^3
Inh=	60	L/min
RAF=	see above	unitless
EF=	1	event/day
ED=	8	hours/event
EP=	130	days
BW=	58	kg
AP=	182	days for non-cancer risk
C=	6.00E-11	conversion factor

c. The Average Daily Dose was calculated for effects on the respiratory system via inhalation using the following equation:

$$ADD_{Inh-Res} = [(OHM_{particulate})*0.5*(PM_{10})*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

$ADD_{Inh-Res}$=	see above	mg/kg/day

d. The Average Daily Dose was converted to an Average Daily Exposure for compatability with dose-response values using the following equation:

$$ADE_{Inh-res} = (ADD_{Inh-res}*BW_{RfC})/Inh_{day}$$

where,

$ADE_{Inh-res}$=	see above	mg/m^3	BW_{RfC} = BW of Receptor used to develop RfC = 70 Kg
Inh_{day}=	20	m^3/day	

e. Toxicity values

f. The Non-Cancer Risk Hazard Index for GI and respiratory systems is calculated using the following equation:

$$HI = (ADD_{Inh-GI}/RfD) + (ADE_{Inh-res}/(RfC/C))$$

where,

HI=	see above	unitless
RfD=	see above	mg/kg/day
RfC=	see above	ug/m^3
C =	1000	ug/mg (conversion of RfC to mg/m^3)

g. Total Hazard Index = Sum of Hazard Indexes

Table Bc1
Lifetime Daily Dose and Increased Cancer Risk Estimates-Soil Ingestion and Dermal Contact
Construction Worker - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Ingestion		Dermal Absorption		Total LADD [d.] (mg/kg/day)	Slope Factor [e.] 1/(mg/kg/d)	ELCR [f.]
		RAF [a.]	LADD [b.] (mg/kg/day)	RAF [a.]	LADD [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	96.83	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	151.36	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes								
Benzene	0.41	1.0E+00	3.6E-09	8.0E-02	1.0E-08	1.4E-08	5.5E-02	7.5E-10
Toluene	17.07	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	10.11	NA	NA	NA	NA	NA	NA	NA
Xylenes	39.81	NA	NA	NA	NA	NA	NA	NA
MTBE	2.58	NA	NA	NA	NA	NA	NA	NA
Naphthalene	3.17	NA	NA	NA	NA	NA	NA	NA
PCBs								
PCBs	4.28	8.5E-01	3.2E-08	1.6E-01	2.1E-07	2.4E-07	2.0E+00	4.8E-07
						TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g.] =		**4.8E-07**

Notes:

NC = Not a Class A or B Carcinogen; NA = Not Available or Not Applicable

a. RAF = Relative Absorption Factor

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation:

$$LADD = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation:

$$LADD = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$LADD_{Total} = LADD_{dermal\ absorption} + LADD_{ingestion}$$

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil}$ * SF

g. Total ELCR = Sum of OHM-Specific ELCR

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate	100	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure	1	(day/event)
EP = Duration of Exposure Period	0.5	(years)
C = Unit conversion factors (ingestion)	1.0E-06	
C = Unit conversion factors (dermal)	1.0E-06	
BW = Body Weight	58	(kg)
AP = Averaging Period	70	(year)
SA = Skin surface area in contact with soil	3477	(cm^2)
AF = Mass of soil adhered to the unit surface area of skin exposed	1.00	(mg/cm^2)

Table Bd1
Lifetime Daily Dose and Increased Cancer Estimates-Dust Inhalation
Construction Worker - Exposure to SIte-Wide Avg Soils (0-15')
88-980 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	RAF [a.]	ADD_{Inh-GI} [b.] (mg/kg/day)	$ADD_{Inh-res}$ [c.] (mg/kg/day)	$ADE_{Inh-res}$ [d.] (mg/m^3)	Cancer Slope Factor [e.] 1/(mg/kg/d)	Unit Risk Factor [e.] 1/(ug/m^3)	$ELCR_{DI}$ [f.]
VPH								
C5-C8 Aliphatic	149.89	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	96.83	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	151.36	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes								
Benzene	0.41	1	1.2E-10	3.1E-11	1.1E-10	5.5E-02	7.8E-06	7.7E-12
Toluene	17.07	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	10.11	NA	NA	NA	NA	NA	NA	NA
Xylenes	39.81	NA	NA	NA	NA	NA	NA	NA
MTBE	2.58	NA	NA	NA	NA	NA	NA	NA
Naphthalene	3.17	NA	NA	NA	NA	NA	NA	NA
PCBs								
PCBs	4.28	0.85	1.1E-09	2.8E-10	9.6E-10	2.0E+00	1.0E-04	2.3E-09
							DUST INHALATION ELCR [g.] =	**2.3E-09**

NOTES:

b. The Average Daily Dose was calculated for effects on the gastrointestinal (GI) system via inhalation using the following equation:

$$ADD_{Inh-GI} = [(OHM_{particulate})*2*PM_{10}*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

ADD_{Inh-GI} =	see above	mg/kg/day
rticulate(max. soil conc.)=	see above	mg/kg
PM_{10}=	60	ug/m^3
Inh=	60	L/min
RAF=	see above	unitless
EF=	1	event/day
ED=	8	hours/event
EP=	130	days
BW=	58	kg
AP=	25550	days for cancer risk
C=	6.00E-11	conversion factor

a. RAF = Relative Absorption Factor

e. Toxicity values

g. Total ELCR = Sum of OHM specific ELCRs

NC = Not a Class A or B Carcinogen

NA = Not Available or Not Applicable

c. The Average Daily Dose was calculated for effects on the respiratory system via inhalation using the following equation:

$$ADD_{Inh-Res} = [(OHM_{particulate})*0.5*(PM_{10})*_{Inh}*RAF*EF*ED*EP*C]/(BW*AP)$$

where,

$ADD_{Inh-Res}$=	see above	mg/kg/day

d. The Average Daily Dose was converted to an Average Daily Exposure for compatability with dose-response values using the following equation:

$$ADE_{Inh-res} = (ADD_{Inh-res}*BW_{RfC})/Inh_{day}$$

where,

$ADE_{Inh-res}$=	see above	mg/m^3
Inh_{day}=	20	m^3/day

BW_{RfC} = BW of Receptor used to develop RfC = 70 Kg

f. The Estimated Lifetime Cancer Risk (ELCR) value was calculated using the following equation:

$$ELCR = (ADD_{Inh-GI}*CSF)+(ADE_{Inh-res}*(URF/C))$$

where,

ELCR=	see above	unitless
er Slope Factor (CSF)=	see above	1/(mg/kg/day)
Init Risk Factor (URF)=	see above	1/(ug/m^3)
C =	1000	1/ug/mg (conversion of URF to 1/mg/m^3)

ATTACHMENT C

Table Ca
Subchronic Dose and Hazard Estimates - Soil Ingestion and Dermal Contact
Child Trespasser - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Child (9 yrs) Ingestion RAF [a.]	Ingestion ADD subchronic [b.] (mg/kg/day)	Dermal Absorption RAF [a.]	Dermal Absorption ADD subchronic [c.] (mg/kg/day)	Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
VPH								
C5-C8 Aliphatic	1870	1	9.0E-04	1.00	9.3E-03	1.0E-02	4.00E-01	0.025518
C9-C12 Aliphatic	935	1	4.5E-04	0.50	2.3E-03	2.8E-03	1.00E+00	0.002777
C9-C10 Aromatic	1650	1	8.0E-04	0.50	4.1E-03	4.9E-03	3.00E-01	0.016338
VPH Target Analytes								
Benzene	5.76	1	2.8E-06	0.08	2.3E-06	5.1E-06	1.00E-02	0.000507
Toluene	291	1	1.4E-04	0.12	1.7E-04	3.1E-04	8.00E-01	0.000393
Ethylbenzene	132	1	6.4E-05	0.20	1.3E-04	2.0E-04	1.00E+00	0.000195
Xylenes	539	1	2.6E-04	0.12	3.2E-04	5.8E-04	2.00E-01	0.002910
MTBE	23.8	1	1.1E-05	0.10	1.2E-05	2.3E-05	1.00E+00	0.000023
Naphthalene	32.9	0.36	5.7E-06	0.10	1.6E-05	2.2E-05	2.00E-01	0.000110
PCBs								
PCBs	32.05	0.85	1.3E-05	0.16	2.6E-05	3.9E-05	5.00E-05	0.773280
						TOTAL CHRONIC INGESTION & ABSORPTION HI [g.]=		**0.82**

NOTES:

a. Relative Absorption Factor (RAF)

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Chronic ADD}_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Chronic ADD}_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Chronic ADD}_{Total} = \text{ADD}_{ingestion} + \text{ADD}_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD $_{Total}$/chronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:			Value
$[OHM]_{Soil}$ = maximum soil concentration			as shown above
IR = Daily soil ingestion rate for a Teen Site Visitor (mg/day)			50
RAF = Relative Absorption Factor (unitless)			as shown above
EF = Exposure frequency (event/day)			2/7
ED = Average duration of each exposure event (day/event)			1
EP = Duration of Exposure Period for Teen Site Visitor (yrs)	*formula:*	(7/12) * 1 =	0.6
C = Unit conversion factors (ingestion)			1.0E-06
C = Unit conversion factors (dermal)			1.0E-06
BW = Body Weight for a Teen Site Visitor (kg)			29.6
AP = Averaging Period for a Teen Site Visitor (year)			0.6
SA = Skin surface area in contact with soil for a Teen Site Visitor (cm^2/day)			3656
AF_C = Weighted Skin-Soil Adherence Factor for a Teen Site Visitor (mg/cm^2)			0.141

Table Cb
Chronic Dose and Hazard Estimates - Soil Ingestion and Dermal Contact
Child/Teen Trespasser - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Child/Teen Trespasser (9 < 16 yrs)				Total ADD [d.] (mg/kg/day)	Chronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		Ingestion		Dermal Absorption				
		RAF [a.]	ADD subchronic [b.] (mg/kg/day)	RAF [a.]	ADD subchronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	1	3.6E-04	1	4.7E-03	5.10E-03	4.00E-02	0.12749
C9-C12 Aliphatic	935	1	1.8E-04	0.5	1.2E-03	1.36E-03	1.00E-01	0.01364
C9-C10 Aromatic	1650	1	3.2E-04	0.5	2.1E-03	2.41E-03	3.00E-02	0.08026
VPH Target Analytes								
Benzene	5.76	1	1.1E-06	0.08	1.2E-06	2.27E-06	4.00E-03	0.00057
Toluene	291	1	5.6E-05	0.12	8.9E-05	1.44E-04	8.00E-02	0.00180
Ethylbenzene	132	1	2.5E-05	0.2	6.7E-05	9.22E-05	1.00E-01	0.00092
Xylenes	539	1	1.0E-04	0.12	1.6E-04	2.67E-04	2.00E-01	0.00134
MTBE	23.8	1	4.6E-06	0.1	6.0E-06	1.06E-05	1.00E-01	0.00011
Naphthalene	32.9	0.36	2.3E-06	0.1	8.3E-06	1.06E-05	2.00E-02	0.00053
PCBs								
PCBs	32.05	0.85	5.2E-06	0.16	1.3E-05	1.82E-05	2.00E-05	0.91106
						TOTAL CHRONIC INGESTION & ABSORPTION HI [g.]=		**1.14**

Notes:

a. Relative Absorption Factor (RAF)

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Chronic ADD}_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Chronic ADD}_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Chronic ADD}_{Total} = \text{ADD}_{ingestion} + \text{ADD}_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD $_{Total}$/chronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:			Value
$[OHM]_{Soil}$ = maximum soil concentration			as shown above
IR = Daily soil ingestion rate for a Teen Site Visitor (mg/day)			50
RAF = Relative Absorption Factor (unitless)			as shown above
EF = Exposure frequency (event/day)			2/7
ED = Average duration of each exposure event (day/event)			1
EP = Duration of Exposure Period for Teen Site Visitor (yrs)	*formula:*	(7/12) * 7 =	4.1
C = Unit conversion factors (ingestion)			1.0E-06
C = Unit conversion factors (dermal)			1.0E-06
BW = Body Weight for a Teen Site Visitor (kg)			43.5
AP = Averaging Period for a Teen Site Visitor (year)			7
SA = Skin surface area in contact with soil for a Teen Site Visitor (cm^2/day)			4727
AF_C = Weighted Skin-Soil Adherence Factor for a Teen Site Visitor (mg/cm^2)			0.140

Table Cc
Chronic Dose and Increased Cancer Risk - Soil Ingestion and Dermal Contact
Child, Teen and Adult Trespasser - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Child/Teen (9-16 yrs)				Teen/Adult (16<29 yrs)				Total LADD [d.] (mg/kg/day)	Slope Factor [e.] 1/(mg/kg/d)	ELCR [f.]
		Ingestion		Dermal Absorption		Ingestion		Dermal Absorption				
		RAF [a.]	LADD subchronic [b.] (mg/kg/day)	RAF [a.]	LADD subchronic [c.] (mg/kg/day)	RAF [a.]	LADD subchronic [b.] (mg/kg/day)	RAF [a.]	LADD subchronic [c.] (mg/kg/day)			
VPH												
C5-C8 Aliphatic	1870	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	935	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	1650	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes												
Benzene	5.76	1	1.1E-07	0.08	1.2E-07	1.0E+00	1.5E-07	8.0E-02	1.9E-07	5.7E-07	5.5E-02	3.1E-08
Toluene	291	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	132	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Xylenes	539	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTBE	23.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	32.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPH												
C9-C-18 Aliphatics	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C19-C36 Aliphatics	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C11-C22 Aromatics	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs												
PCBs	32.05	0.85	5.2E-07	0.16	1.3E-06	8.5E-01	7.3E-07	1.6E-01	2.1E-06	4.6E-06	2.0E+00	9.3E-06
										TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g.] =		**9.3E-06**

NOTES:

a. Relative Absorption Factor (RAF)

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation.

$$LADD = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation.

$$LADD = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$LADD_{Total} = LADD_{dermal\ absorption} + LADD_{ingestion}$$

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil} * SF$

g. Total ELCR = Sum of OHM-Specific ELCR

WHERE:

			Value
$[OHM]_{Soil}$ = maximum soil concentration			as shown above
IR = Daily soil ingestion rate for a Teen Site Visitor (mg/day)			50
IR = Daily soil ingestion rate for an Adult Site Visitor (mg/day)			50
RAF = Relative Absorption Factor (unitless)			as shown above
EF = Exposure frequency (event/day)			2/7
ED = Average duration of each exposure event (day/event)			1
EP = Duration of Exposure Period for a Teen Site Visitor (yrs)	*formula:*	(7/12) * 7 =	4.1
EP = Duration of Exposure Period for an Adult Site Visitor (yrs)	*formula:*	(7/12) * 13 =	8
C = Unit conversion factors (ingestion)			1.0E-06
C = Unit conversion factors (dermal)			1.0E-06
BW = Body Weight for a Teen Site Visitor (kg)			43.5
BW = Body Weight for an Adult Site Visitor (kg)			57.9
AP = Averaging Period for a Teen Site Visitor (year)			70
AP = Averaging Period for an Adult Site Visitor (year)			70
SA = Skin surface area in contact with soil for a Teen Site Visitor (cm^2/day)			4727
SA = Skin surface area in contact with soil for a Adult Site Visitor (cm^2/day)			5670
AF_C = Weighted Skin-Soil Adherence Factor for a Teen Site Visitor (mg/cm^2)			0.140
AF_A = Weighted Skin-Soil Adherence Factor for an Adult Site Visitor (mg/cm^2)			0.135

Table Ca1
Subchronic Dose and Hazard Estimates - Soil Ingestion and Dermal Contact
Child Trespasser - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Child (9 yrs)				Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		Ingestion		Dermal Absorption				
		RAF [a.]	ADD subchronic [b.] (mg/kg/day)	RAF [a.]	ADD subchronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	1	7.2E-05	1.00	7.5E-04	8.2E-04	4.00E-01	0.002045
C9-C12 Aliphatic	96.83	1	4.7E-05	0.50	2.4E-04	2.9E-04	1.00E+00	0.000288
C9-C10 Aromatic	151.36	1	7.3E-05	0.50	3.8E-04	4.5E-04	3.00E-01	0.001499
VPH Target Analytes								
Benzene	0.41	1	2.0E-07	0.08	1.6E-07	3.6E-07	1.00E-02	0.000036
Toluene	17.07	1	8.2E-06	0.12	1.0E-05	1.8E-05	8.00E-01	0.000023
Ethylbenzene	10.11	1	4.9E-06	0.20	1.0E-05	1.5E-05	1.00E+00	0.000015
Xylenes	39.81	1	1.9E-05	0.12	2.4E-05	4.3E-05	2.00E-01	0.000215
MTBE	2.58	1	1.2E-06	0.10	1.3E-06	2.5E-06	1.00E+00	0.000003
Naphthalene	3.17	0.36	5.5E-07	0.10	1.6E-06	2.1E-06	2.00E-01	0.000011
PCBs								
PCBs	4.28	0.85	1.8E-06	0.16	3.4E-06	5.2E-06	5.00E-05	0.103226
							TOTAL CHRONIC INGESTION & ABSORPTION HI [g.]=	**0.11**

NOTES:

a. Relative Absorption Factor (RAF)

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Chronic ADD}_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Chronic ADD}_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Chronic ADD}_{Total} = \text{ADD}_{ingestion} + \text{ADD}_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD $_{Total}$/chronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:			Value
$[OHM]_{Soil}$ = maximum soil concentration			as shown above
IR = Daily soil ingestion rate for a Teen Site Visitor (mg/day)			50
RAF = Relative Absorption Factor (unitless)			as shown above
EF = Exposure frequency (event/day)			2/7
ED = Average duration of each exposure event (day/event)			1
EP = Duration of Exposure Period for Teen Site Visitor (yrs)	*formula:*	(7/12) * 1 =	0.6
C = Unit conversion factors (ingestion)			1.0E-06
C = Unit conversion factors (dermal)			1.0E-06
BW = Body Weight for a Teen Site Visitor (kg)			29.6
AP = Averaging Period for a Teen Site Visitor (year)			0.6
SA = Skin surface area in contact with soil for a Teen Site Visitor (cm^2/day)			3656
AF_C = Weighted Skin-Soil Adherence Factor for a Teen Site Visitor (mg/cm^2)			0.141

Table Cb1
Chronic Dose and Hazard Estimates - Soil Ingestion and Dermal Contact
Child/Teen Trespasser - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Child/Teen Trespasser (9 < 16 yrs)				Total ADD [d.] (mg/kg/day)	Chronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		Ingestion		Dermal Absorption				
		RAF [a.]	ADD subchronic [b.] (mg/kg/day)	RAF [a.]	ADD subchronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	1	2.9E-05	1	3.8E-04	4.09E-04	4.00E-02	0.01022
C9-C12 Aliphatic	96.83	1	1.9E-05	0.5	1.2E-04	1.41E-04	1.00E-01	0.00141
C9-C10 Aromatic	151.36	1	2.9E-05	0.5	1.9E-04	2.21E-04	3.00E-02	0.00736
VPH Target Analytes								
Benzene	0.41	1	7.8E-08	0.08	8.3E-08	1.61E-07	4.00E-03	0.00004
Toluene	17.07	1	3.3E-06	0.12	5.2E-06	8.46E-06	8.00E-02	0.00011
Ethylbenzene	10.11	1	1.9E-06	0.2	5.1E-06	7.07E-06	1.00E-01	0.00007
Xylenes	39.81	1	7.6E-06	0.12	1.2E-05	1.97E-05	2.00E-01	0.00010
MTBE	2.58	1	4.9E-07	0.1	6.5E-07	1.15E-06	1.00E-01	0.00001
Naphthalene	3.17	0.36	2.2E-07	0.1	8.0E-07	1.02E-06	2.00E-02	0.00005
PCBs								
PCBs	4.28	0.85	7.0E-07	0.16	1.7E-06	2.43E-06	2.00E-05	0.12162
						TOTAL CHRONIC INGESTION & ABSORPTION HI [g.]=		**0.14**

Notes:

a. Relative Absorption Factor (RAF)

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Chronic ADD}_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Chronic ADD}_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Chronic ADD}_{Total} = \text{ADD}_{ingestion} + \text{ADD}_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD $_{Total}$/chronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:			Value
$[OHM]_{Soil}$ = maximum soil concentration			as shown above
IR = Daily soil ingestion rate for a Teen Site Visitor (mg/day)			50
RAF = Relative Absorption Factor (unitless)			as shown above
EF = Exposure frequency (event/day)			2/7
ED = Average duration of each exposure event (day/event)			1
EP = Duration of Exposure Period for Teen Site Visitor (yrs)	*formula:*	(7/12) * 7 =	4.1
C = Unit conversion factors (ingestion)			1.0E-06
C = Unit conversion factors (dermal)			1.0E-06
BW = Body Weight for a Teen Site Visitor (kg)			43.5
AP = Averaging Period for a Teen Site Visitor (year)			7
SA = Skin surface area in contact with soil for a Teen Site Visitor (cm^2/day)			4727
AF_C = Weighted Skin-Soil Adherence Factor for a Teen Site Visitor (mg/cm^2)			0.140

Table Cc1
Chronic Dose and Increased Cancer Risk - Soil Ingestion and Dermal Contact
Child, Teen and Adult Trespasser - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Child/Teen (9-16 yrs)				Teen/Adult (16<29 yrs)				Total LADD [d.] (mg/kg/day)	Slope Factor [e.] 1/(mg/kg/d)	ELCR [f.]
		Ingestion		Dermal Absorption		Ingestion		Dermal Absorption				
		RAF [a.]	LADD subchronic [b.] (mg/kg/day)	RAF [a.]	LADD subchronic [c.] (mg/kg/day)	RAF [a.]	LADD subchronic [b.] (mg/kg/day)	RAF [a.]	LADD subchronic [c.] (mg/kg/day)			
VPH												
C5-C8 Aliphatic	149.89	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	96.83	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	151.36	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes												
Benzene	0.41	1	7.8E-09	0.08	8.3E-09	1.0E+00	1.1E-08	8.0E-02	1.3E-08	4.0E-08	5.5E-02	2.2E-09
Toluene	17.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	10.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Xylenes	39.81	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTBE	2.58	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	3.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs												
PCBs	4.28	0.85	7.0E-08	0.16	1.7E-07	8.5E-01	9.7E-08	1.6E-01	2.8E-07	6.2E-07	2.0E+00	1.2E-06
										TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g.] =		**1.2E-06**

NOTES:

a. Relative Absorption Factor (RAF)

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation.

$$LADD = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation.

$$LADD = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$LADD_{Total} = LADD_{dermal\ absorption} + LADD_{ingestion}$$

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil} * SF$

g. Total ELCR = Sum of OHM-Specific ELCR

WHERE:

			Value
$[OHM]_{Soil}$ = maximum soil concentration			as shown above
IR = Daily soil ingestion rate for a Teen Site Visitor (mg/day)			50
IR = Daily soil ingestion rate for an Adult Site Visitor (mg/day)			50
RAF = Relative Absorption Factor (unitless)			as shown above
EF = Exposure frequency (event/day)			2/7
ED = Average duration of each exposure event (day/event)			1
EP = Duration of Exposure Period for a Teen Site Visitor (yrs)	*formula:*	(7/12) * 7 =	4.1
EP = Duration of Exposure Period for an Adult Site Visitor (yrs)	*formula:*	(7/12) * 13 =	8
C = Unit conversion factors (ingestion)			1.0E-06
C = Unit conversion factors (dermal)			1.0E-06
BW = Body Weight for a Teen Site Visitor (kg)			43.5
BW = Body Weight for an Adult Site Visitor (kg)			57.9
AP = Averaging Period for a Teen Site Visitor (year)			70
AP = Averaging Period for an Adult Site Visitor (year)			70
SA = Skin surface area in contact with soil for a Teen Site Visitor (cm^2/day)			4727
SA = Skin surface area in contact with soil for a Adult Site Visitor (cm^2/day)			5670
AF_C = Weighted Skin-Soil Adherence Factor for a Teen Site Visitor (mg/cm^2)			0.140
AF_A = Weighted Skin-Soil Adherence Factor for an Adult Site Visitor (mg/cm^2)			0.135

ATTACHMENT D

Table Da
Subchronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Child Resident - Exposure to Site-Wide Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Child (1<2 yrs)				Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		Ingestion		Dermal Absorption				
		RAF [a.]	ADD subchronic [b.] (mg/kg/day)	RAF [a.]	ADD subchronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	1.00	1.2E-02	1.00	7.3E-02	8.5E-02	4.00E-01	0.21362
C9-C12 Aliphatic	935	1.00	6.2E-03	0.50	1.8E-02	2.4E-02	1.00E+00	0.02448
C9-C10 Aromatic	1650	1.00	1.1E-02	0.50	3.2E-02	4.3E-02	3.00E-01	0.14402
VPH Target Analytes								
Benzene	5.76	1.00	3.8E-05	0.08	1.8E-05	5.6E-05	1.00E-02	0.00564
Toluene	291	1.00	1.9E-03	0.12	1.4E-03	3.3E-03	8.00E-01	0.00413
Ethylbenzene	132	1.00	8.8E-04	0.20	1.0E-03	1.9E-03	1.00E+00	0.00191
Xylenes	539	1.00	3.6E-03	0.12	2.5E-03	6.1E-03	2.00E-01	0.03061
MTBE	23.8	1.00	1.6E-04	0.10	9.3E-05	2.5E-04	1.00E+00	0.00025
Naphthalene	32.9	0.36	7.9E-05	0.10	1.3E-04	2.1E-04	2.00E-01	0.00104
PCBs								
PCBs	32.05	0.85	1.8E-04	0.16	2.0E-04	3.8E-04	5.00E-05	7.63894
					TOTAL SUBCHRONIC INGESTION & ABSORPTION HI g.=			**8.1**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Subchronic ADD}_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Subchronic ADD}_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Subchronic ADD}_{Child} = \text{Child ADD}_{ingestion} + \text{Child ADD}_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD /subchronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate, child 1<2 years	100	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	7/12	(years)
C = Unit conversion factors	1.0E-06	(ingestion)
C = Unit conversion factors	1.0E-06	(dermal)
BW = Body Weight, child 1<2 years	10.7	(kg)
AP = Averaging Period	7/12	(year)
SA = Skin surface area in contact with soil, child 1<2 year	1670	(cm^2)
AF = Weighted Skin-Soil Adherence Factor, child 1<2 yea	0.35	(mg/cm^2)

Table Db
Chronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Child Resident - Exposure to Soil MAX (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Child (1-8 yrs)				Total ADD [d.] (mg/kg/day)	Chronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		Ingestion		Dermal Absorption				
		RAF [a.]	ADD chronic [b.] (mg/kg/day)	RAF [a.]	ADD chronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	1870	1.00	4.6E-03	1.00	4.0E-02	4.4E-02	4.00E-02	1.1037
C9-C12 Aliphatic	935	1.00	2.3E-03	0.50	9.9E-03	1.2E-02	1.00E-01	0.1220
C9-C10 Aromatic	1650	1.00	4.1E-03	0.50	1.7E-02	2.2E-02	3.00E-02	0.7174
VPH Target Analytes								
Benzene	5.76	1.00	1.4E-05	0.08	9.7E-06	2.4E-05	4.00E-03	0.0060
Toluene	291	1.00	7.2E-04	0.12	7.4E-04	1.5E-03	8.00E-02	0.0182
Ethylbenzene	132	1.00	3.3E-04	0.20	5.6E-04	8.9E-04	1.00E-01	0.0089
Xylenes	539	1.00	1.3E-03	0.12	1.4E-03	2.7E-03	2.00E-01	0.0135
MTBE	23.8	1.00	5.9E-05	0.10	5.0E-05	1.1E-04	1.00E-01	0.0011
Naphthalene	32.9	0.36	2.9E-05	0.10	7.0E-05	9.9E-05	2.00E-02	0.0049
PCBs								
PCBs	32.05	0.85	6.8E-05	0.16	1.1E-04	1.8E-04	2.00E-05	8.7956
						TOTAL CHRONIC INGESTION & ABSORPTION HI g.=		**10.8**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

Chronic $ADD_{ingestion}$= {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

Chronic ADD_{dermal}= {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose

Chronic ADD_{Total} = $ADD_{ingestion}$ + $ADD_{dermal\ absorption}$

e. Toxicity values

f. Hazard index = ADD_{Total}/chronic RfD

g. Total Hazard Index = Sum of Hazard Indices

WHERE:		Value	
$[OHM]_{Soil}$ = maximum soil concentration		as shown above	
IR = Daily soil ingestion rate, child 1<8 years		100	(mg/day)
RAF = Relative Absorption Factor		as shown above	(unitless)
EF = Exposure frequency		5/7	(events/days)
ED = Average duration of each exposure event		1	(day/event)
EP = Duration of Child Exposure Period	(7mos/12mos) x 7 yrs =	4.1	(years)
C = Unit conversion factors (ingestion)		1.0E-06	
C = Unit conversion factors (dermal)		1.0E-06	
BW = Body Weight, child 1<8 years		16.8	(kg)
AP = Averaging Period, child 1<8 years		7	(years)
SA = Skin surface area in contact with soil, child 1<8 years		2434	(cm^2)
AF = Weighted Skin-Soil Adherence Factor, child 1<8 years		0.35	(mg/cm^2)

Table Dc
Lifetime Daily Dose and Increased Cancer Risk Estimates-Soil Ingestion and Dermal Contact
Child and Older Child/Adult Resident - Exposure to Max Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide MAX Soil (0-15') (mg/kg)	Child (1 < 8 yrs)				Child/Teen (8 < 15 yrs)				Adult (15 < 31 yrs)				Total LADD [d] (mg/kg/day)	Slope Factor [a] 1/(mg/kg/d)	ELCR [f]
		Ingestion		Dermal Absorption		Ingestion		Dermal Absorption		Ingestion		Dermal Absorption				
		RAF [a]	LADD chronic [b] (mg/kg/day)	RAF [a]	LADD chronic [c] (mg/kg/day)	RAF [a]	LADD chronic [b] (mg/kg/day)	RAF [a]	LADD chronic [c] (mg/kg/day)	RAF [a]	LADD chronic [b] (mg/kg/day)	RAF [a]	LADD chronic [c] (mg/kg/day)			
VPH																
C5-C8 Aliphatic	1870	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	935	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	1650	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes																
Benzene	5.76	1	1.4E-06	0.08	9.7E-07	1	3.0E-07	0.08	3.0E-07	1	5.1E-07	0.08	6.0E-07	4.1E-06	5.5E-02	2.3E-07
Toluene	291	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	132	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Xylenes	539	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTBE	23.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	32.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs																
PCBs	32.05	0.85	6.8E-06	0.16	1.1E-05	0.85	1.4E-06	0.16	3.3E-06	0.85	2.4E-06	0.16	6.6E-06	3.1E-05	2.0E+00	6.3E-05
														TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g] =		**6.3E-05**

NOTES:

NC = Not a Class A or B Carcinogen

NA = Not Available or Not Applicable

a. RAF = Relative Absorption Factor

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation.

LADD = {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation.

LADD = {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose:

$LADD_{Total}$ = ($LADD_{dermal\ absorption}$ + $LADD_{ingestion}$)Child + ($LADD_{dermal\ absorption}$ + $LADD_{ingestion}$) Older Child/Adult

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil}$ * SF

g. Total ELCR = Sum of OHM-Specific ELCR

EPC - Exposure Point Concentration

WHERE:

		Value	
$[OHM]_{Soil}$ = maximum soil concentration		as shown above	
IR_C = Daily soil ingestion rate, Child		100	(mg/day)
IR_A = Daily soil ingestion rate, Older Child/Adult		50	(mg/day)
RAF = Relative Absorption Factor		as shown above	(unitless)
EF = Exposure frequency		5/7	(events/days)
ED = Average duration of each exposure event		1	(day/event)
EP_C = Duration Exposure Period, Child	(7mos/12mos) x 7 yrs =	4.1	(years)
EP_C = Duration Exposure Period, Child/Teen	(7mos/12mos) x 7 yrs =	4.1	(years)
EP_A = Duration Exposure Period, Adult	(7mos/12mos) x 16 yrs =	9	(years)
C = Unit conversion factors (ingestion)		1.0E-06	
C = Unit conversion factors (dermal)		1.0E-06	
BW_C = Body Weight, Child		16.8	(kg)
BW_{CT} = Body Weight, Child/Teen		39.7	(kg)
BW_A = Body Weight, Adult		54.2	(kg)
AP_C = Averaging Period, Child		70	(years)
AP_{CT} = Averaging Period, Child/Teen		70	(years)
AP_A = Averaging Period, Adult		70	(years)
SA_C = Skin surface area in contact with soil, Child		2431	(cm^2)
SA_{CT} = Skin surface area in contact with soil, Child/Teen		4427	(cm^2)
SA_A = Skin surface area in contact with soil, Older Child/Adult		5654	(cm^2)
AF_C = Weighted Skin-Soil Adherence Factor, Child		0.35	(mg/cm_2)
AF_C = Weighted Skin-Soil Adherence Factor, Child/Teen		0.14	(mg/cm_2)
AF_A = Weighted Skin-Soil Adherence Factor, Adult		0.13	(mg/cm_2)

Table Da1
Subchronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Child Resident - Exposure to Site-Wide Avg Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Child (1<2 yrs)				Total ADD [d.] (mg/kg/day)	Subchronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
		Ingestion		Dermal Absorption				
		RAF [a.]	ADD subchronic [b.] (mg/kg/day)	RAF [a.]	ADD subchronic [c.] (mg/kg/day)			
VPH								
C5-C8 Aliphatic	149.89	1.00	1.0E-03	1.00	5.8E-03	6.8E-03	4.00E-01	0.01712
C9-C12 Aliphatic	96.83	1.00	6.5E-04	0.50	1.9E-03	2.5E-03	1.00E+00	0.00254
C9-C10 Aromatic	151.36	1.00	1.0E-03	0.50	3.0E-03	4.0E-03	3.00E-01	0.01321
VPH Target Analytes								
Benzene	0.41	1.00	2.7E-06	0.08	1.3E-06	4.0E-06	1.00E-02	0.00040
Toluene	17.07	1.00	1.1E-04	0.12	8.0E-05	1.9E-04	8.00E-01	0.00024
Ethylbenzene	10.11	1.00	6.8E-05	0.20	7.9E-05	1.5E-04	1.00E+00	0.00015
Xylenes	39.81	1.00	2.7E-04	0.12	1.9E-04	4.5E-04	2.00E-01	0.00226
MTBE	2.58	1.00	1.7E-05	0.10	1.0E-05	2.7E-05	1.00E+00	0.00003
Naphthalene	3.17	0.36	7.6E-06	0.10	1.2E-05	2.0E-05	2.00E-01	0.00010
PCBs								
PCBs	4.28	0.85	2.4E-05	0.16	2.7E-05	5.1E-05	5.00E-05	1.01973
					TOTAL SUBCHRONIC INGESTION & ABSORPTION HI g.=			**1.1**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Subchronic } ADD_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Subchronic } ADD_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Subchronic } ADD_{Child} = \text{Child } ADD_{ingestion} + \text{Child } ADD_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD /subchronic RfD

g. Total Hazard Index = Sum of Hazard Indexes

WHERE:	Value	
$[OHM]_{Soil}$ = maximum soil concentration	as shown above	
IR = Daily soil ingestion rate, child 1<2 years	100	(mg/day)
RAF = Relative Absorption Factor	as shown above	(unitless)
EF = Exposure frequency	5/7	(events/days)
ED = Average duration of each exposure event	1	(day/event)
EP = Duration of Exposure Period	7/12	(years)
C = Unit conversion factors	1.0E-06	(ingestion)
C = Unit conversion factors	1.0E-06	(dermal)
BW = Body Weight, child 1<2 years	10.7	(kg)
AP = Averaging Period	7/12	(year)
SA = Skin surface area in contact with soil, child 1<2 year:	1670	(cm^2)
AF = Weighted Skin-Soil Adherence Factor, child 1<2 yea	0.35	(mg/cm^2)

Table Db1
Chronic Dose and Hazard Estimates-Soil Ingestion and Dermal Contact
Child Resident - Exposure to Soil Avg (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Child (1-8 yrs) Ingestion RAF [a.]	Ingestion ADD chronic [b.] (mg/kg/day)	Dermal Absorption RAF [a.]	Dermal Absorption ADD chronic [c.] (mg/kg/day)	Total ADD [d.] (mg/kg/day)	Chronic Oral RfD [e.] (mg/kg/day)	Ingestion & Absorption Hazard Index [f.]
VPH								
C5-C8 Aliphatic	149.89	1.00	3.7E-04	1.00	3.2E-03	3.5E-03	4.00E-02	0.0885
C9-C12 Aliphatic	96.83	1.00	2.4E-04	0.50	1.0E-03	1.3E-03	1.00E-01	0.0126
C9-C10 Aromatic	151.36	1.00	3.8E-04	0.50	1.6E-03	2.0E-03	3.00E-02	0.0658
VPH Target Analytes								
Benzene	0.41	1.00	1.0E-06	0.08	6.9E-07	1.7E-06	4.00E-03	0.0004
Toluene	17.07	1.00	4.2E-05	0.12	4.3E-05	8.6E-05	8.00E-02	0.0011
Ethylbenzene	10.11	1.00	2.5E-05	0.20	4.3E-05	6.8E-05	1.00E-01	0.0007
Xylenes	39.81	1.00	9.9E-05	0.12	1.0E-04	2.0E-04	2.00E-01	0.0010
MTBE	2.58	1.00	6.4E-06	0.10	5.4E-06	1.2E-05	1.00E-01	0.0001
Naphthalene	3.17	0.36	2.8E-06	0.10	6.7E-06	9.5E-06	2.00E-02	0.0005
PCBs								
PCBs	4.28	0.85	9.0E-06	0.16	1.4E-05	2.3E-05	2.00E-05	1.1741
						TOTAL CHRONIC INGESTION & ABSORPTION HI g.=		**1.3**

Notes:

a. RAF = Relative Absorption Factor

b. The Average Daily Dose was calculated for ingestion using the following equation:

$$\text{Chronic ADD}_{ingestion} = \{[OHM]*IR*RAF*EF*ED*EP*C\}/(BW*AP)$$

c. The Average Daily Dose was calculated for dermal absorption using the following equation:

$$\text{Chronic ADD}_{dermal} = \{[OHM]*SA*AF*RAF*EF*ED*EP*C\}/(BW*AP)$$

d. Total dose is equal to the ingestion dose plus the dermal dose

$$\text{Chronic ADD}_{Total} = \text{ADD}_{ingestion} + \text{ADD}_{dermal\ absorption}$$

e. Toxicity values

f. Hazard index = ADD $_{Total}$/chronic RfD

g. Total Hazard Index = Sum of Hazard Indices

WHERE:		Value	
$[OHM]_{Soil}$ = maximum soil concentration		as shown above	
IR = Daily soil ingestion rate, child 1<8 years		100	(mg/day)
RAF = Relative Absorption Factor		as shown above	(unitless)
EF = Exposure frequency		5/7	(events/days)
ED = Average duration of each exposure event		1	(day/event)
EP = Duration of Child Exposure Period	(7mos/12mos) x 7 yrs =	4.1	(years)
C = Unit conversion factors (ingestion)		1.0E-06	
C = Unit conversion factors (dermal)		1.0E-06	
BW = Body Weight, child 1<8 years		16.8	(kg)
AP = Averaging Period, child 1<8 years		7	(years)
SA = Skin surface area in contact with soil, child 1<8 years		2434	(cm^2)
AF = Weighted Skin-Soil Adherence Factor, child 1<8 years		0.35	(mg/cm^2)

Table Dc1
Lifetime Daily Dose and Increased Cancer Risk Estimates-Soil Ingestion and Dermal Contact
Child and Older Child/Adult Resident - Exposure to AVG Soils (0-15')
88-90 South Maple Street
Westfield, MA

Chemical of Concern	Site-Wide AVG Soil (0-15') (mg/kg)	Child (1 < 8 yrs)				Child/Teen (8 < 15 yrs)				Adult (15 < 31 yrs)				Total LADD [d.] (mg/kg/day)	Slope Factor [e.] 1/(mg/kg/d)	ELCR [f.]
		Ingestion		Dermal Absorption		Ingestion		Dermal Absorption		Ingestion		Dermal Absorption				
		RAF [a.]	LADD chronic [b.] (mg/kg/day)	RAF [a.]	LADD chronic [c.] (mg/kg/day)	RAF [a.]	LADD chronic [b.] (mg/kg/day)	RAF [a.]	LADD chronic [c.] (mg/kg/day)	RAF [a.]	LADD chronic [b.] (mg/kg/day)	RAF [a.]	LADD chronic [c.] (mg/kg/day)			
VPH																
C5-C8 Aliphatic	149.89	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C12 Aliphatic	96.83	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C9-C10 Aromatic	151.36	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
VPH Target Analytes																
Benzene	0.41	1	1.0E-07	0.08	6.9E-08	1	2.1E-08	0.08	2.1E-08	1	3.6E-08	0.08	4.2E-08	2.9E-07	5.5E-02	1.6E-08
Toluene	17.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	10.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Xylenes	39.81	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTBE	2.58	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	3.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs																
PCBs	4.28	0.85	9.0E-07	0.16	1.4E-06	0.85	1.9E-07	0.16	4.5E-07	0.85	3.2E-07	0.16	8.8E-07	4.2E-06	2.0E+00	8.4E-06
															TOTAL INGESTION AND DERMAL ABSORPTION ELCR [g.] =	**8.4E-06**

NOTES:

NC = Not a Class A or B Carcinogen

NA = Not Available or Not Applicable

a. RAF = Relative Absorption Factor

b. The Lifetime Average Daily Dose was calculated for ingestion using the following equation.

LADD = {[OHM]*IR*RAF*EF*ED*EP*C}/(BW*AP)

c. The Lifetime Average Daily Dose was calculated for dermal absorption using the following equation.

LADD = {[OHM]*SA*AF*RAF*EF*ED*EP*C}/(BW*AP)

d. Total dose is equal to the ingestion dose plus the dermal dose:

$LADD_{Total}$ = ($LADD_{dermal\ absorption}$ + $LADD_{ingestion}$)Child + ($LADD_{dermal\ absorption}$ + $LADD_{ingestion}$) Older Child/Adult

e. Toxicity values

f. Excess Lifetime Cancer Risk (ELCR) = $LADD_{Soil}$ * SF

g. Total ELCR = Sum of OHM-Specific ELCR

EPC - Exposure Point Concentration

WHERE:

		Value	
$[OHM]_{Soil}$ = maximum soil concentration		as shown above	
IR_C = Daily soil ingestion rate, Child		100	(mg/day)
IR_A = Daily soil ingestion rate, Older Child/Adult		50	(mg/day)
RAF = Relative Absorption Factor		as shown above	(unitless)
EF = Exposure frequency		5/7	(events/days)
ED = Average duration of each exposure event		1	(day/event)
EP_C = Duration Exposure Period, Child	(7mos/12mos) x 7 yrs =	4.1	(years)
EP_C = Duration Exposure Period, Child/Teen	(7mos/12mos) x 7 yrs =	4.1	(years)
EP_A = Duration Exposure Period, Adult	(7mos/12mos) x 16 yrs =	9	(years)
C = Unit conversion factors (ingestion)		1.0E-06	
C = Unit conversion factors (dermal)		1.0E-06	
BW_C = Body Weight, Child		16.8	(kg)
BW_{CT} = Body Weight, Child/Teen		39.7	(kg)
BW_A = Body Weight, Adult		54.2	(kg)
AP_C = Averaging Period, Child		70	(years)
AP_{CT} = Averaging Period, Child/Teen		70	(years)
AP_A = Averaging Period, Adult		70	(years)
SA_C = Skin surface area in contact with soil, Child		2431	(cm^2)
SA_{CT} = Skin surface area in contact with soil, Child/Teen		4427	(cm^2)
SA_A = Skin surface area in contact with soil, Older Child/Adult		5654	(cm^2)
AF_C = Weighted Skin-Soil Adherence Factor, Child		0.35	(mg/cm_2)
AF_C = Weighted Skin-Soil Adherence Factor, Child/Teen		0.14	(mg/cm_2)
AF_A = Weighted Skin-Soil Adherence Factor, Adult		0.13	(mg/cm_2)

APPENDIX D

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Consultants | Engineers | Contractors

March 28, 2008

Health Department
Westfield City Hall
59 Court St.
Westfield, MA 01085

RE: Notice of Availability of Class A-3 Response Action Outcome Statement
Sunoco Station
88-90 South Maple Street
Westfield, Massachusetts 01103
DUNS: 0374-5593
MA DEP RTN: 1-15718
CEA File No. 5795-05

To Whom It May Concern:

Pursuant to the provisions of the Massachusetts Contingency Plan 310 CMR 40.1403(3)(d), Corporate Environmental Advisors, Inc. (CEA) hereby provides notification that Class A-3 Response Action Outcome (RAO) Statement has been prepared for the above-referenced Site, in accordance with 310 CMR 40.1035 of the Massachusetts Contingency Plan. This RAO is supported by a Method 3 Risk Characterization which documents that a condition of No Significant Risk (NSR) to safety, public welfare and the environment exists at the Site; however, an Activity and Use Limitation is required to achieve a condition of NSR to human health for current and future site conditions. An AUL has been recorded at the Town of Westfield Registry of Deeds concurrent with the filing of this RAO.

A copy of the above-stated documents may be reviewed at the MA DEP Northeast Region Office located at 436 Dwight Street, Suite 500 in Springfield, Massachusetts. If there are any questions, or if you wish to obtain a copy of this report from CEA, please contact the undersigned at (508) 835-8822.

Sincerely,
Corporate Environmental Advisors, Inc

Jeff Healey
Sr. Risk Assessor

ADDRESS Hartwell Business Park
127 Hartwell Street, West Boylston, MA 01583
TEL 508.835.8822 . 800.358.7960
FAX 508.835.8812
WEB www.cea-inc.com

CORPORATE ENVIRONMENTAL ADVISORS, INC.

Consultants | Engineers | Contractors

March 28, 2008

Chief Municipal Officer
Westfield City Hall
59 Court St.
Westfield, MA 01085

RE: Notice of Availability of Class A-3 Response Action Outcome Statement
Sunoco Station
88-90 South Maple Street
Westfield, Massachusetts 01103
DUNS: 0374-5593
MA DEP RTN: 1-15718
CEA File No. 5795-05

To Whom It May Concern:

Pursuant to the provisions of the Massachusetts Contingency Plan 310 CMR 40.1403(3)(d), Corporate Environmental Advisors, Inc. (CEA) hereby provides notification that Class A-3 Response Action Outcome (RAO) Statement has been prepared for the above-referenced Site, in accordance with Section 40.1035 of the Massachusetts Contingency Plan. This RAO is supported by a Method 3 Risk Characterization which documents that a condition of No Significant Risk (NSR) to safety, public welfare and the environment exists at the Site; however, an Activity and Use Limitation is required to achieve a condition of NSR to human health for current and future site conditions. An AUL has been recorded at the Town of Westfield Registry of Deeds concurrent with the filing of this RAO.

A copy of the above-stated documents may be reviewed at the MA DEP Northeast Region Office located at 436 Dwight Street, Suite 500 in Springfield, Massachusetts. If there are any questions, or if you wish to obtain a copy of this report from CEA, please contact the undersigned at (508) 835-8822.

Sincerely,
Corporate Environmental Advisors, Inc

Jeff Healey
Sr. Risk Assessor

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