7 September 2016

Sharee Rusnak
Connecticut Department of Public Health
Environmental and Occupational Health Assessment Program
410 Capital Avenue, MS#11EOH
P. O. Box 340308
Hartford, CT 06134-0308

RE: Human Health Risk Assessment Summary Letter
Western Middle School
1 Western Junior Highway
Greenwich, Connecticut
Langan Project No.: 140148201

Dear Ms. Rusnak:

Langan CT, Inc. (Langan) prepared a Human Health Risk Assessment Report (HHRA) on behalf of Greenwich Public Schools for the Western Middle School property located in Greenwich, Connecticut. The area subject to this HHRA (the "Site") includes the Western Middle School athletic fields and an undeveloped grassy area to the northwest of the fields. The Site encompasses approximately 6.9 acres of the Western Middle School parcel identified as Tax ID 04-4519/5 by the Town of Greenwich Assessor's Office.

This is being provided to your office for formal review and approval.

BACKGROUND

In June 2016, The New Lebanon School (NLS) Building Committee was evaluating the construction of temporary swing space for its students on a portion of the Western Middle School property located to the west of the existing athletic fields. As part of the evaluation, Langan was contracted to sample soils in the proposed construction area to evaluate potential environmental concerns. Laboratory analytical results of the subsurface material identified elevated concentrations of arsenic at depths ranging from 0 to 6 inches and from 2 to 2.5 feet. Although not applicable to this property, the Connecticut Department of Energy and Environmental Protection (CTDEEP) Remediation Standard Regulation (RSR) Residential Direct Exposure Criteria (RDEC) were used for comparison. Additionally, Langan collected three soil samples specifically for potential soil disposal during construction. These results indicated elevated concentrations of lead and polychlorinated biphenyls (PCBs) exceeding the RDEC at depths ranging from 0.5 to 4 feet.

Based on the results of the sampling completed for the proposed modular classroom unit at the Western Middle School, Langan completed a HHRA to provide a site-specific evaluation of potential health risks associated with the constituents identified in soils at the Subject Property. The HHRA was submitted to your office for review and comment on 29 June 2016. Following your initial review, you had requested that the remaining portions of the Western Middle School playing field be tested and incorporated into the HHRA. Although Western Middle School is no longer being considered as a swing space location for New Lebanon students, Greenwich Public Schools administration continued with the testing in order to finalize the HHRA as requested.

HUMAN HEALTH RISK ASSESSMENT

The primary goal of the HHRA is to provide a site-specific evaluation of potential health risks associated with polychlorinated biphenyls, chlordane, arsenic and lead identified in soils at the Site. Based on an evaluation of current and likely future use of the property, a list of receptor populations was identified as follows: elementary school students, middle school students, teachers, and construction workers. Cancer risks and non-cancer hazards were calculated for each of these receptors consistent with current risk assessment guidance from the United States Environmental Protection Agency (USEPA). Receptors were assessed using reasonable maximum exposure assumptions to evaluate incidental ingestion of soil, dermal contact with soil, and inhalation of fugitive dust. Site-specific lead standards were also derived for surface and subsurface soil using USEPA guidance on the assessment of intermittent or variable exposures at lead sites, and the USEPA's Adult Lead Model.

Incremental lifetime cancer risks and hazards for all receptors are summarized in the tables below. In accordance with USEPA publications, acceptable cancer risk values range from 1E-04 to 1E-06, and an acceptable hazard index is less than 1.0.

Elementary School Student

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.2	1E-06	0.03	2E-07	0.0004	3E-10	0.2	1E-06
Aroclor 1248	NA	5E-07	NA	5E-07	NA	2E-11	NA	1E-06
Aroclor 1260	NA	1E-07	NA	1E-07	NA	3E-12	NA	2E-07
Aroclor 1262	NA	3E-08	NA	2E-08	NA	8E-13	NA	5E-08
Chlordane	0.02	5E-08	0.01	1E-08	0.000002	2E-12	0.03	7E-08
						Total	0.2	3E-06

Middle School Student

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.1	1E-06	0.02	4E-07	0.0004	1E-09	0.1	2E-06
Aroclor 1248	NA	7E-07	NA	1E-06	NA	5E-11	NA	2E-06
Aroclor 1260	NA	1E-07	NA	2E-07	NA	1E-11	NA	4E-07
Aroclor 1262	NA	4E-08	NA	5E-08	NA	2E-12	NA	8E-08
Chlordane	0.009	7E-08	0.004	3E-08	0.000002	5E-12	0.01	1E-07
						Total	0.1	4E-06

Teacher

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.02	3E-06	0.004	6E-07	0.0005	1E-08	0.02	3E-06
Aroclor 1248	NA	1E-06	NA	2E-06	NA	6E-10	NA	3E-06
Aroclor 1260	NA	3E-07	NA	3E-07	NA	1E-10	NA	6E-07
Aroclor 1262	NA	6E-08	NA	7E-08	NA	3E-11	NA	1E-07
Chlordane	0.002	1E-07	0.001	4E-08	0.000002	5E-11	0.003	2E-07
						Total	0.02	7E-06

Construction Worker

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.2	1E-06	0.01	1E-07	0.08	7E-08	0.2	1E-06
Aroclor 1248	NA	7E-08	NA	3E-08	NA	5E-10	NA	1E-07
Aroclor 1254	0.03	2E-08	0.01	7E-09	NA	1E-10	0.04	2E-08
Aroclor 1260	NA	2E-08	NA	8E-09	NA	1E-10	NA	2E-08
						Total	0.3	1E-06

Lead in Soil

The USEPA's Technical Review Workgroup for lead recommends that the arithmetic mean soil lead concentration from an exposure area be applied as the exposure point concentration. The arithmetic mean lead concentration across the entire exposure domain at this Site is calculated to be 328 mg/kg, which is less than the RDEC screening value of 400 mg/kg. Applying this approach would result in no remediation being required.

However, a more conservative approach was to calculate a site-specific exposure point concentration and remediate lead in soils to that action level. Langan calculated an action level of 606 mg/kg lead in soil, in accordance with USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead in children. The site-specific standard for student exposure to lead is exceeded at surface soil locations: SS-24, SS-28, and several associated step-out sampling locations.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this HHRA, the calculated cumulative carcinogenic and non-carcinogenic risks are each below 1E-05, and within the USEPA's acceptable risk range of 1E-06 to 1E-04. The hazard index for systemic effects was well below 1.0 for all receptors, indicating adverse health effects are unlikely to occur.

Risk assessment is just one of many input factors that contribute to risk management and remedial decision-making. In addition to risk assessment, risk management is also informed by regulatory policy, social, economic, and political concerns. Often there are a variety of stakeholders in risk management decisions that have differing perspectives on risk and cleanup. Langan is committed to a framework for risk management decision-making that balances the concerns of the town and state departments of health, Greenwich Public Schools, and the affected public. Although the calculated site specific risk values fall within USEPA acceptable ranges, the following actions are proposed for the Site:

- Development and execution of action plans for the protection of students, faculty, on-site workers, community, and the environment during soil disturbance activities (i.e. remedial action plan, community air monitoring plan, etc.);
- Excavation and off-site disposal of lead impacted soils exceeding 606 mg/kg;
- Excavation and off-site disposal of PCB impacted soils exceeding 1 mg/kg;
- Collection and analysis of confirmation endpoint soil samples; and,
- Backfilling of remedial excavation areas to grade with certified clean fill.

CLOSING

Thank you for your time and guidance throughout this process, and we look forward to hearing back from you. Should you have any questions or require additional information regarding the HHRA or proposed actions, please do not hesitate to contact us.

Sincerely,
Langan CT, Inc.

Emily Strake
Senior Project Chemist/Risk Assessor

Jamie P. Barr, L.E.P.
Senior Associate/Vice President

cc: Ryan J. Wohlstrom – Langan

LANGAN

HUMAN HEALTH RISK ASSESSMENT

For

WESTERN MIDDLE SCHOOL
1 Western Junior Highway
Greenwich, Connecticut

Prepared For:

Greenwich Public Schools
290 Greenwich Avenue
Greenwich, Connecticut 06830

Prepared By:

Langan CT, Inc.
555 Long Wharf Drive
New Haven, Connecticut 06511-6107

LANGAN

September 2016
140148201

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Langan CT, Inc. (Langan) has prepared this Human Health Risk Assessment Report (HHRA) on behalf of Greenwich Public Schools for the Western Middle School property (the "Site") located in the Greenwich, Fairfield County, Connecticut (Figure 1). The Site encompasses approximately 6.9 acres of a larger, 18.75-acre parcel identified as Tax ID 04-4519/5 by the Town of Greenwich Assessor's Office.

1.1 Background and Purpose

In June 2016, The New Lebanon School (NLS) Building Committee was evaluating the construction of temporary swing space for its students on a portion of the Western Middle School property located to the west of the existing athletic fields. As part of the evaluation, Langan was contracted to sample soils in the proposed construction area to evaluate potential environmental concerns. Laboratory analytical results of the subsurface material identified impacts from arsenic at concentrations exceeding the Connecticut Department of Energy and Environmental Protection (CTDEEP) Remediation Standard Regulation (RSR) Residential Direct Exposure Criteria (RDEC) at depths ranging from 0 to 6 inches and from 2 to 2.5 feet. Additionally, Langan's waste characterization soil sampling identified impacts from lead and polychlorinated biphenyls (PCBs) at concentrations above the RDEC at depths ranging from 0.5 to 4 feet.

Based on the results of the sampling completed for the proposed modular classroom unit at the Western Middle School, Langan completed a Human Health Risk Assessment (HHRA) to provide a site-specific evaluation of potential health risks associated with the constituents identified in soils at the Subject Property. The HHRA was submitted to Sharee Rusnak with the Connecticut Department of Public Health (DPH) for review and comment. Following their initial review, the DPH requested that the remaining portions of the Western Middle School playing field be tested and incorporated into the HHRA. Although Western Middle School is no longer being considered as a swing space location for New Lebanon students, Greenwich Public Schools administration continued with the testing in order to finalize the HHRA as requested by the State DPH. The areas of the Site that are subject to this HHRA (including the previously-considered swing space and the school's athletic fields) are shown on Figures 2 and 3.

The purpose of this study is to evaluate potential human health risks posed by chemicals in soil under site-specific land use scenarios for potential receptors at the Site. This HHRA was performed in accordance with methodology developed by the United States Environmental Protection Agency (USEPA).

The following potential receptors are evaluated in this HHRA:

1. Elementary school students, previously evaluated for the installation of modular classrooms;
2. Middle school students;
3. School teachers; and,
4. Construction workers (previously assessed as part of the previous plan to use the Site as a swing space for New Lebanon School students).

Based on the land use assumption for Western Middle School, any other human receptor populations would incur lower exposure than that which is represented by the students, teachers, and construction workers.

The technical approach for the HHRA consists of the following basic steps: data analysis and identification of constituents of potential concern (COPCs), exposure assessment, toxicity assessment, and risk characterization, which includes an assessment of the uncertainty associated with each stage of the HHRA process. The HHRA uses reasonable maximum exposure point soil concentrations of chemicals to derive risks and hazards to potentially exposed human populations for all complete (or potentially complete) exposure pathways. Incomplete pathways are not relevant to human health risks and are not considered in the HHRA. Cancer risk results were compared to USEPA's acceptable cumulative risk threshold of one in ten thousand (1E-04), and non-cancer hazards were compared to a non-cancer hazard index threshold of 1.0.

2.0 PREVIOUS SITE INVESTIGATIONS

Phase I Environmental Site Assessment – Proposed NLS Modular Building Location

A Phase I Environmental Site Assessment (ESA) was completed in June 2016 (Langan 2016) to identify the presence or likely presence, use, or release on the Site of hazardous substances or petroleum products as defined in ASTM E1527-13 as a Recognized Environmental Condition (REC). Based on information obtained during the visual inspection of the Site, review of environmental databases and historic information, and contact with federal/state/local official agencies, no RECs were identified.

Limited Phase II Environmental Site Investigation – Proposed NLS Modular Building Location

A Limited Phase II Environmental Site Investigation (ESI) of the previously proposed NLS modular area was completed by Langan on 9 June 2016 to identify potential environmental issues, which may impact construction activities associated with the proposed modular building construction, and to investigate the presence and/or extent of metal-impacts to the Site's surficial soils. The Western Middle School is no longer being considered as a swing space location for New Lebanon students.

A total of eleven discrete soil borings (SB-1 through SB-3 and SS-1 through SS-8) were advanced during the Limited Phase II ESI. The locations of the soil borings are shown on Figure 2. Soil borings were advanced using direct-push and hang auger techniques to depths ranging from 0 to 2.5 feet below ground surface (bgs).

Surficial Soil Sampling Program at the Western Middle School Athletic Fields

A Surficial Soil Investigation was conducted by Langan on 27 July 2016 to characterize chemicals in soil in the athletic fields northeast of the School building. The fields are currently covered primarily with grass and secondarily with infield clay. A total of 30 surface soil samples (SS-9 through SS-38) were collected and analyzed for semivolatile organic compounds (SVOCs), herbicides, pesticides, polychlorinated biphenyls (PCBs) and metals. On 9 August 2016, additional surface soils samples were collected to delineate lead impacts identified at SS-24 and SS-28. The locations of the soil borings are shown on Figure 3. The results of the Phase II ESI and Surficial Soil Investigation were used to conduct the HHRA as discussed in the following sections.

3.0 CONCEPTUAL SITE MODEL

This section presents a Human Health Conceptual Site Model (CSM) for the 6.3-acre area comprising the athletic fields and the 0.6-acre area to the northwest of the athletic fields (formerly proposed area for the NLS modular buildings). As part of the Human Health CSM, potential receptors are assessed in order to determine whether potentially complete exposure pathways exist. An exposure pathway is considered complete if all four of the following elements exist:

1. A source of constituents of potential concern (COPC);
2. A potential transport mechanism to an exposure medium (this is not needed if the source medium is the exposure medium);

3. Contact between a potential receptor and the exposure medium; and
4. An uptake mechanism associated with the potential receptor (e.g., dermal absorption).

3.1 Potential Constituent Migration Routes

As part of the human health CSM, potential migration routes (transport mechanisms) for constituents in surface and subsurface soil were evaluated, taking into consideration hydrogeological conditions. The potential constituent migration routes retained for receptor-specific evaluation include:

Surface Soil and Subsurface Soil

- Particulate emission of entrained constituents (fugitive dust) from surface soil to outdoor air;
- Particulate emission of entrained constituents from subsurface soil exposed through intrusive activities to outdoor air;
- Leaching of constituents from subsurface soil to groundwater

Langan believes that there are no potentially complete exposure pathways to groundwater based on the following conditions:

- Groundwater is not currently used for any purpose at the Site: The Site is provided water by the same municipal supply that serves the town of Greenwich. According to the *Water Quality Classifications Greenwich, CT* map (CTDEEP, November 2015) the groundwater underlying the Subject Property is GB. Based on the Connecticut Water Quality Standards and Criteria, Class GB designated uses are industrial process water and cooling water, and baseflow for hydraulically-connected water bodies. The groundwater is presumed not suitable for human consumption without treatment.
- Depth-to-Groundwater: The Phase II ESI indicated depth-to-groundwater is greater than 11 feet bgs. At these depths, there is no plausible condition for receptors to be exposed to groundwater.

Based on this rationale, exposure to groundwater is not considered a complete exposure pathway for students or faculty, and thus is not evaluated in the HHRA.

3.2 Potential Receptors and Exposure Pathways

The portion of the Site previously designated for installation of temporary modular classrooms and the School's athletic fields (Figures 2 and 3) has been identified as a single unit of exposure for students and teachers. The construction worker was assumed to incur exposure to constituents only in the area of the Site previously designated to receive the modular classrooms (Figure 2). Receptors were selected to represent individuals who are most likely to come into contact with source media based on the use of the parcel. Descriptions of the elementary school student, middle school student, teacher, and construction worker are provided below along with the exposure pathways that are retained. Exposure pathways are retained based on the potential sources of COPCs, migration potential, and the activities of the receptor.

<u>Students</u>

The students are assumed to come into contact with soil covered primarily with grass and secondarily with infield clay. Given that students on-site would likely be exposed to surface soil only, potentially complete exposure pathways for the student include incidental ingestion of soil, dermal exposure to soil, and inhalation of fugitive dust from wind erosion of soils to a depth of 0.5 feet bgs. The grass field that is part of the previously designated modular building area may also support recreation and sporting activities (i.e., playgrounds, ball fields, etc.).

The student receptor is divided into two potential receptor groups: an elementary school student (age 6 years, kindergarten) and a middle school student (11-13 years, grades 6 through 8). This division allows for a more realistic risk evaluation in that age-specific factors can be applied to exposure models. The elementary school student was evaluated for the previously proposed installation of modular classrooms on the portion of the Subject Property. The redevelopment project has subsequently been withdrawn.

<u>Teacher</u>

As a result of the continued use of the property as a school, teachers are considered appropriate receptors to be evaluated. The teacher is potentially exposed to COPCs in surface soil (0 to 0.5 feet bgs) during supervision of outdoor activities. Potentially complete exposure pathways for the teacher include incidental ingestion of soil, dermal contact with soil, and inhalation of fugitive dust.

Construction Worker

The construction worker is an individual who would be involved in excavation and grading operations on the 0.6-acre area previously proposed for redevelopment. The construction worker is assumed to come in contact with both surface and subsurface soil to a maximum depth of 4 feet bgs. Potentially complete exposure pathways for the construction worker include incidental ingestion of soil, dermal contact with soil, and inhalation of fugitive dust.

4.0 DATA ANALYSIS

This section presents the soil data used in this HHRA, including: a description of the dataset, results of the data screening used to identify COPCs, and the process used to calculate exposure point concentrations (concentrations of constituents that may be contacted by receptors).

4.1 Regulatory Background

The analytical results for soil were compared to the numeric criteria listed in the Connecticut RSRs, sections 22a-133k-1 through 22a-133k-3 of the Regulations of Connecticut State Agencies dated January 1996, and to numeric criteria in the "Approved Criteria for Additional Polluting Substances" dated 30 April 1999. The RSRs were developed by the CTDEEP to define the remediation performance standards for soil and groundwater, specific numeric cleanup criteria, and processes for establishing alternative site-specific standards. The RSRs apply specifically to sites at which remedial actions are required by the CTDEEP under Chapters 445 or 446k of the Connecticut General Statutes such as under an administrative order, subsequent to a transfer of an establishment under CGS Section 22a-134a, and to sites that are enrolled in a Voluntary Remediation Program under CGS Sections 22a-133x or 22a-133y.

The Subject Property is not formally enrolled in, or subject to a CTDEEP program; however, Langan used the numeric criteria in the RSRs as guidelines to assess the Subject Property and to draw conclusions regarding concentrations of regulated compounds detected in soil. The following sections provide a brief summary of the criteria evaluated during this environmental investigation.

The RSRs provide two criteria for soil: the Direct Exposure Criteria (DEC) and Pollutant Mobility Criteria (PMC), summarized below.

Direct Exposure Criteria

The DEC is established to protect human health from risks associated with direct exposure to pollutants in contaminated soil within 15 feet of the ground surface. Different DEC apply to a property depending on land use, either "residential" or "industrial/commercial", as defined by the CTDEEP. The CTDEEP defines use of a property as a school as "residential".

Pollutant Mobility Criteria

The PMC is established to protect groundwater quality by reducing or eliminating the migration of pollutants to the groundwater from contaminated soil. Different PMC apply to a property depending on the quality of groundwater at the site, as designated by the CTDEEP. In a "GB" groundwater classification area, the GB PMC apply to soil located above the seasonal high water table (CGS 22a-133k-2(c)(1)).

4.2 Identification of Constituents of Potential Concern

The soil data set for the elementary school student, middle school student, and teacher evaluations included 38 soil samples collected from the 0 to 0.5 feet bgs interval (Table 1). The soil data set used for the construction worker included 11 samples collected from the 0 to 2.5 feet bgs interval, and three composite samples collected from 0.5 to 4 feet bgs (Table 1).

4.2.1 Student and Teacher Data Set

The maximum detected constituent concentrations in soil were compared to the CTDEEP RDEC for soil to establish a list of COPCs for students and teachers. Arsenic, lead, chlordane and PCBs (as Aroclors) were identified as COPCs and carried forward in the HHRA for quantitative evaluation. The following table presents summary statistics for the student and teacher COPCs:

Constituent	*Detection Frequency*	*Maximum Concentration (mg/kg)*	*Number of RDEC Exceedances*
Arsenic	38/38	37 (SS-5)	5
Lead	38/38	1,640 (SS-24)	5
Chlordane	20/30	6.76 (SS-22)	18

Constituent	*Detection Frequency*	*Maximum Concentration (mg/kg)*	*Number of RDEC Exceedances*
Aroclor 1248	10/30	4.19 (SS-37)	--
Aroclor 1260	18/30	0.845 (SS-37)	--
Aroclor 1262	1/30	0.2 (SS-21)	--
Total PCBs	20/30	5.03 (SS-37)	2

4.2.2 Construction Worker Data Set

The maximum detected constituent concentrations in soil at the previously proposed modular building area were compared to the Connecticut Department of Energy and Environmental Protection (CTDEEP) Residential Direct Exposure Criteria (RDEC) for soil to establish a list of COPCs. Arsenic was the only COPC in surface and subsurface soil to be identified and carried forward in the HHRA for quantitative evaluation in the previously proposed modular construction area. Arsenic naturally occurs throughout Connecticut at concentrations above risk-based screening levels; however, the CTDEEP DEC for arsenic (10 mg/kg) represents a background arsenic concentration. In the context of this document, "background" refers to arsenic concentrations that represent natural abundance conditions in areas that have not been impacted by a chemical release. Thus, the exceedance of the arsenic DEC indicates the presence of arsenic above background, but does not characterize arsenic in terms of the potential health effects of exposure consistent with residential or non-residential default exposure scenarios.

Composite waste characterization samples were also collected at the previously proposed modular building area in June 2016. Lead exceeded the CT RDEC (400 mg/kg) in one five-point composite sample collected from depths ranging from 0.5 to 4 feet bgs at a concentration of 685 mg/kg. Lead was not detected above the RDEC in discrete surface soil samples in the area designated for redevelopment. Given that the construction worker is the only receptor potentially exposed to subsurface soil, lead was carried forward for quantitative evaluation in the risk assessment for this receptor.

One composite waste characterization sample exhibited an exceedance of the RDEC (1 mg/kg) for polychlorinated biphenyls (PCBs) at a concentration of 1.57 mg/kg. To maintain the conservatism of the risk assessment, PCBs were carried forward in the quantitative evaluation of the construction worker.

4.3 Exposure Point Concentrations

The exposure point concentration is the concentration of a constituent in a medium (e.g., surface soil) that is expected to be contacted by an individual and is assumed to be universally present throughout the Site. For this HHRA, the 95% upper confidence limit (UCL_{95}) of the mean arsenic and chlordane concentrations were utilized in the receptor-specific exposure models to develop conservative estimates of exposure and risk for each scenario and to account for uncertainty associated with deriving a reasonable upper bound exposure concentration based on the available soil data. The UCL_{95} is typically used as an appropriate reasonable maximum exposure (RME) estimate of concentrations likely to be contacted over time, and is the recommended exposure point concentration in human health risk assessments, except in cases where the UCL_{95} is higher than the maximum concentration (USEPA 1989, 1992). The intent of the RME is to estimate a conservative exposure case (i.e., well above the average case) that is still within the range of possible exposures.

The USEPA's ProUCL (Version 5.1) software was used to calculate the UCL_{95}. Since the calculation of the UCL_{95} is dependent on the underlying distribution of sample data, this software tests for normality, lognormality, and a gamma distribution of the dataset (Singh et al. 2004). Calculation of a reliable estimate of the UCL_{95} requires sample data from four samples or more; arsenic and chlordane had sufficient datasets to calculate the UCL_{95} using ProUCL for associated receptors. In the 0-2.5 feet bgs dataset used to evaluate construction worker risks and hazards, arsenic concentrations were gamma distributed; therefore, the UCL_{95} was calculated to be 22.86 mg/kg using the 95% adjusted gamma UCL. The 0-0.5 feet bgs dataset used to evaluate students and teachers was non-parametric; therefore, the UCL_{95} was calculated to be 11.1 mg/kg using the 95% Chebyshev (Mean, Sd) UCL. Chlordane was normally distributed in surface soil; thus, the 95%Kaplan-Meier (t) UCL was used and is equivalent to 2.271 mg/kg.

For sample locations with field duplicates, the higher of the parent sample and field duplicate result was selected to maintain the conservatism of the assessment (Table 1). Dixon's Outlier Test was performed to evaluate potential outliers in the datasets, and the results indicate the concentration detected at location SS-5 (37 mg/kg) is a statistical outlier at 5% significance. However; the result was utilized in the derivation of the EPC for all receptor exposure models to err on the side of health-protectiveness.

A box plot was developed to provide a graphical display of the outlier (Appendix A). The horizontal line within the box represents the median arsenic concentration (y-axis in mg/kg), and the upper and lower ends of the box are the spread of the central portion of the data with 25% above and below the range. The whiskers show the extent of the data (right [low end] and left [high end] tails) and the second point above the horizontal fences depicts the SS-5 result at 37 mg/kg.

The number of detections for Aroclors was limited; therefore, the maximum detected concentration of individual Aroclors was used as the RME EPC for all associated receptors.

5.0 EXPOSURE ASSESSMENT

This section presents the equations and assumptions used to calculate constituent intakes for the incidental ingestion and dermal contact exposure pathways, and exposure concentrations for the inhalation exposure pathway (fugitive dust).

Based on the evaluation presented in Section 3.0, calculations were completed for the following exposure pathways and receptors:

- Incidental ingestion of soil (0 to 0.5 feet bgs) for the elementary school student, middle school student and teacher;
- Dermal contact (dermal exposure) with soil (0 to 0.5 feet bgs) for the elementary school student, middle school student and teacher; and,
- Inhalation of fugitive dust for the elementary school student, middle school student and teacher (0 to 0.5 feet bgs).
- Incidental ingestion of soil (0 to 4 feet bgs) for the construction worker;
- Dermal contact with soil (0 to 4 feet bgs) for the construction worker;
- Inhalation of fugitive dust for the construction worker (0 to 4 feet bgs);

These exposure pathways are the focus of this section, which is divided into three parts: the first part presents the intake equations for the incidental and dermal contact exposure pathways; the second part presents the exposure concentration equations for the inhalation exposure pathway; and the third part presents the receptor-specific assumptions used.

5.1 Intake Calculations

This section presents the intake (or absorbed dose) equations for the incidental ingestion and dermal contact exposure pathways identified above. Chemical exposure/intake is expressed as the amount of the agent at the exchange boundaries of an organism (e.g., skin, lungs, and intestinal tract) that is available for systemic absorption. If the exposure occurs over time, the total exposure can be divided by the time-period of interest to obtain an average exposure rate (e.g., mg/kg-day) applicable to arsenic, chlordane and PCBs.

5.1.1 Incidental Ingestion of Soil

As presented in Exhibit 6-14 of the *Risk Assessment Guidance for Superfund* (RAGS) Part A (USEPA 1989), the equation for estimating a time-weighted average intake from incidental ingestion of soil is:

$$Intake = \frac{C_S \times IngR \times EF \times ED \times CF}{BW \times AT}$$

where:

Intake = Intake from incidental ingestion of soil (mg/kg-day);

C_S = Constituent source concentration in soil (mg/kg);

IngR = Incidental soil ingestion rate (mg/day);

EF = Exposure frequency (days/year);

ED = Exposure duration (years);

CF = Conversion factor (1×10^{-6} kg/mg)

BW = Body weight of exposed individual (kg); and

AT = Averaging time (period over which exposure is averaged, usually measured in days).

The ingestion rate (*IngR*) is the amount of soil incidentally ingested per day or event, and is receptor-specific. The exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are also receptor-specific and defined in the intake assumptions for each receptor (Section 5.3). The averaging time (*AT*) for carcinogenic effects (AT_c) is 25,550 days (based on a lifetime of 70 years multiplied by 365 days/year) and applies to all receptors (USEPA 1991). The averaging time for non-carcinogenic effects (AT_n) is equal to the receptor-specific exposure duration multiplied by 365 days/year.

5.1.2 Dermal Exposure to Soil

As presented in RAGS Part E (USEPA 2004), the equation for estimating a time weighted average intake (absorbed dose) from dermal exposure to soil is:

$$Intake = \frac{DA_{event} \times SA \times EF \times ED \times EV}{BW \times AT}$$

where:

Intake = Absorbed dose from dermal exposure to soil (mg/kg-day);

DA_{event} = Absorbed dose per event (mg/cm^2-event);

SA = Exposed skin surface area (cm^2);

EF = Exposure frequency (days/year);

ED = Exposure duration (years);

EV = Event frequency (events/day);

BW = Body weight of exposed individual (kg); and,

AT = Averaging time (period over which exposure is averaged, usually measured in days).

The exposed skin surface area (SA), EF, ED, event frequency (EV), and BW are receptor-specific and defined in the intake assumptions for each receptor (see Section 5.3). The averaging time (AT) is discussed above. Finally, the dermal absorption per event (DA_{event}) is estimated using the equation:

$$DA_{event} = C_S \times AF \times ABS \times CF$$

where:

C_S = Constituent source concentration in soil (mg/kg);

AF = Soil adherence factor (mg/cm^2);

ABS = Soil absorption factor (mg/mg); and,

CF = Conversion factor (1×10^{-6} kg/mg).

The soil adherence factor (AF) is the density of soil adhering to the exposed fraction of the body and is receptor-specific. The soil absorption factor (ABS) is constituent-specific and accounts for the fraction of the constituent absorbed from soil through the skin.

5.1.3 Lead Intake

Risk characterization of lead is independent of the cumulative risk and hazard estimates for the chemicals described in Section 5.1.1 and 5.1.2. The potential health hazard from exposure to lead are estimated based on predicted blood lead levels in sensitive populations. The general equation for exposure to lead from soil (direct and through indoor soil-derived dust) as defined by USEPA (2003):

$$Intake\left(\frac{ug}{day}\right) = \frac{PbS \times IR \times EF}{AT}$$

where:

Intake = Daily average intake (ingestion) of lead from soil taken over the averaging time (μg/day)

PbS = Soil lead concentration (μg/g) (appropriate average concentration for individual)

IR = Intake rate of soil, including outdoor soil and indoor soil-derived dust (g/day)

EF = Exposure frequency for contact with assessed soils and/or dust derived in part from these soils (days/year)

AT = Averaging time (the total period during which soil contact may occur)

Lead uptake is the daily average uptake of lead from the gastrointestinal tract into systemic circulation (μg/day) and is derived by multiplying intake from the equation above by the dimensionless absolute gastrointestinal absorption fraction (AF) for ingested lead in soil and lead in dust derived from soil.

5.2 Exposure Concentration Equations

When estimating risk via inhalation, it is recommended that the concentration of the constituents in air be used as the exposure metric (e.g., mg/m^3) rather than the inhalation intake of a constituent in air based on inhalation rate and body weight (USEPA 2009). This section presents the exposure concentration equations for the inhalation of fugitive dust exposure pathway.

Based on RAGS Part F (USEPA 2009), the equation for estimating the exposure concentration from inhalation of fugitive dust is:

$$EC = \frac{C_A \times ET \times EF \times ED}{AT}$$

where:

EC	=	Exposure concentration (mg/m^3);
C_A	=	Constituent source concentration in air (mg/m^3);
ET	=	Exposure time (hr/day);
EF	=	Exposure frequency (days/year);
ED	=	Exposure duration (years); and
AT	=	Averaging time (hours).

The exposure time (ET), EF, and ED are receptor-specific and defined in the intake assumptions for each receptor (see Section 5.3). The AT_c is 613,200 hours (based on a lifetime of 70 years) and applies to all receptors (USEPA 1991). The AT_n is equal to the receptor-specific ED in hours.

The constituent source concentration in air is calculated using the equation:

$$C_A = C_S \times \left(\frac{1}{PEF}\right)$$

where:

C_S	=	Constituent source concentration in soil (mg/kg); and
PEF	=	Particulate emission factor (m^3/kg).

The particulate emission factor (PEF) converts constituent concentrations in soil to constituent concentrations on dust particles in the air as a result of fugitive dust emissions from bare surfaces of fine-grained soils. Particulate emissions from soil-impacted sites are due to wind erosion, and therefore depend on the potential erosion of the soils.

In the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2002), the USEPA provides the methodology required to calculate the PEF. Separate equations were used to estimate the PEF for the construction worker, students and teachers.

Students and Teachers

Students and teachers may be exposed to constituents in soil via inhalation of fugitive dust particles. Inhalation exposures to dust-entrained constituents for students and teachers were estimated using a methodology originally developed by the USEPA for commercial/industrial land uses in RAGS Part B (USEPA 1991), and further described in USEPA 1996 and USEPA 2002. The equation used to derive the PEF for the students and teachers is as follows:

$$PEF = (Q/C) \times \frac{3600}{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x)}$$

where:

Q/C	=	Inverse dispersion factor (g/m^2-sec)/(kg/m^3);
V	=	Fraction of vegetative cover (unitless);
U_m	=	Mean annual wind speed (m/sec);
U_t	=	Equivalent threshold value of wind speed at 7 m (m/sec); and
F(x)	=	Function dependent on U_m/U_t.

The inverse dispersion factor (Q/C) for students and teachers is 47.44 (g/m2-sec)/(kg/m3) based on a site area (A_{site}) of 6.9 acres and the constants presented above. Site-specific values for the fraction of vegetative cover (V) and mean annual wind speed (U_m) were estimated to derive the PEF. The value of V was set at 0.50 based on the conservatively predicted proportions of vegetation and continued maintenance of the grass-covered fields. The value of U_m was set at 5.9 m/s based on available wind speed data for Greenwich, Connecticut for the period of 1980 to 2010 (USA.com 2016). Default parameter values provided in Equation 4-5 of USEPA 2002 were utilized for U_t

(11.32) and F(x) (0.194). Based on the values presented above, the resulting PEF for students and teachers is 3.46E+08 m^3/kg.

Construction Worker

Construction workers may inhale wind-borne dust particles during a variety of construction activities. The USEPA considers the majority of dust emissions during construction to be liberated from truck traffic on unpaved roads. Consequently, the PEF is based on fugitive dusts that may be generated as a result of construction traffic. The equation used to derive the subchronic PEF for the construction worker is as follows:

$$PEF = (Q/C) \times \left(\frac{1}{F_D}\right) \times \left[\frac{T \times A_R}{556 \times (W/3)^{0.4} \times \frac{365-p}{365} \times \sum VKT}\right]$$

where:

Q/C	=	Inverse dispersion factor (g/m^2-sec)/(kg/m^3);
F_D	=	Dispersion correction factor (unitless);
T	=	Total time over which construction occurs (sec);
A_R	=	Surface area of contaminated road segment (m^2);
W	=	Mean vehicle weight (tons);
p	=	Number of days with at least 0.01 inch of precipitation (days/year); and
$\sum VKT$	=	Sum of fleet vehicle kilometers traveled during the exposure duration (km).

The inverse dispersion factor (Q/C) is calculated using the equation (USEPA 2002):

$$Q/C = A \times \exp\left[\frac{(\ln A_{site} - B)^2}{C}\right]$$

where:

A	=	Constant (12.9351, default from Equation 5-6 of USEPA 2002);
B	=	Constant (5.7383, default from Equation 5-6 of USEPA 2002);
C	=	Constant (71.7711, default from Equation 5-6 of USEPA 2002); and,

A_{site} = Affected area of site (acres).

The inverse dispersion factor (Q/C) for the construction worker is 22.29 (g/m2-sec)/(kg/m3) based on a site area (A_{site}) of 0.60 acres (approximate size of the portion of the parcel proposed for redevelopment) and the constants presented above. The default parameter value provided in Equation 5-5 of USEPA 2002 was utilized for F_D (0.185).

Site-specific values for the total time over which construction occurs (T), surface area of contaminated road segment (A_R), mean vehicle weight (W), and vehicle kilometers traveled (VKT) used to derive the PEF for the construction worker include:

The value of T was set at 3.15E+07 seconds, which is based on the exposure duration (ED) of 1 year. As presented in USEPA (2002), the value for A_R is determined from an assumed length of road segment (LR) and width of road segment (WR). Assuming that the affected area of the site (A_{site} of 0.60 acres or 2,428 m^2) is configured as a square with the unpaved road segment dividing the square evenly (USEPA 2002), the road length would be equal to the square root of A_{site} (approximately 49 m or 0.049 km). Based on the assumption of a road width equal to 60 feet (18.3 m), the surface area of contaminated road equals 902 m^2.

The mean vehicle weight (W) was set at 8 tons, which is based on the assumption of 20 two-ton cars and 10 20-ton trucks driving daily on the Site during the 180 day construction period (USEPA 2002).

The sum of vehicle kilometers traveled (∑VKT) was set at 2,171 km, which is based on the assumption of the 30 vehicles driving the length of the road once per day on the Site during the 180-day construction period (USEPA 2002).

For the Greenwich area, the estimated mean number of days with precipitation equal to or greater than 0.01 inch per year is 150 days (USEPA 2002). Based on these values, the resulting PEF for the construction worker is 3.26E+06 m^3/kg.

5.3 Exposure Parameters

This section presents the receptor-specific exposure assumptions for the middle school student, elementary school student, teacher, and construction worker. The receptor-specific exposure parameters quantify activity patterns and body characteristics for each of the receptors, such as the amount of time a receptor may spend at the Site, the frequency the receptor visits the Site, body weight of the receptor, and soil ingestion rates. The receptor-specific exposure assumptions were selected using USEPA default assumptions, when available. Otherwise, reasonable assumptions were made based on site-specific information and best professional judgment.

5.3.1 General Exposure Parameters

Constituent concentration, exposure frequency (EF), exposure duration (ED), averaging time (AT), and body weight (BW) are general parameters that are included in the intake calculations for each exposure route.

The EF describes the number of times per year an event is likely to occur. Variables such as weather, vacations, and institutional controls are considered when determining reasonable and realistic exposure frequencies. The following is a summary of the EFs applied in the receptor-specific exposure models:

- For the elementary and middle school students, an EF of 180 days was assumed, consistent with the number of school days in the school year.
- For the teacher, an EF of 250 days was assumed, consistent with USEPA default value for indoor workers.
- For the construction worker scenario, an EF value of 180 days per year was assumed, which corresponds to five days per week for 36 weeks of construction work. This conservative number was derived using professional judgment and is considered to best represent an upper bound exposure experienced by a construction worker at the Site. Typical construction projects generally involve several phases of activity prior to completion. To complete each of these phases, a different team of specialized contractors is usually employed to perform the tasks for which they are most qualified. As a result, an individual may only remain at the construction site for a few weeks until his/her task is complete and the next phase is initiated. This is often the case for those activities involving direct contact with soil. Thus, an EF of 180 days per year for the construction worker scenario is considered to be conservative.

The ED parameter in the intake equation represents the number of years over which an event is likely to occur. Factors affecting this parameter include variables such as age of the receptor and population mobility. The EDs applied for each receptor is discussed below:

- For the elementary school student: An ED of 1 year was originally used based on the assumption that the use of modular classrooms by these students was temporary.
- For the middle school student: An ED of 3 years was assumed based on the typical duration of middles school attendance for grades six through eight.
- For the teacher: A value of 25 years was used to assess exposure, based on the USEPA default value for non-residential exposures.
- Construction worker: The construction worker ED value utilized in the exposure model was one year, a reasonable assumption based on the previously proposed modular building area.

For inhalation exposure scenarios, it is necessary to apply an exposure time (ET) to account for the number of hours spent at the Site. All receptors were assumed to be on-site for a typical (8-hour) day; therefore, 8 hours was selected as the appropriate ET.

The AT parameter is the period over which exposure is averaged. For non-carcinogenic effects, AT_n was used in calculating an average daily exposure, and is calculated as the product of the receptor-specific exposure duration and the 365 days of the year.

The assumptions for AT_n are described as follows:

- Given that the construction worker is presumed to be on-Site for one year, the non-carcinogenic averaging time for this receptor was 365 days.
- The AT_n value for an elementary school student was set to 365 days (365 days x 1 years).
- The AT_n value for a middle school student was set to 1,095 days (365 days x 3 years).
- The AT_n value for a teacher was set to 9,125 days (365 days x 25 years).

Exposures to carcinogens were averaged over a lifetime. The carcinogenic averaging time (AT_c) is the product of a 365-day year and a 70-year lifetime, or 25,550 days. This value was used for all receptor scenarios, in keeping with USEPA guidance.

The body weight (BW) used for the construction worker and teacher was set at 176 lbs, in accordance with USEPA recommendations for adult body mass. For the elementary school student, a body weight of 48 lbs was applied to the exposure models. This represents the mean body weight estimate for combined male and female 6 year-olds (USEPA 2011). The BW for middle school students was calculated as the mean BW for male and female individuals age 11 to 13 (47.8 kg or 105 lbs) (USEPA 2011).

5.3.2 Route-Specific Exposure Parameters

Intakes due to contact with chemicals vary, depending largely on the physicochemical properties of the chemical and the pathway by which the chemical enters the body. Dermal contact, ingestion, and inhalation exposure-specific parameters take these differences into account and are addressed in this section.

Incidental Ingestion of Soil

The intake rate is the soil ingestion rate for oral exposures to soils.

- For the student scenarios, a soil ingestion rate of 200 mg/day was conservatively selected, consistent with the USEPA ingestion rate for children under a residential land use assumption.
- The USEPA default soil ingestion rate for nonresidential exposures (indoor worker) was utilized for the teacher exposure scenario (50 mg/day).
- Given the nature of the activities associated with construction (e.g., grading, excavation), the construction worker scenario is anticipated to be more soil contact-intensive than a generic non-residential worker scenario. As such, a USEPA soil ingestion rate of 330 mg/day was adopted for this assessment based on the USEPA recommended value for a construction worker (USEPA 2002).

Dermal Exposure to Soil

The following route-specific parameters have been included to estimate dermal uptake of constituents for the selected receptors: skin surface area available for exposure, skin soil adherence factor, and dermal absorption factor.

Skin Surface Area Available for Exposure: The amount of skin available for exposure (SA) is strongly dependent on the age of the receptor and the nature of activity or work they are doing. Values for the SA parameter are described for each receptor as follows:

- For the elementary school student scenario, the SA was set to 6,520 cm^2. This is the mean skin surface area for individuals aged six to eleven years assuming the head, arms, hands, feet and legs are exposed (USEPA 2011).
- For the middle school student scenario, the SA was set to 9,600 cm^2. This is the mean skin surface area for individuals aged 11 through 16 years assuming the head, arms, hands, feet and legs are exposed (USEPA 2011).
- For the construction worker and teacher scenarios, an exposed surface area of 3,527 cm^2 was assumed. This value assumes that the head, hands, and forearms are exposed (USEPA 2011).

Soil-to-Skin Adherence Factor: The soil-to-skin adherence factor (AF) is influenced by soil types and varies considerably across different parts of the body (USEPA 2004). Values for the AF parameter were extracted from USEPA (2004), and are described for each receptor below:

- For the student scenarios, the resident soil adherence factor for children (0.2 mg/cm^2) was used.
- For the teacher scenario, the USEPA recommends a body part-weighted AF of 0.12 mg/cm^2 (composite worker).
- For the construction worker scenario, the USEPA recommends a body part-weighted AF of 0.3 mg/cm^2.

Dermal Absorption Fraction: Another exposure factor necessary to estimate dose, and therefore, risk via dermal contact with impacted soils, is the absorption factor (ABS) of the specific constituent from soil. The ABS is used to estimate an absorbed dose that reflects the absorption of a chemical across the skin and into the blood stream. The absorbed dose is typically a fraction of the amount of the chemical that actually contacts the skin. The USEPA (2004) recommends ABS values of 0.03 for arsenic, 0.04 for chlordane and 0.14 for PCBs. These ABS values were used to estimate dermal exposures to arsenic, chlordane and PCBs for associated receptors. There is no ABS for lead.

6.0 TOXICITY ASSESSMENT

This section presents the toxicity assessment for the Western Middle School HHRA. Toxicity assessment involves the evaluation of available toxicity information to be used in the risk assessment process. Toxicity values derived from dose-response relationships can be used to estimate the potential for the occurrence of adverse effects in individuals exposed to various constituent levels. In accordance with recent USEPA guidance, toxicity values specific to the oral and inhalation pathways were obtained from the sources listed hierarchically below:

- Integrated Risk Information System (IRIS) on-line database;
- Provisional peer-reviewed toxicity values (PPRTV) obtained from the USEPA's Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center;
- Health Effects Assessment Summary Tables (HEAST); and,
- Other peer-reviewed sources of toxicity data.

6.1 Non-Carcinogenic Toxicity Values

Adverse effects can be caused by acute exposure, which is a single or short-term exposure to a toxic substance, or by chronic exposure to lower levels on a continuous or repeated basis over an extended period of time. "Acceptable" acute or chronic levels of exposure to non-carcinogens are considered to be levels without any anticipated adverse effects. Such exposure levels are commonly expressed as reference doses (RfDs) and reference concentrations (RfCs). An acceptable exposure level is calculated to provide an adequate margin of safety.

RfDs have been developed by the USEPA for chronic (e.g., lifetime) exposure to constituents based on the most sensitive non-carcinogenic effects. Chronic RfDs, which have been derived for a number of chemicals, are used to evaluate exposures lasting 7 to 70 years (USEPA 1989) for exposure scenarios such as the teacher. Subchronic RfDs, if available, are used to evaluate exposures of shorter duration (2 weeks to 7 years). Due to the lack of available subchronic values, only chronic RfDs and RfCs were used in this HHRA. Oral RfDs and inhalation RfCs were extracted from USEPA's Integrated Risk Information System (IRIS). The non-carcinogenic toxicity values are provided in the table below:

Constituent	*Reference Dose (mg/kg-day)*	*Reference Concentration (mg/m^3)*
Arsenic	3.0E-04	1.5E-05
Chlordane	5.0E-04	7.0E-04
Aroclor 1254	2.0E-05	--

6.2 Carcinogenic Toxicity Values

Carcinogenic risk refers to the probability of developing cancer resulting from exposure to known or suspected carcinogens. A cancer slope factor (CSF) is a plausible upper-bound estimate of the probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen. Cancer slope factors were used to determine the oral excess cancer risks associated with arsenic, chlordane and PCBs at the Site. Similarly, Inhalation Unit Risks (IURs) were used to evaluate the inhalation pathway. Oral CSFs and inhalation IURs used in the HHRA were extracted from USEPA's IRIS. The carcinogenic toxicity values are provided in the table below:

Constituent	*Oral Cancer Slope Factor (mg/kg-day)$^{-1}$*	*Inhalation Unit Risk (μg/m^3)$^{-1}$*
Arsenic	1.5+00	4.3E-03
Chlordane	3.5E-01	1.0E-01
Aroclors 1248, 1254, 1260 and 1262	2.0+00	5.7E-04

6.3 Adjustment for Dermal Absorption

Toxicity criteria have not been developed by the USEPA specifically for dermal absorption; instead, oral toxicity criteria are adjusted to assess the dermal exposure pathway. In order to have a meaningful comparison between the dermal absorption dose estimates, which represent internal (or absorbed) doses, and oral toxicity criteria, which typically represent potential (or administered) doses, toxicity criteria are modified to represent absorbed doses.

Toxicity values are adjusted for gastrointestinal absorption only if chemical-specific gastrointestinal absorption values are less than 50 percent. For arsenic, chlordane, and PCBs, no adjustment for dermal absorption is necessary (USEPA 2004).

6.4 Bioavailability of Arsenic

Relative bioavailability (RBA) is the ratio of the absorbed fraction from soil at the Site to the absorbed fraction from the dosing medium used in the critical toxicity study. USEPA's *Recommendations for Default Value for Relative Bioavailability of Arsenic in Soil* (December 2012) determined that the empirical distribution of RBA values for arsenic suggest arsenic RBA exceeding 60% is relatively uncommon. A 100% RBA was conservatively assumed for the elementary school student, middle school student, teacher, and construction worker risk characterization models.

6.5 Lead Toxicity

Inorganic lead does not currently have a RfD. Instead, the potential health hazard from exposure to environmental lead can be estimated based on predicted blood lead levels in sensitive populations. The USEPA's Technical Review Workgroup (TRW) has developed an interim guidance for assessing lead risks and establishing action levels for lead that are protective of both adults and the fetus of a pregnant adult. Action levels and target blood lead levels are estimated using USEPA's Adult Lead Model (ALM) (USEPA, 2003). The primary assumption in the ALM methodology is that the most sensitive receptor is the developing fetus of a worker exposed in the workplace, since the USEPA identified the developing fetus as part of the sensitive U.S. population. For the Western Middle School Site, this would be defined as a construction worker that becomes pregnant in the course of the exposure duration. The lead model does not assume that a pregnant worker is present at the site for the entire pregnancy, rather, that the worker has worked at the site long enough to result in an elevated blood lead level (PbB) to which a fetus could be subsequently exposed.

The ALM methodology is designed to estimate an average soil lead concentration that is not expected to result in a greater than 5% probability that the fetus of a female worker of child-bearing age has a blood lead level exceeding the level of concern of 10 µg/dL of blood (USEPA, 2003).

The derivation of a health-protective remediation goal for students was calculated consistent with USEPA guidance regarding intermittent or variable exposures (USEPA

2003a). The student screening level was based on achieving a weighted average soil lead concentration of 400 mg/kg, assuming that a child is exposed part of the year to soil at home (hypothetically) and part of the year to soil at the Site. The following assumptions were used in the calculation:

- The weighted soil lead level for student exposure may not exceed 400 mg/kg. The 400 mg/kg value is the USEPA default residential soil screening level that corresponds to a 5 percent probability of exceeding a PbB concentration of 10 μg/dL.
- Student exposure at the Site is assumed to occur 180 days per year, as described in Section 5.3.1. The 0-6 year age group is protected by the 400 mg/kg residential soil screening level, and is considered to be conservatively protective of the 6-13 year age group.
- Exposure to lead in soil at the hypothetical residence occurs for the remainder of the year.
- The concentration of lead in soil at the home was assumed to be 200 mg/kg, the default soil/dust lead concentration used in the USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead in children (USEPA 2003a).

7.0 RISK CHARACTERIZATION

This section presents the overall risk characterization for constituents identified at the Site. The objective of the risk characterization is to determine potential risk to receptors by combining the results of the exposure and toxicity assessments.

7.1 Risk Calculation Framework

Two types of potential human health effects were calculated in this risk characterization: carcinogenic effects and non-carcinogenic effects. Carcinogenic effects are evaluated by calculating a cancer risk. Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk). Carcinogenic risks for the incidental ingestion and dermal contact exposure pathways are estimated using the equation (USEPA 1989):

$$Risk = Intake \times CSF$$

<u>where:</u>

Intake = Intake or absorbed dose of a constituent (mg/kg-day); and

CSF = Cancer slope factor of a constituent $(mg/kg\text{-}day)^{-1}$.

Carcinogenic risks for the inhalation exposure pathway (fugitive dust) are estimated using the equation (USEPA 2009):

$$Risk = EC \times IUR$$

where:

EC = Exposure concentration of a constituent (mg/m^3); and

IUR = Inhalation unit risk factor of a constituent $(mg/m^3)^{-1}$.

This calculation is performed for all exposure pathways and the risks are summed across to obtain the total risk for a specific receptor. The USEPA endorses a risk management range between 1 in 10,000 (1E-04) and 1 in 1,000,000 (1E-06). The cumulative excess risk to exposed populations may not be greater than 1 in 10,000 (1E-04).

Potential non-carcinogenic effects are evaluated by calculating a hazard index (HI). For a single constituent and intake route, a hazard quotient (HQ) is calculated. A hazard quotient for the incidental ingestion and dermal contact exposure pathways is estimated using the equation (USEPA 1989):

$$HQ = Intake \;/\; RfD$$

where:

Intake = Intake or absorbed dose of a constituent (mg/kg-day); and,

RfD = Reference dose of a constituent (mg/kg-day).

A hazard quotient for the inhalation exposure pathway (fugitive dust) is estimated using the equation (USEPA 2009):

$$HQ = EC \;/\; RfC$$

where:

EC = Exposure concentration of a constituent (mg/m^3); and,

RfC = Reference concentration of a constituent (mg/m^3).

For each exposure pathway, this calculation is performed and the hazard quotients are summed to obtain the total hazard index (HI) for a specific receptor. If the Site-specific exposure level exceeds the effects-based threshold (i.e., the HI exceeds a value greater than one), there may be concern for potential non-cancer effects.

7.2 Results

A discussion of the risk estimates for each receptor is provided in the following sections and the results are presented in Tables 2 through 10 and Tables 12 through 14. A summary of cumulative risk results is presented in Table 11.

7.2.1 Elementary School Student Hazards and Risks

Non-carcinogenic HQs for the elementary school student potentially exposed to Site surface soils are 0.2 for ingestion, 0.04 for dermal contact, and 0.0004 for inhalation of fugitive dust. The incremental lifetime cancer risks for this receptor are 2E-06 (ingestion), 8E-07 (dermal), and 3E-10 (inhalation). Summing the risks across exposure pathways yields an acceptable cumulative ILCR of 3E-06 and an acceptable non-carcinogenic HI of 0.2.

7.2.2 Middle School Student Hazards and Risks

Non-carcinogenic HQs for the middle school student potentially exposed to Site surface soils are 0.1 for ingestion, 0.03 for dermal contact, and 0.0004 for inhalation of fugitive dust. The incremental lifetime cancer risks for this receptor are 2E-06 (ingestion), 2E-06 (dermal), and 1E-09 (inhalation). Summing the risks across exposure pathways yields an acceptable cumulative ILCR of 4E-06 and an acceptable non-carcinogenic HI of 0.1.

7.2.3 Teacher Hazards and Risks

Non-carcinogenic HQs for the teacher potentially exposed to Site surface soils are 0.02 for ingestion, 0.005 for dermal contact, and 0.0005 for inhalation of fugitive dust. The incremental lifetime cancer risks for this receptor are 4E-06 (ingestion), 2E-06 (dermal), and 1E-08 (inhalation). Summing the risks across exposure pathways yields an acceptable cumulative ILCR of 7E-06 and an acceptable non-carcinogenic HI of 0.02.

7.2.4 Construction Worker Hazards and Risks

Ingestion, dermal, and inhalation assessments for the construction worker exposed to surface and subsurface soils resulted in HQs of 0.2, 0.03, and 0.08, respectively. These non-carcinogenic estimates of health effects are below the acceptable threshold of 1. The incremental lifetime cancer risk (ILCR) for ingestion and dermal contact for the construction worker are 1E-06 and 1E-07, which are within or below USEPAs acceptable risk range. The ILCR associated with inhalation of fugitive dust is 7E-08, also an acceptable risk. The non-carcinogenic health effects and carcinogenic risks across all pathways are 0.3 and 1E-06, respectively, indicating *de minimis* cumulative risk posed to the construction worker from these pathways.

7.3 Lead Standards

7.3.1 Students and Teachers

The approach used to calculate a site-specific student standard for lead is presented below. In order to ensure that the standard is adequately protective, the lead soil standard presented in this risk assessment was calculated using the default values and assumptions recommended by USEPA and the site-specific student EF. Derivation of a lead standard for student exposure is also health-protective for teachers.

The USEPA developed methodology appropriate for the assessment of lead risks at secondary locations within a community where soil concentrations differ from the residential scenario (e.g., daycare, parks or play areas). The site-specific standard for students is calculated using a time-weighting approach consistent with the conceptual structure of the IEUBK model. The decision tree for determining the approach for assessing cumulative lead risk from one or more locations requires the following criteria be met:

- Minimum exposure frequency and duration of 1 day/week for 3-4 months.
- The secondary location has a soil lead concentration greater than 400 mg/kg.
- The residential scenario does not adequately cover all exposure scenarios.

There are no default recommendations for the relative weights to be used in calculating time-weighted soil concentrations; rather, the assumptions must reflect plausible estimates of the typical exposure scenario. The USEPA recommends time-weighted exposure calculations reflect the fraction of outdoor exposure to residential or Site soil as follows:

$$C_{school} = \frac{(C_{total} \times 365) - (C_{res} \times EF_{res})}{EF_{school}}$$

where:

C_{school} = Acceptable Student soil concentration

C_{total} = Residential acceptable soil lead concentration

C_{res} = USEPA Default soil/dust concentration in backyard of residence

EF_{res} = 365 days per year minus exposure frequency at the School

EF_{school} = Conservative estimate for student exposure frequency (180 days/year)

An action level of 606 mg/kg lead in soil for the student was established using the above equation as shown in Table 15. The site-specific standard for student exposure to lead is exceeded at surface soil locations: SS-24, SS-28, and several of their associated step-out locations (Figure 3). The USEPA's TRW recommends that the arithmetic mean soil lead concentration from an exposure area be applied in the IEUBK model. The arithmetic mean lead concentration across the entire exposure domain is less than the student lead standard at 328 mg/kg, which is less than the RDEC screening value of 400 mg/kg. Applying this approach would result in no remediation being required for lead at the site.

Average conditions of lead in surface soil (328 mg/kg) are not expected to result in unacceptable blood lead levels in elementary or middle school students. Given that a child is the more sensitive receptor to the potential effects of lead, the 606 mg/kg site-specific lead standard is also considered protective of teachers.

7.3.2 Construction Worker

The approach used to calculate a site-specific construction worker standard for lead is presented below. In order to ensure that the standard is adequately protective, the lead soil standard presented in this risk assessment was calculated using the default values and assumptions recommended by USEPA and the construction worker EF. The ALM methodology relates site lead concentrations to blood lead concentration in the mother and developing fetus based on the following additional assumptions:

- Fetal blood lead levels are proportional to maternal blood lead levels.
- Maternal blood lead levels can be predicted based on starting blood lead concentrations and an expected site-related increase.
- The site-related increase in maternal blood lead concentrations can be estimated using a linear biokinetic slope factor (BKSF) which is multiplied by the estimated lead uptake.
- Lead uptake can be estimated based on site concentrations of lead and assumptions regarding adult ingestion rates and the estimated AF of ingested lead.
- A lognormal model can be used to estimate the distribution of blood lead concentrations in a population of individuals who contact similar environmental lead levels.

The basis for the calculation of the blood lead concentration for women of child-bearing age is given by:

$$PbB_{adult,central,goal} = PbB_{adult,0} + \frac{PbS * BKSF * IR * AF * EF}{AT}$$

where:

$PbB_{a,c,g}$ = Goal for central estimate of blood lead concentration

$PbB_{adult,0}$ = Typical blood lead concentration

PbS = Soil lead concentration (appropriate average concentration for individual)

BKSF = Biokinetic slope factor

IR = Intake rate of soil

AF = Absolute gastrointestinal absorption fraction

EF = Exposure frequency

AT = Averaging time

Given that the effects of lead are well understood, and the mean PbB is recognized as an acceptable predictor of the potential health effects associated with lead exposure, the approach outlined in the ALM derives a soil lead concentration that is considered protective of all employees. The foundation for the site-specific standard calculation is the relationship between the mean soil lead concentration and the blood lead concentration in the developing fetus expressed by the following equation:

$$PRG = \frac{(PbB_{adult,central,goal} - PbB_{adult,0}) * AT}{BKSF * IR * AF * EF}$$

where:

PRG = Preliminary Remediation Goal, implemented as the site-specific standard

Consistent with the USEPA's 2009 *Update of the Adult Lead Methodology's Default Baseline Blood Lead Concentration and Geometric Standard Deviation Parameters* (USEPA 2009), the most current background blood lead level and geometric standard deviation parameter made available from the 1999-2004 National Health and Nutrition Examination Survey (Center for Disease Control, 2005) is utilized in the ALM. An action level of 1,362 µg/g (ppm) lead in soil for the construction worker was established using Equations 1 and 2 as shown in Table 16.

The site-specific standard for lead is greater than the maximum detected lead concentration; therefore, based on the target fetal blood lead distribution identified in USEPA guidance as posing an acceptable level of risk, adverse health effects to the construction worker in the area proposed for redevelopment are not likely to occur.

7.4 Chlordane Standards

The USEPA's Regional Screening Level (RSL) calculator was utilized to calculate site-specific risk-based chlordane standards for each receptor (Appendix B). The input parameters for the calculator correspond to the exposure and toxicity values presented in sections 5.0 and 6.0 of this HHRA. The target risk was set to 1E-06 and the hazard quotient was set to unity. The USEPA RSL calculator developed the following site-specific chlordane standards:

- Elementary School Student = 33.8 mg/kg
- Middle School Student = 21.4 mg/kg
- Teacher = 8.47 mg/kg

The prevailing chlordane standard is the lowest calculated standard, i.e., 8.47 mg/kg. The maximum detected concentration on-site was 6.76 mg/kg; therefore, consistent with the results of the forward risk calculations, remediation of chlordane is not necessary for the protection of human health.

7.5 Uncertainty

Although the methods used to calculate carcinogenic and systemic risk at the Western Middle School comply with USEPA standards, there are uncertainties associated with the quantitative risk estimates discussed above. These uncertainties are introduced because of the following:

- The need to extrapolate below the dose range of experimental tests;
- The variability of the receptor population (e.g., smoker vs. nonsmoker, genetic predisposition);
- Assumed dose-response relationship between animals and humans;
- Differences in exposure routes;
- Conservative assumptions; and,
- Ignoring background risks.

These recognized uncertainties are raised to point out the limitations of this type of study. The assumptions used to estimate exposure were consistently conservative in nature and biased toward protecting human health. For example, it is unlikely that teachers or students would be exposed to soils each day throughout the school year given the number of inclement weather days (e.g., wet, cold, snow) that reduce outdoor activities. In addition to chemical concentration, route, and duration of exposure, many other factors may influence the likelihood of developing cancer. These include differences in individual nutrition, health status, age, sex, and inherited characteristics, which may affect susceptibility (Versar 1991).

Uncertainty is also compounded with regard to assumptions about scenario settings and availability of contaminated soil for contact. For purposes of this risk assessment, it was assumed that all ground cover consisted of bare soils available for direct contact. The risk and hazard attributable to background concentrations of arsenic (i.e., 10 mg/kg) were not distinguished from “Site-risk” above background; therefore, the risk characterization potentially overestimates risk associated with exposure to arsenic as a result of a depositional release to soil.

The default AF parameter for lead is based, in part, on the assumption that the relative bioavailability of lead in soil compared to soluble lead is 0.6. The default AF represents a weight of evidence determination based on experimental estimates of the bioavailability of ingested lead in adult humans with consideration of three major sources of variability that are likely to be present in populations, but are not always represented in experimental studies. These include: variability in food intake, lead intake, and the lead form and particle size. The TRW considers 0.6 to be a plausible default point estimate for the relative bioavailability of lead in soil when site-specific data are not available. The RBA for arsenic was not adjusted, which could result in an overestimate of risks and hazards attributable to arsenic.

7.6 Conclusions

Based on the results of this HHRA, the calculated cumulative carcinogenic and non-carcinogenic risks are within the acceptable values as governed by the United States Environmental Protection Agency. These conclusions are based on site-specific modeling results for all potentially-complete exposure pathways for the receptors most likely to incur exposure, and the site-specific standards developed for lead.

Risk assessment is just one of many input factors that contribute to risk management and remedial decision-making. In addition to risk assessment, risk management is also informed by regulatory policy, social, economic, and political concerns. Often there are a variety of stakeholders in risk management decisions that have differing perspectives on risk and cleanup. Langan is committed to a framework for risk management decision-making that balances the concerns of the town and state departments of health, Greenwich Public Schools, and the affected public.

8.0 REFERENCES

Center for Disease Control. 2005. National Center for Health Statistics. *National Health and Nutrition Examination Survey Data*. Hyattsville, MD.

Langan 2016. Phase I Environmental Site Assessment for Proposed Modular Classrooms at Western Middle School.

USEPA 1989. Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. Office of Emergency and Remedial Response. Washington, DC.

USEPA 1991. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals). Interim. EPA/540/R-92/003. Office of Research and Development. Washington, D.C.

USEPA 1992. Supplemental Guidance to RAGS: Calculating the Concentration Term. Publication 9285.7-081. Office of Solid Waste and Emergency Response, Washington, D.C.

USEPA 1996. Soil Screening Guidance: User's Guide. Publication 9355.4-23. Office of Solid Waste and Emergency Response, Washington, D.C.

USEPA 2011. Exposure Factors Handbook. 2011 Edition. EPA/600/R-09/052F. Office of Research and Development, Washington, DC.

USEPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Office of Solid Waste and Emergency Response. OSWER 9355.4-24. Washington, DC.

USEPA. 2003. Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil. EPA-540-R-03-001. Technical Review Workgroup for Lead. Washington, DC. January 2003.

USEPA. 2003a. Assessing Intermittent or Variable Exposures at Lead Sites. EPA-540-R-03-008. OSWER #9285.7-76. Office of Solid Waste and Emergency Response. Washington, DC.

USEPA 2004. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Final. Office of Superfund Remediation and Technology Innovation. Washington, DC.

USEPA 2009. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment). EPA-540-R-070-002. Office of Superfund Remediation and Technology Innovation. Washington, DC.

USEPA 2015. ProUCL Version 5.1.00 User Guide. EPA/600/R-07/041. Office of Research and Development. October 2015.

Versar 1991. Populations - Identifying and Quantifying Highly Exposed and Sensitive Populations at Superfund Sites. A Report Produced for the USEPA Office of Health and Environmental Assessments.

USA.com 2016. Weather Station History, Greenwich, CT.

http://www.usa.com/greenwich-ct-weather.htm

Tables

TABLE 1
SUMMARY OF SOIL SAMPLES FOR RECEPTORS
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Construction Worker

Location	Depth (feet below ground surface)	
SB-1	2-2.5	
SB-2	2-2.5	
SB-3	2-2.5	(Higher of SB-3 and Field Duplicate)
SS-1	0-0.5	
SS-2	0-0.5	
SS-3	0-0.5	
SS-4	0-0.5	
SS-5	0-0.5	
SS-6	0-0.5	
SS-7	0-0.5	
SS-8	0-0.5	
COMP-1	0.5-4.0	
DUP-2	0.5-4.0	Field Duplicate of COMP-1
COMP-2	0.5-4.0	

Elementary School Student, Middle School Student, and Teacher

Location	Depth (feet below ground surface)	
SS-1	0-0.5	
SS-2	0-0.5	
SS-3	0-0.5	
SS-4	0-0.5	
SS-5	0-0.5	
SS-6	0-0.5	
SS-7	0-0.5	
SS-8	0-0.5	
SS-9	0-0.5	
SS-10	0-0.5	
SS-11	0-0.5	
SS-12	0-0.5	
SS-13	0-0.5	
SS-14	0-0.5	(Higher of SS-14 and Field Duplicate)
SS-15	0-0.5	
SS-16	0-0.5	
SS-17	0-0.5	
SS-18	0-0.5	
SS-19	0-0.5	
SS-20	0-0.5	
SS-21	0-0.5	
SS-22	0-0.5	
SS-23	0-0.5	
SS-24	0-0.5	
SS-25	0-0.5	
SS-26	0-0.5	(Higher of SS-26 and Field Duplicate)
SS-27	0-0.5	
SS-28	0-0.5	
SS-29	0-0.5	
SS-30	0-0.5	
SS-31	0-0.5	
SS-32	0-0.5	
SS-33	0-0.5	
SS-34	0-0.5	
SS-35	0-0.5	
SS-36	0-0.5	
SS-37	0-0.5	
SS-38	0-0.5	
SS-39	0-0.5	

TABLE 2
ELEMENTARY SCHOOL STUDENT - INCIDENTAL SOIL INGESTION
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Intake (mg/kg-day) = $\frac{Cs*IngR*EF*ED*CF}{BW*AT}$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
IngR - Ingestion rate for soil =	mg/day	200	USEPA 2002
EF - Exposure frequency =	days/year	180	Best Professional Judgment
ED - Exposure duration =	years	1	Best Professional Judgment
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	22	USEPA 2011
AT_n - Averaging time - noncarcinogenic =	days	365	Best Professional Judgment
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Oral RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
Pesticides							
Chlordane	2.27E+00	1.03E-05	5.00E-04	0.02	1.47E-07	3.50E-01	5E-08
PCBs							
Aroclor 1248	4.19E+00	NA	NA	NA	2.72E-07	2.00E+00	5E-07
Aroclor 1262	2.00E-01	NA	NA	NA	1.30E-08	2.00E+00	3E-08
Aroclor 1260	8.45E-01	NA	NA	NA	5.49E-08	2.00E+00	1E-07
Metals							
Arsenic	1.11E+01	5.05E-05	3.00E-04	0.2	7.21E-07	1.50E+00	1E-06
			Hazard Index =	0.2		**Total Cancer Risk =**	2E-06

TABLE 3
ELEMENTARY SCHOOL STUDENT - DERMAL CONTACT WITH SOIL
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Intake (mg/kg-day) = $\frac{DA_{event}*SA*EF*ED*EV}{BW*AT}$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
SA - Surface area available for exposure =	cm^2	6520	USEPA 2011
AF - Adherence factor =	mg/cm^2	0.2	USEPA 2004
ABS - Absorption fraction =	mg/mg	Chemical Specific	USEPA 2004
EF - Exposure frequency =	days/year	180	Best Professional Judgment
EV - Event frequency =	events/day	1	USEPA 2004
ED - Exposure duration =	years	1	Best Professional Judgment
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	22	USEPA 2011
AT_n - Averaging time - noncarcinogenic =	days	365	Best Professional Judgment
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

DA_{event} (mg/cm^2-event)= Cs*CF*AF*ABS

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Dermal RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
Pesticides							
Chlordane	2.27E+00	2.69E-06	5.00E-04	0.01	3.85E-08	3.50E-01	1E-08
PCBs							
Aroclor 1248	4.19E+00	NA	NA	NA	2.48E-07	2.00E+00	5E-07
Aroclor 1262	2.00E-01	NA	NA	NA	1.19E-08	2.00E+00	2E-08
Aroclor 1260	8.45E-01	NA	NA	NA	5.01E-08	2.00E+00	1E-07
Metals							
Arsenic	1.11E+01	9.87E-06	3.00E-04	0.03	1.41E-07	1.50E+00	2E-07
			Hazard Index =	0.04		**Total Cancer Risk =**	8E-07

TABLE 4
ELEMENTARY SCHOOL STUDENT - INHALATION OF FUGITIVE DUST
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Exposure Concentration (mg/m^3) = $\frac{Ca \times EF \times ED \times ET}{AT}$

Parameter	Unit	Value	Source	
Ca - Concentration in air =	mg/m3	see below	Calculated	
EF - Exposure frequency =	days/year	180	Best Professional Judgment	
ED - Exposure duration =	years	1	Best Professional Judgment	
ET - Exposure time =	hr/day	8	USEPA 2002	
AT_n - Averaging time - noncarcinogenic =	hours	8760	Best Professional Judgment	
AT_c - Averaging time - carcinogenic =	hours	613200	USEPA 2009	
Ca - Concentration in air (mg/m^3) =	Cs × 1/PEF	see below	Calculated	
Cs - Concentration in soil =	mg/kg	see below		
PEF - Particulate Emission Factor =	m^3/kg	3.46E+08	Calculated	
PEF (m^3/kg) =	$(Q/C)*3600/(0.036*(1-V)*(U_m/U_t)^3*F(x)$			
Q/C - Dispersion factor =	g/m^2 per kg/m^3	47.44	Calculated	
V - Fraction of vegetative cover =		0.50	USEPA 2002	
U_m - Mean annual windspeed =	m/sec	5.90	Site-specific	
U_t - Equivalent threshold value of windspeed at 7 m =	m/sec	11.32	USEPA 2002	
F(x) - Um/Ut-dependent function =		1.94E-01	USEPA 2002	
Q/C (g/m^2 per kg/m^3) =	$A*(exp((lnA_{site}-B)^2/C)$			
A - dispersion constant =		12.5907	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
B - dispersion constant =		18.8368	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
C - dispersion constant =		215.4377	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
A_{site} - affected area of site (acres) =	acres	6.9	Site-specific	

Constituent	RME Concentration in Soil mg/kg	Concentration in Air mg/m^3	Non-Carcinogenic Exposure Concentration mg/m^3	Inhalation RfC mg/m^3	Hazard Quotient	Carcinogenic Exposure Concentration mg/m^3	Inhalation Unit Risk $(mg/m^3)^{-1}$	Cancer Risk
Pesticides								
Chlordane	2.27E+00	6.56E-09	1.08E-09	7.00E-04	0.000002	1.54E-11	1.00E-01	2E-12
PCBs								
Aroclor 1248	4.19E+00	1.21E-08	NA	NA	NA	2.84E-11	5.70E-01	2E-11
Aroclor 1262	2.00E-01	5.78E-10	NA	NA	NA	1.36E-12	5.70E-01	8E-13
Aroclor 1260	8.45E-01	2.44E-09	NA	NA	NA	5.73E-12	5.70E-01	3E-12
Metals								
Arsenic	1.11E+01	3.21E-08	5.27E-09	1.50E-05	0.0004	7.53E-11	4.30E+00	3E-10
				Hazard Index =	0.0004		**Total Cancer Risk =**	3E-10

TABLE 5
MIDDLE SCHOOL STUDENT - INCIDENTAL SOIL INGESTION
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Intake (mg/kg-day) = $\frac{Cs*IngR*EF*ED*CF}{BW*AT}$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
IngR - Ingestion rate for soil =	mg/day	200	USEPA 2002
EF - Exposure frequency =	days/year	180	Best Professional Judgment
ED - Exposure duration =	years	3	Best Professional Judgment
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	48	USEPA 2011 Mean Ages 11 to 13
AT_n - Averaging time - noncarcinogenic =	days	1095	Best Professional Judgment
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Oral RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
Pesticides							
Chlordane	2.27E+00	4.68E-06	5.00E-04	0.009	2.01E-07	3.50E-01	7E-08
PCBs							
Aroclor 1248	4.19E+00	NA	NA	NA	3.71E-07	2.00E+00	7E-07
Aroclor 1262	2.00E-01	NA	NA	NA	1.77E-08	2.00E+00	4E-08
Aroclor 1260	8.45E-01	NA	NA	NA	7.47E-08	2.00E+00	1E-07
Metals							
Arsenic	1.11E+01	2.29E-05	3.00E-04	0.1	9.82E-07	1.50E+00	1E-06
			Hazard Index =	0.1		**Total Cancer Risk =**	2E-06

TABLE 6
MIDDLE SCHOOL STUDENT - DERMAL CONTACT WITH SOIL
WESTERN MIDDLE SCHOOL
GREENWICH, CT

$$\text{Intake (mg/kg-day)} = \frac{DA_{event} * SA * EF * ED * EV}{BW * AT}$$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
SA - Surface area available for exposure =	cm^2	9600	USEPA 2011 Mean Ages 11 to 16
AF - Adherence factor =	mg/cm^2	0.2	USEPA 2004
ABS - Absorption fraction =	mg/mg	Chemical Specific	USEPA 2004
EF - Exposure frequency =	days/year	180	Best Professional Judgment
EV - Event frequency =	events/day	1	USEPA 2004
ED - Exposure duration =	years	3	Best Professional Judgment
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	48	USEPA 2011 Mean Ages 11 to 13
AT_n - Averaging time - noncarcinogenic =	days	1095	Best Professional Judgment
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

$$DA_{event}\ (mg/cm^2\text{-event}) = Cs * CF * AF * ABS$$

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Dermal RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
Pesticides							
Chlordane	2.27E+00	1.799E-06	5.00E-04	0.004	7.71E-08	3.50E-01	3E-08
PCBs							
Aroclor 1248	4.19E+00	NA	NA	NA	4.98E-07	2.00E+00	1E-06
Aroclor 1262	2.00E-01	NA	NA	NA	2.38E-08	2.00E+00	5E-08
Aroclor 1260	8.45E-01	NA	NA	NA	1.00E-07	2.00E+00	2E-07
Metals							
Arsenic	1.11E+01	6.60E-06	3.00E-04	0.02	2.83E-07	1.50E+00	4E-07
			Hazard Index =	0.03		**Total Cancer Risk =**	2E-06

TABLE 7
MIDDLE SCHOOL STUDENT - INHALATION OF FUGITIVE DUST
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Exposure Concentration (mg/m^3) = $\frac{Ca \times EF \times ED \times ET}{AT}$

Parameter	Unit	Value	Source	
Ca - Concentration in air =	mg/m3	see below	Calculated	
EF - Exposure frequency =	days/year	180	Best Professional Judgment	
ED - Exposure duration =	years	3	Best Professional Judgment	
ET - Exposure time =	hr/day	8	USEPA 2002	
AT_n - Averaging time - noncarcinogenic =	hours	26280	Best Professional Judgment	
AT_c - Averaging time - carcinogenic =	hours	613200	USEPA 2009	
Ca - Concentration in air (mg/m^3) =	Cs × 1/PEF	see below	Calculated	
Cs - Concentration in soil =	mg/kg	see below		
PEF - Particulate Emission Factor =	m^3/kg	3.46E+08	Calculated	
PEF (m^3/kg) =	$(Q/C)*3600/(0.036*(1-V)*(U_m/U_t)^3*F(x)$			
Q/C - Dispersion factor =	g/m^2 per kg/m^3	47.44	Calculated	
V - Fraction of vegetative cover =		0.50	USEPA 2002	
U_m - Mean annual windspeed =	m/sec	5.90	Site-specific	
U_t - Equivalent threshold value of windspeed at 7 m =	m/sec	11.32	USEPA 2002	
F(x) - Um/Ut-dependent function =		1.94E-01	USEPA 2002	
Q/C (g/m^2 per kg/m^3) =	$A*(exp((lnA_{site}-B)^2/C)$			
A - dispersion constant =		12.5907	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
B - dispersion constant =		18.8368	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
C - dispersion constant =		215.4377	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
A_{site} - affected area of site (acres) =	acres	6.9	Site-specific	

Constituent	RME Concentration in Soil mg/kg	Concentration in Air mg/m^3	Non-Carcinogenic Exposure Concentration mg/m^3	Inhalation RfC mg/m^3	Hazard Quotient	Carcinogenic Exposure Concentration mg/m^3	Inhalation Unit Risk (mg/m^3)$^{-1}$	Cancer Risk
Pesticides								
Chlordane	2.27E+00	6.56E-09	1.08E-09	7.00E-04	0.000002	4.62E-11	1.00E-01	5E-12
PCBs								
Aroclor 1248	4.19E+00	1.21E-08	NA	NA	NA	8.53E-11	5.70E-01	5E-11
Aroclor 1262	2.00E-01	5.78E-10	NA	NA	NA	4.07E-12	5.70E-01	2E-12
Aroclor 1260	8.45E-01	2.44E-09	NA	NA	NA	1.72E-11	5.70E-01	1E-11
Metals								
Arsenic	1.11E+01	3.21E-08	5.27E-09	1.50E-05	0.0004	2.26E-10	4.30E+00	1E-09
				Hazard Index =	0.0004		**Total Cancer Risk =**	1E-09

TABLE 8
TEACHER - INCIDENTAL SOIL INGESTION
WESTERN MIDDLE SCHOOL
GREENWICH, CT

$$\text{Intake (mg/kg-day)} = \frac{Cs*IngR*EF*ED*CF}{BW*AT}$$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
IngR - Ingestion rate for soil =	mg/day	50	USEPA 2002
EF - Exposure frequency =	days/year	250	USEPA 2002
ED - Exposure duration =	years	25	USEPA 2002
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	80	USEPA 2011
AT_n - Averaging time - noncarcinogenic =	days	9125	USEPA 1989
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Oral RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
Pesticides							
Chlordane	2.27E+00	9.72E-07	5.00E-04	0.002	3.47E-07	3.50E-01	1E-07
PCBs							
Aroclor 1248	4.19E+00	NA	NA	NA	6.41E-07	2.00E+00	1E-06
Aroclor 1262	2.00E-01	NA	NA	NA	3.06E-08	2.00E+00	6E-08
Aroclor 1260	8.45E-01	NA	NA	NA	1.29E-07	2.00E+00	3E-07
Metals							
Arsenic	1.11E+01	4.75E-06	3.00E-04	0.02	1.70E-06	1.5E+00	3E-06
			Hazard Index =	0.02		**Total Cancer Risk =**	4E-06

TABLE 9
TEACHER - DERMAL CONTACT WITH SOIL
WESTERN MIDDLE SCHOOL
GREENWICH, CT

$$\text{Intake (mg/kg-day)} = \frac{DA_{event} \cdot SA \cdot EF \cdot ED \cdot EV}{BW \cdot AT}$$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
SA - Surface area available for exposure =	cm^2	3527	USEPA 2011
AF - Adherence factor =	mg/cm^2	0.12	USEPA 2004
ABS - Absorption fraction =	mg/mg	Chemical Specific	USEPA 2004
EF - Exposure frequency =	days/year	250	USEPA 2002
EV - Event frequency =	events/day	1	USEPA 2004
ED - Exposure duration =	years	25	USEPA 2002
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	80	USEPA 2011
AT_n - Averaging time - noncarcinogenic =	days	9125	USEPA 1989
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

DA_{event} (mg/cm^2-event)= Cs*CF*AF*ABS

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Dermal RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
Pesticides							
Chlordane	2.27E+00	3.29E-07	5.00E-04	0.001	1.18E-07	3.50E-01	4E-08
PCBs							
Aroclor 1248	4.19E+00	NA	NA	NA	7.59E-07	2.00E+00	2E-06
Aroclor 1262	2.00E-01	NA	NA	NA	3.62E-08	2.00E+00	7E-08
Aroclor 1260	8.45E-01	NA	NA	NA	1.53E-07	2.00E+00	3E-07
Metals							
Arsenic	1.11E+01	1.21E-06	3.00E-04	0.004	4.31E-07	1.50E+00	6E-07
			Hazard Index =	0.005		**Total Cancer Risk =**	2E-06

TABLE 10
TEACHER - INHALATION OF FUGITIVE DUST
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Exposure Concentration (mg/m^3) = $\frac{Ca \times EF \times ED \times ET}{AT}$

Parameter	Unit	Value	Source	
Ca - Concentration in air =	mg/m3	see below	Calculated	
EF - Exposure frequency =	days/year	250	USEPA 2002	
ED - Exposure duration =	years	25	USEPA 2002	
ET - Exposure time =	hr/day	8	USEPA 2002	
AT_n - Averaging time - noncarcinogenic =	hours	219000	USEPA 2009	
AT_c - Averaging time - carcinogenic =	hours	613200	USEPA 2009	
Ca - Concentration in air (mg/m^3) =	Cs × 1/PEF	see below	Calculated	
Cs - Concentration in soil =	mg/kg	see below		
PEF - Particulate Emission Factor =	m^3/kg	3.46E+08	Calculated	
PEF (m^3/kg) =	$(Q/C)*3600/(0.036*(1-V)*(U_m/U_t)^3*F(x)$			
Q/C - Dispersion factor =	g/m^2 per kg/m^3	47.44	Calculated	
V - Fraction of vegetative cover =		0.50	USEPA 2002	
U_m - Mean annual windspeed =	m/sec	5.90	Site-specific	
U_t - Equivalent threshold value of windspeed at 7 m =	m/sec	11.32	USEPA 2002	
F(x) - Um/Ut-dependent function =		1.94E-01	USEPA 2002	
Q/C (g/m^2 per kg/m^3) =	$A*(exp((lnA_{site}-B)^2/C)$			
A - dispersion constant =		12.5907	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
B - dispersion constant =		18.8368	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
C - dispersion constant =		215.4377	USEPA 2002	Exhibit D-2; Zone 8, Hartford, CT
A_{site} - affected area of site (acres) =	acres	6.9	Site-specific	

Constituent	RME Concentration in Soil mg/kg	Concentration in Air mg/m^3	Non-Carcinogenic Exposure Concentration mg/m^3	Inhalation RfC mg/m^3	Hazard Quotient	Carcinogenic Exposure Concentration mg/m^3	Inhalation Unit Risk $(mg/m^3)^{-1}$	Cancer Risk
Pesticides								
Chlordane	2.27E+00	6.56E-09	1.50E-09	7.00E-04	0.000002	5.35E-10	1.00E-01	5E-11
PCBs								
Aroclor 1248	4.19E+00	1.21E-08	NA	NA	NA	9.87E-10	5.70E-01	6E-10
Aroclor 1262	2.00E-01	5.78E-10	NA	NA	NA	4.71E-11	5.70E-01	3E-11
Aroclor 1260	8.45E-01	2.44E-09	NA	NA	NA	1.99E-10	5.70E-01	1E-10
Metals								
Arsenic	1.11E+01	3.21E-08	7.32E-09	1.50E-05	0.0005	2.62E-09	4.30E+00	1E-08
				Hazard Index =	0.0005		**Total Cancer Risk =**	1E-08

TABLE 11
CUMULATIVE RISK SUMMARY
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Construction Worker

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.2	1E-06	0.01	1E-07	0.08	7E-08	0.2	1E-06
Aroclor 1248	NA	7E-08	NA	3E-08	NA	5E-10	NA	1E-07
Aroclor 1254	0.03	2E-08	0.01	7E-09	NA	1E-10	0.04	2E-08
Aroclor 1260	NA	2E-08	NA	8E-09	NA	1E-10	NA	2E-08
						Total	0.3	1E-06

Elementary School Student

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.2	1E-06	0.03	2E-07	0.0004	3E-10	0.2	1E-06
Aroclor 1248	NA	5E-07	NA	5E-07	NA	2E-11	NA	1E-06
Aroclor 1260	NA	1E-07	NA	1E-07	NA	3E-12	NA	2E-07
Aroclor 1262	NA	3E-08	NA	2E-08	NA	8E-13	NA	5E-08
Chlordane	0.02	5E-08	0.01	1E-08	0.000002	2E-12	0.03	7E-08
						Total	0.2	3E-06

Middle School Student

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.1	1E-06	0.02	4E-07	0.0004	1E-09	0.1	2E-06
Aroclor 1248	NA	7E-07	NA	1E-06	NA	5E-11	NA	2E-06
Aroclor 1260	NA	1E-07	NA	2E-07	NA	1E-11	NA	4E-07
Aroclor 1262	NA	4E-08	NA	5E-08	NA	2E-12	NA	8E-08
Chlordane	0.009	7E-08	0.004	3E-08	0.000002	5E-12	0.01	1E-07
						Total	0.1	4E-06

Teacher

	Incidental Ingestion of Soil		Dermal Exposure to Soil		Inhalation of Fugitive Dust		Total Hazard and Risk	
Chemical	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HQ**	**Cancer Risk**	**HI**	**Cancer Risk**
Arsenic	0.02	3E-06	0.004	6E-07	0.0005	1E-08	0.02	3E-06
Aroclor 1248	NA	1E-06	NA	2E-06	NA	6E-10	NA	3E-06
Aroclor 1260	NA	3E-07	NA	3E-07	NA	1E-10	NA	6E-07
Aroclor 1262	NA	6E-08	NA	7E-08	NA	3E-11	NA	1E-07
Chlordane	0.002	1E-07	0.001	4E-08	0.000002	5E-11	0.003	2E-07
						Total	0.02	7E-06

TABLE 12
CONSTRUCTION WORKER - INCIDENTAL SOIL INGESTION
WESTERN MIDDLE SCHOOL
GREENWICH, CT

$$\text{Intake (mg/kg-day)} = \frac{Cs*IngR*EF*ED*CF}{BW*AT}$$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
IngR - Ingestion rate for soil =	mg/day	330	USEPA 2002
EF - Exposure frequency =	days/year	180	Best Professional Judgment
ED - Exposure duration =	years	1	Best Professional Judgment
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	80	USEPA 2011
AT_n - Averaging time - noncarcinogenic =	days	365	USEPA 1989
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Oral RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
PCBs							
Aroclor 1248	1.28E+00	NA	NA	NA	3.72E-08	2.00E+00	7E-08
Aroclor 1254	2.78E-01	5.66E-07	2.00E-05	0.03	8.08E-09	2.00E+00	2E-08
Aroclor 1260	2.93E-01	NA	NA	NA	8.51E-09	2.00E+00	2E-08
Metals							
Arsenic	2.29E+01	4.65E-05	3.00E-04	0.2	6.64E-07	1.50E+00	1E-06
			Hazard Index =	0.2		**Total Cancer Risk =**	1E-06

TABLE 13
CONSTRUCTION WORKER - DERMAL CONTACT WITH SOIL
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Intake (mg/kg-day) = $\frac{DA_{event}*SA*EF*ED*EV}{BW*AT}$

Parameter	Unit	Value	Source
Cs - Concentration in soil =	mg/kg	see below	
SA - Surface area available for exposure =	cm^2	3527	USEPA 2011
AF - Adherence factor =	mg/cm^2	0.3	USEPA 2004
ABS - Absorption fraction =	mg/mg	Chemical Specific	USEPA 2004
EF - Exposure frequency =	days/year	180	Best Professional Judgment
EV - Event frequency =	events/day	1	USEPA 2004
ED - Exposure duration =	years	1	Best Professional Judgment
CF - Conversion factor =	kg/mg	1.00E-06	
BW - Body weight =	kg	80	USEPA 2011
AT_n - Averaging time - noncarcinogenic =	days	365	USEPA 1989
AT_c - Averaging time - carcinogenic =	days	25550	USEPA 1991

DA_{event} (mg/cm^2-event)= Cs*CF*AF*ABS

Constituent	RME Concentration in Soil mg/kg	Average Daily Intake mg/kg-day	Dermal RfD mg/kg-day	Hazard Quotient	Average Lifetime Daily Intake mg/kg-day	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Cancer Risk
PCBs							
Aroclor 1248	1.28E+00	NA	NA	NA	1.67E-08	2.00E+00	3E-08
Aroclor 1254	2.78E-01	2.54E-07	2.00E-05	0.01	3.63E-09	2.00E+00	7E-09
Aroclor 1260	2.93E-01	NA	NA	NA	3.82E-09	2.00E+00	8E-09
Metals							
Arsenic	2.29E+01	4.47E-06	3.00E-04	0.01	6.39E-08	1.50E+00	1E-07
			Hazard Index =	0.03		**Total Cancer Risk =**	1E-07

TABLE 14
CONSTRUCTION WORKER - INHALATION OF FUGITIVE DUST
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Exposure Concentration (mg/m^3) = $\frac{Ca \times EF \times ED \times ET}{AT}$

Parameter	Unit	Value	Source
Ca - Concentration in air =	mg/m3	see below	Calculated
EF - Exposure frequency =	days/year	180	Best professional judgment
ED - Exposure duration =	years	1	Best professional judgment
ET - Exposure time =	hr/day	8	USEPA 2009
AT_n - Averaging time - noncarcinogenic =	hours	8760	Best professional judgment
AT_c - Averaging time - carcinogenic =	hours	613200	USEPA 2009
Ca - Concentration in air (mg/m^3) =	Cs * 1/PEF	see below	Calculated
Cs - Concentration in soil =	mg/kg	see below	
PEF - Particulate Emission Factor =	m^3/kg	3.26E+06	Calculated (see below)

PEF = $(Q/C)*(1/F_d)*[T*A_r/(556*(W/3)^{0.4}*((365-p)/365)*\Sigma VKT]$

Parameter	Unit	Value	Source
Q/C - Dispersion factor =	g/m^2 per kg/m^3	22.29	Calculated (see below)
F_D - Dispersion correction factor =		0.185	USEPA 2002
T - Total time over which construction occurs =	s	3.15E+07	Site-specific
A_r - Surface area of contaminated road segment =	m^2	902	Site-specific
W - Mean vehicle weight =	tons	8	USEPA 2002
p - Number of days with ≥0.01 inches of precipitation per year =	days	150	USEPA 2002
ΣVKT - Sum of fleet vehicle kilometers traveled during exposure duration =	km	2171	USEPA 2002

Q/C = $A*(exp((lnA_{site}-B)^2/C)$

Parameter	Unit	Value	Source
A - dispersion constant =		12.9351	USEPA 2002
B - dispersion constant =		5.7383	USEPA 2002
C - dispersion constant =		71.7711	USEPA 2002
A_{site} - affected area of site (acres) =	acres	0.6	Site-specific

Constituent	RME Concentration in Soil mg/kg	Concentration in Air mg/m^3	Non-Carcinogenic Exposure Concentration mg/m^3	Inhalation RfC mg/m^3	Hazard Quotient	Carcinogenic Exposure Concentration mg/m^3	Inhalation Unit Risk $(mg/m^3)^{-1}$	Cancer Risk
PCBs								
Aroclor 1248	1.28E+00	3.93E-07	NA	NA	NA	9.23E-10	5.70E-01	5E-10
Aroclor 1254	2.78E-01	8.54E-08	NA	NA	NA	2.01E-10	5.70E-01	1E-10
Aroclor 1260	2.93E-01	9.00E-08	NA	NA	NA	2.11E-10	5.70E-01	1E-10
Metals								
Arsenic	2.23E+01	6.85E-06	1.13E-06	1.50E-05	0.08	1.61E-08	4.30E+00	7E-08
				Hazard Index =	0.08		**Total Cancer Risk =**	7E-08

TABLE 15
CALCULATION OF ACCEPTABLE SOIL LEAD LEVEL FOR A STUDENT
WESTERN MIDDLE SCHOOL
GREENWICH, CT

Objective: Calculate a weighted average that reflects the fraction of each year during which a student is exposed to surface soil and dust with different lead concentrations.

Where:

$C_{total} = (C_{school} \times EF_{school} + C_{res} \times EF_{res})/365$ ***(Equation 1)***

Rearranging to solve for C_{school}:

$C_{school} = ((C_{total} \times 365)-(C_{res} \times EF_{res}))/EF_{school}$ ***(Equation 2)***

Variable	Description of Variable	Value	Units	Rationale/Source
C_{total}	Residential acceptable soil lead level	400	mg/kg	CTDEEP Residential MSC for lead in surface soils
C_{school}	Student soil level	Calculated	mg/kg	
C_{res}	Assumed lead level in backyard of residence	200	mg/kg	Default soil/dust concentration from USEPA IEUBK Model (USEPA 2002)
EF_{school}	Exposure frequency at the school	180	days/yr	Conservative estimate for student (5 day/week during each week of the year)
EF_{res}	Exposure frequency at backyard of residence	185	days/yr	365 days per year minus exposure frequency at Site

Using Equation 2: **C_{school} = 606 mg/kg**

Table 16
Calculation of a Site-Specific Lead Standard for the Construction Worker
Western Middle School
Greenwich, CT

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 1999-2004	Rationale
$PbB_{fetal, 0.95}$	95^{th} percentile PbB in fetus	ug/dL	10	USEPA 2003
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9	USEPA 2003
BKSF	Biokinetic Slope Factor	ug/dL per ug/day	0.4	USEPA 2003
GSD_i	Geometric standard deviation PbB	--	1.8	NHANES 1999-2004
PbB_0	Baseline PbB	ug/dL	1.0	NHANES 1999-2004
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.100	NHANES 1999-2004
$AF_{S, D}$	Absorption fraction (same for soil and dust)	--	0.12	Absorption factor of soluble lead of 0.2 and soil matrix effect of 0.6 (USEPA 2003)
$EF_{S, D}$	Exposure frequency (same for soil and dust)	days/yr	180	Receptor-specific value
$AT_{S, D}$	Averaging time (same for soil and dust)	days/yr	365	USEPA 2003
PRG		**ppm**	**1,362**	

Figures

2,000 0 2,000

SCALE IN FEET

Notes:
Topographic basemap is provided through Langan's Esri ArcGIS software licensing and ArcGIS online © 2011 National Geographic Society, i-cubed.

LANGAN
ENGINEERING & ENVIRONMENTAL SERVICES

555 Long Wharf Drive
New Haven, CT 06511-6107
T: 203.562.5771 F: 203.789.6142
www.langan.com

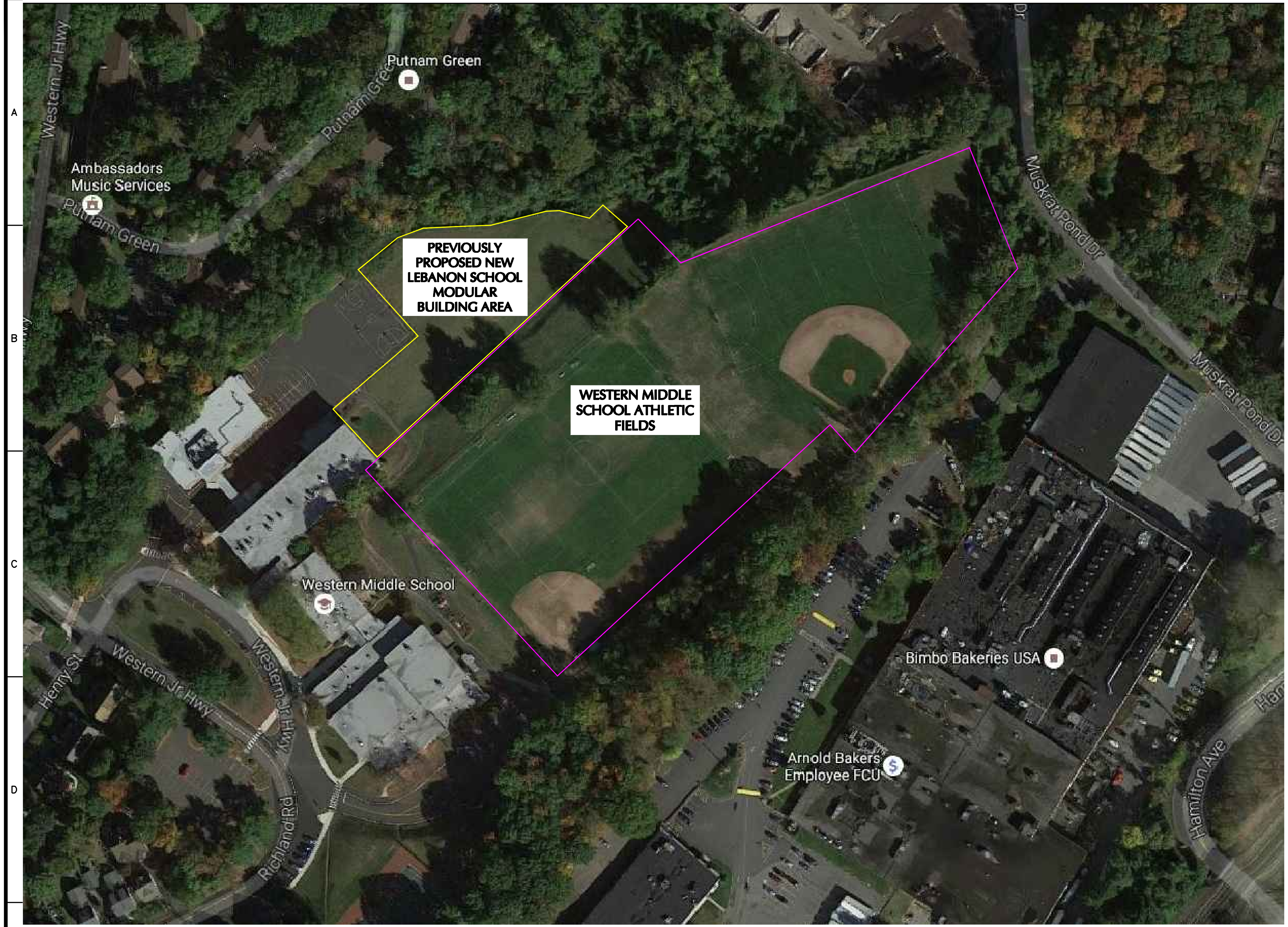
NEW JERSEY NEW YORK VIRGINIA CALIFORNIA
PENNSYLVANIA CONNECTICUT FLORIDA

ABU DHABI ATHENS DOHA
DUBAI ISTANBUL

Project
WESTERN MIDDLE SCHOOL
1 WESTERN JUNIOR HIGHWAY
GREENWICH
FAIRFIELD CONNECTICUT

Drawing Title
SITE LOCATION MAP

Project No.	Figure
140131911	1
Date: 6/10/2016	
Scale: 1"=2,000'	
Drawn By: DC	
Submission Date: SEPTEMBER 2016	Sheet 1 of 5



LEGEND

- PREVIOUSLY PROPOSED NEW LEBANON SCHOOL MODULAR BUILDING AREA (yellow)
- WESTERN MIDDLE SCHOOL ATHLETIC FIELDS (magenta)

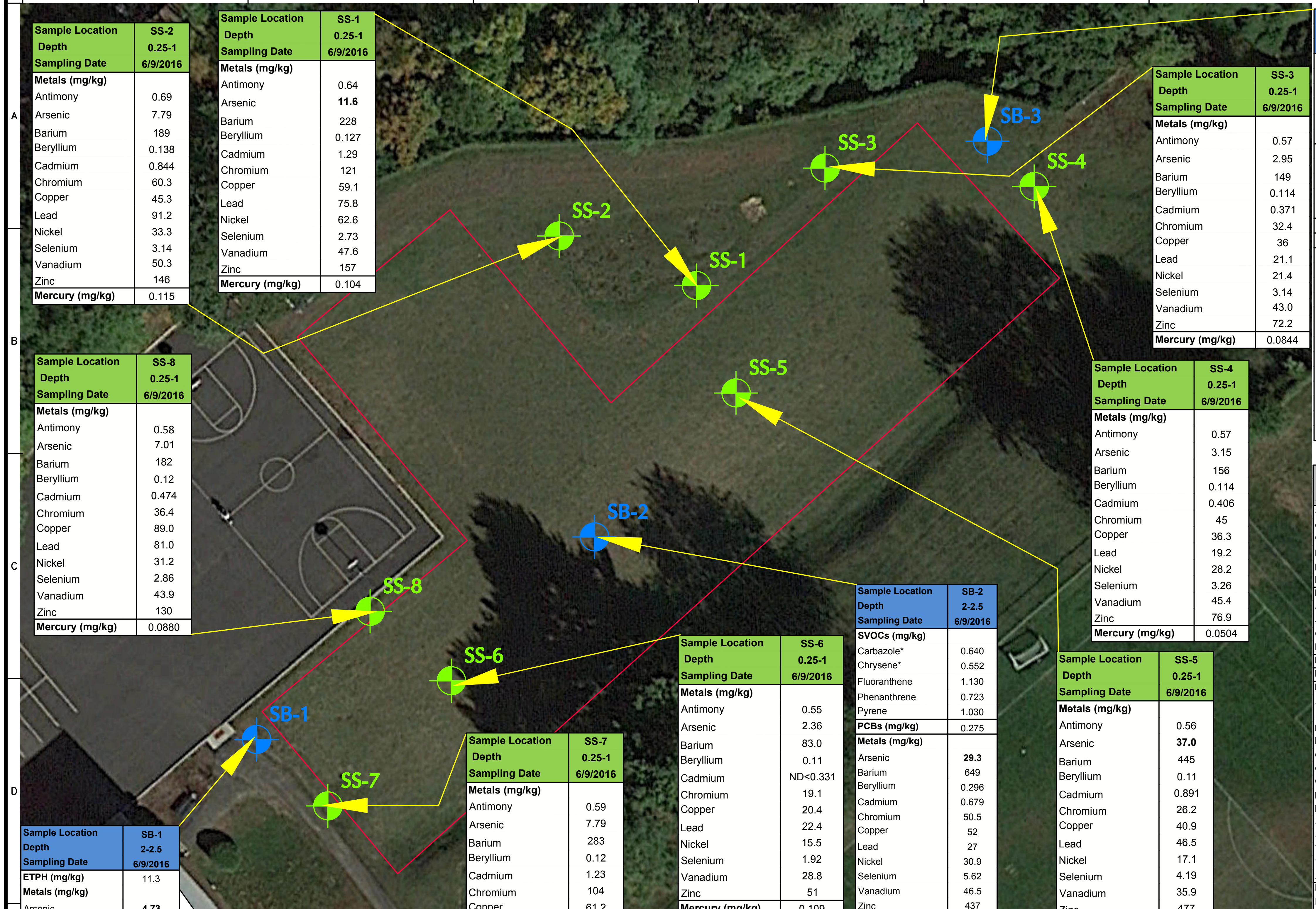
NOTES

1. BACKGROUND AERIAL OBTAINED FROM GOOGLE MAPS.

LANGAN
555 Long Wharf Drive
New Haven, CT 06511
T: 203.562.5771 F: 203.789.6142 www.langan.com
Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C. S.A.
Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C.
Langan Engineering and Environmental Services, Inc.
Langan CT, Inc.
Langan International LLC
Collectively known as Langan

Project	WESTERN MIDDLE SCHOOL, 1 WESTERN JUNIOR HIGHWAY, GREENWICH, CONNECTICUT
Drawing Title	HHRA EVALUATION AREAS
Project No.	140131911
Date	9/2/2016
Scale	1"=150'
Drawn By	HHG
Checked By	RJW
Submission Date	SEPTEMBER 2016
Drawing No.	2
Sheet	2 of 5

Filename: \\langan.com\data\NHV\data2\140148201\Cadd Data - 140148201\2D-DesignFiles\140131911 - HHRA Evaluation Areas.dwg Date: 9/2/2016 Time: 11:50 User: hgriesbach Style Table: Langan.stb Layout: ANSIB-BL



Sample Location	SS-2
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.69
Arsenic	7.79
Barium	189
Beryllium	0.138
Cadmium	0.844
Chromium	60.3
Copper	45.3
Lead	91.2
Nickel	33.3
Selenium	3.14
Vanadium	50.3
Zinc	146
Mercury (mg/kg)	0.115

Sample Location	SS-1
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.64
Arsenic	**11.6**
Barium	228
Beryllium	0.127
Cadmium	1.29
Chromium	121
Copper	59.1
Lead	75.8
Nickel	62.6
Selenium	2.73
Vanadium	47.6
Zinc	157
Mercury (mg/kg)	0.104

Sample Location	SS-3
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.57
Arsenic	2.95
Barium	149
Beryllium	0.114
Cadmium	0.371
Chromium	32.4
Copper	36
Lead	21.1
Nickel	21.4
Selenium	3.14
Vanadium	43.0
Zinc	72.2
Mercury (mg/kg)	0.0844

Sample Location	SB-3	SB-3 (DUP-1)
Depth	2-2.5	2-2.5
Sampling Date	6/9/2016	6/9/2016
SVOCs (mg/kg)		
Carbazole*	ND<0.581	ND<0.583
Chrysene*	ND<0.581	ND<0.583
Fluoranthene	1	0.721
Phenanthrene	0.592	ND<0.583
Pyrene	0.893	0.634
Pesticides (mg/kg)		
4,4-DDE	ND<0.00290	0.0183
4,4'-DDT	ND<0.00290	0.0204
Chlordane, total	ND<0.0115	0.218
Heptachlor epoxide	ND<0.00290	0.00584
PCBs (mg/kg)	0.0533	0.104
ETPH (mg/kg)	116	112
Metals (mg/kg)		
Arsenic	**18.6**	**16.2**
Barium	256	215
Beryllium	ND<0.116	ND<0.117
Cadmium	0.962	0.895
Chromium	36.7	34.7
Copper	48.5	46.7
Lead	128	117
Nickel	20.9	19.9
Selenium	3.46	2.63
Vanadium	39.1	32.3
Zinc	373	273
Mercury (mg/kg)	0.144	0.168

LEGEND

- SB-3 LANGAN SOIL BORINGS
- SS-4 LANGAN SURFICAL SOIL BORINGS
- PROPOSED LOCATION OF MODULAR CLASSROOMS

GENERAL NOTES

1. LANGAN "SB" SOIL BORINGS WERE ADVANCED TO 15 FEET BELOW GRADE
2. LANGAN "SS" SOIL BORINGS ADVANCED TO 6 INCHES BELOW GRADE
3. ONLY ANALYTES WITH DETECTIONS AREA SHOWN IN THE TABLE
4. BOLD INDICATES AN EXCEEDANCE OF THE RESIDENTIAL DIRECT EXPOSURE CRITERIA
5. SHADING INDICATES AN EXCEEDANCE OF THE POLLUTANT MOBILITY CRITERIA
6. ND = NOT DETECTED ABOVE LABORATORY REPORTING LIMITS
7. MG/KG = MILLIGRAMS PER KILOGRAM
8. VOCS = VOLATILE ORGANIC COMPOUNDS
9. SVOCS = SEMI-VOLATILE ORGANIC COMPOUNDS

Sample Location	SS-8
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.58
Arsenic	7.01
Barium	182
Beryllium	0.12
Cadmium	0.474
Chromium	36.4
Copper	89.0
Lead	81.0
Nickel	31.2
Selenium	2.86
Vanadium	43.9
Zinc	130
Mercury (mg/kg)	0.0880

Sample Location	SS-4
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.57
Arsenic	3.15
Barium	156
Beryllium	0.114
Cadmium	0.406
Chromium	45
Copper	36.3
Lead	19.2
Nickel	28.2
Selenium	3.26
Vanadium	45.4
Zinc	76.9
Mercury (mg/kg)	0.0504

Analyte	Residential Direct Exposure Criteria	GB Pollutant Mobility Criteria
SVOCs (mg/kg)		
Carbazole*	31	1
Chrysene*	84	1
Fluoranthene	1,000	56
Phenanthrene	1,000	40
Pyrene	1,000	40
Pesticides (mg/kg)		
4,4-DDE*	1.8	0.02
4,4'-DDT*	1.8	0.02
Chlordane, total	0.49	0.066
Heptachlor epoxide	0.067	0.02
PCBs (mg/kg)	1	NE
ETPH (mg/kg)	500	2,500
Metals (mg/kg)		
Antimony	27	NE
Arsenic	10	NE
Barium	4,700	NE
Beryllium	2	NE
Cadmium	34	NE
Chromium	4,000	NE
Copper	2,500	NE
Lead	400	NE
Nickel	1,400	NE
Selenium	340	NE
Silver	340	NE
Thallium	5.4	NE
Vanadium	470	NE
Zinc	20,000	NE
Mercury (mg/kg)		
Mercury	20	NE

Sample Location	SB-2
Depth	2-2.5
Sampling Date	6/9/2016
SVOCs (mg/kg)	
Carbazole*	0.640
Chrysene*	0.552
Fluoranthene	1.130
Phenanthrene	0.723
Pyrene	1.030
PCBs (mg/kg)	0.275
Metals (mg/kg)	
Arsenic	**29.3**
Barium	649
Beryllium	0.296
Cadmium	0.679
Chromium	50.5
Copper	52
Lead	27
Nickel	30.9
Selenium	5.62
Vanadium	46.5
Zinc	437

Sample Location	SS-6
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.55
Arsenic	2.36
Barium	83.0
Beryllium	0.11
Cadmium	ND<0.331
Chromium	19.1
Copper	20.4
Lead	22.4
Nickel	15.5
Selenium	1.92
Vanadium	28.8
Zinc	51
Mercury (mg/kg)	0.109

Sample Location	SS-5
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.56
Arsenic	**37.0**
Barium	445
Beryllium	0.11
Cadmium	0.891
Chromium	26.2
Copper	40.9
Lead	46.5
Nickel	17.1
Selenium	4.19
Vanadium	35.9
Zinc	477
Mercury (mg/kg)	0.0773

Sample Location	SS-7
Depth	0.25-1
Sampling Date	6/9/2016
Metals (mg/kg)	
Antimony	0.59
Arsenic	7.79
Barium	283
Beryllium	0.12
Cadmium	1.23
Chromium	104
Copper	61.2
Lead	63.5
Nickel	51.5
Selenium	3.18
Vanadium	65.5
Zinc	147
Mercury (mg/kg)	0.102

Sample Location	SB-1
Depth	2-2.5
Sampling Date	6/9/2016
ETPH (mg/kg)	11.3
Metals (mg/kg)	
Arsenic	**4.73**
Barium	198
Beryllium	ND<0.107
Cadmium	0.471
Chromium	89.2
Copper	35.8
Lead	25.5
Nickel	43.7
Selenium	3.43
Vanadium	61.1
Zinc	64.2
Pesticides (mg/kg)	
4,4'-DDT*	0.00347

N

40 0 10 25 40

SCALE IN FEET

LANGAN
555 Long Wharf Drive
New Haven, CT 06511
T: 203.562.5771 F: 203.789.6142 www.langan.com
Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C. S.A.
Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C.
Langan Engineering and Environmental Services, Inc.
Langan CT, Inc.
Langan International LLC
Collectively known as Langan

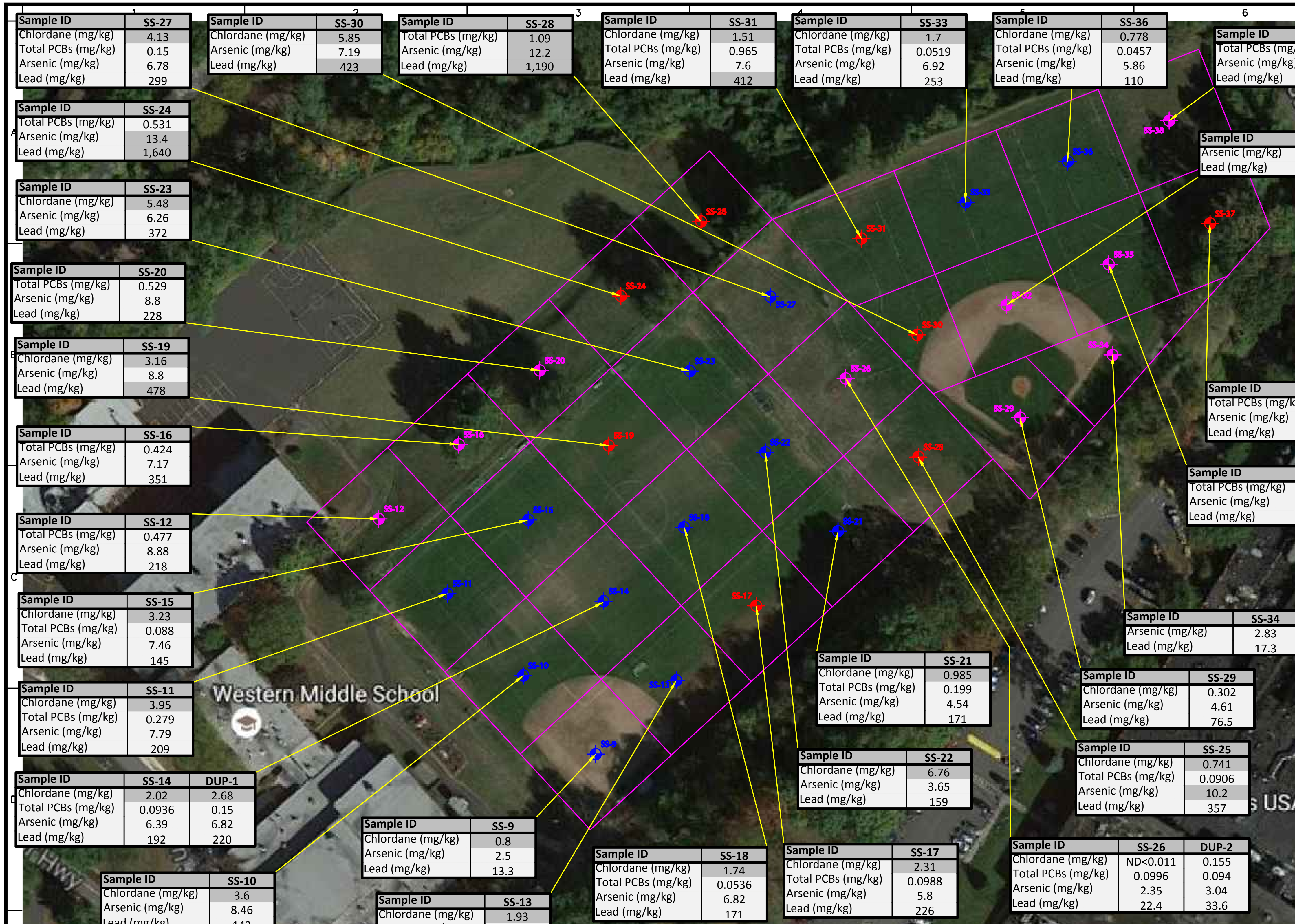
Project
WESTERN MIDDLE SCHOOL
TAX ID: 04-4519
GREENWICH
FAIRFIELD COUNTY CONNECTICUT

Drawing Title
SOIL ANALYTICAL RESULTS MAP, REDEVELOPMENT AREA

Project No. 140131911
Date 6/24/2016
Scale 1"=40'
Drawn By DC
Checked By RJW
Submission Date SEPTEMBER 2016

Drawing No.
3

Filename: \\langan.com\data\NH\data9\140131911\Cadd Data - 140131911\SheetFiles\Figure 3 ALL Boring Locations with Tags 6-27-2016.dwg Date: 9/2/2016 Time: 15:13 User: hgriesbach Style Table: Langan.stb Layout: ANSIB-BL



Sample ID	SS-27
Chlordane (mg/kg)	4.13
Total PCBs (mg/kg)	0.15
Arsenic (mg/kg)	6.78
Lead (mg/kg)	299

Sample ID	SS-30
Chlordane (mg/kg)	5.85
Arsenic (mg/kg)	7.19
Lead (mg/kg)	423

Sample ID	SS-28
Total PCBs (mg/kg)	1.09
Arsenic (mg/kg)	12.2
Lead (mg/kg)	1,190

Sample ID	SS-31
Chlordane (mg/kg)	1.51
Total PCBs (mg/kg)	0.965
Arsenic (mg/kg)	7.6
Lead (mg/kg)	412

Sample ID	SS-33
Chlordane (mg/kg)	1.7
Total PCBs (mg/kg)	0.0519
Arsenic (mg/kg)	6.92
Lead (mg/kg)	253

Sample ID	SS-36
Chlordane (mg/kg)	0.778
Total PCBs (mg/kg)	0.0457
Arsenic (mg/kg)	5.86
Lead (mg/kg)	110

Sample ID	SS-38
Total PCBs (mg/kg)	0.742
Arsenic (mg/kg)	7.03
Lead (mg/kg)	303

Sample ID	SS-32
Arsenic (mg/kg)	3.49
Lead (mg/kg)	7.74

Sample ID	SS-24
Total PCBs (mg/kg)	0.531
Arsenic (mg/kg)	13.4
Lead (mg/kg)	1,640

Sample ID	SS-23
Chlordane (mg/kg)	5.48
Arsenic (mg/kg)	6.26
Lead (mg/kg)	372

Sample ID	SS-20
Total PCBs (mg/kg)	0.529
Arsenic (mg/kg)	8.8
Lead (mg/kg)	228

Sample ID	SS-19
Chlordane (mg/kg)	3.16
Arsenic (mg/kg)	8.8
Lead (mg/kg)	478

Sample ID	SS-16
Total PCBs (mg/kg)	0.424
Arsenic (mg/kg)	7.17
Lead (mg/kg)	351

Sample ID	SS-12
Total PCBs (mg/kg)	0.477
Arsenic (mg/kg)	8.88
Lead (mg/kg)	218

Sample ID	SS-15
Chlordane (mg/kg)	3.23
Total PCBs (mg/kg)	0.088
Arsenic (mg/kg)	7.46
Lead (mg/kg)	145

Sample ID	SS-11
Chlordane (mg/kg)	3.95
Total PCBs (mg/kg)	0.279
Arsenic (mg/kg)	7.79
Lead (mg/kg)	209

Sample ID	SS-14	DUP-1
Chlordane (mg/kg)	2.02	2.68
Total PCBs (mg/kg)	0.0936	0.15
Arsenic (mg/kg)	6.39	6.82
Lead (mg/kg)	192	220

Sample ID	SS-10
Chlordane (mg/kg)	3.6
Arsenic (mg/kg)	8.46
Lead (mg/kg)	142

Sample ID	SS-9
Chlordane (mg/kg)	0.8
Arsenic (mg/kg)	2.5
Lead (mg/kg)	13.3

Sample ID	SS-13
Chlordane (mg/kg)	1.93
Arsenic (mg/kg)	6.48
Lead (mg/kg)	95.7

Sample ID	SS-18
Chlordane (mg/kg)	1.74
Total PCBs (mg/kg)	0.0536
Arsenic (mg/kg)	6.82
Lead (mg/kg)	171

Sample ID	SS-17
Chlordane (mg/kg)	2.31
Total PCBs (mg/kg)	0.0988
Arsenic (mg/kg)	5.8
Lead (mg/kg)	226

Sample ID	SS-21
Chlordane (mg/kg)	0.985
Total PCBs (mg/kg)	0.199
Arsenic (mg/kg)	4.54
Lead (mg/kg)	171

Sample ID	SS-22
Chlordane (mg/kg)	6.76
Arsenic (mg/kg)	3.65
Lead (mg/kg)	159

Sample ID	SS-26	DUP-2
Chlordane (mg/kg)	ND<0.011	0.155
Total PCBs (mg/kg)	0.0996	0.094
Arsenic (mg/kg)	2.35	3.04
Lead (mg/kg)	22.4	33.6

Sample ID	SS-25
Chlordane (mg/kg)	0.741
Total PCBs (mg/kg)	0.0906
Arsenic (mg/kg)	10.2
Lead (mg/kg)	357

Sample ID	SS-29
Chlordane (mg/kg)	0.302
Arsenic (mg/kg)	4.61
Lead (mg/kg)	76.5

Sample ID	SS-34
Arsenic (mg/kg)	2.83
Lead (mg/kg)	17.3

Sample ID	SS-35
Total PCBs (mg/kg)	0.237
Arsenic (mg/kg)	5.17
Lead (mg/kg)	168

Sample ID	SS-37
Total PCBs (mg/kg)	5.03
Arsenic (mg/kg)	7.17
Lead (mg/kg)	244

LEGEND

SS-## SOIL BORING LOCATION WITH NO EXCEEDENCES OF THE RESIDENTIAL DIRECT EXPOSURE CRITERIA

SS-## SOIL BORING LOCATION WITH MORE THAN ONE EXCEEDENCE OF THE RESIDENTIAL DIRECT EXPOSURE CRITERIA

SS-## SOIL BORING LOCATION WITH CHLORDANE CONCENTRATIONS EXCEEDING RESIDENTIAL DIRECT EXPOSURE CRITERIA

NOTES

1. ALL SURFICIAL SOIL SAMPLES WERE COLLECTED 0 TO 3 INCHES BELOW GROUND SURFACE.
2. SHADING INDICATES AN EXCEEDANCE OF THE RDEC AS INDICATED BELOW.

Analyte	Residential Direct Exposure Criteria (mg/kg)
Chlordane	0.49
Total PCBs	1
Arsenic	10
Lead	400

100 0 50 100
SCALE IN FEET

LANGAN
555 Long Wharf Drive
New Haven, CT 06511
T: 203.562.5771 F: 203.789.6142 www.langan.com
Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C. S.A.
Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C.
Langan Engineering and Environmental Services, Inc.
Langan CT, Inc.
Langan International LLC
Collectively known as Langan

Project
WESTERN MIDDLE SCHOOL
1 WESTERN JUNIOR HIGHWAY
GREENWICH CONNECTICUT

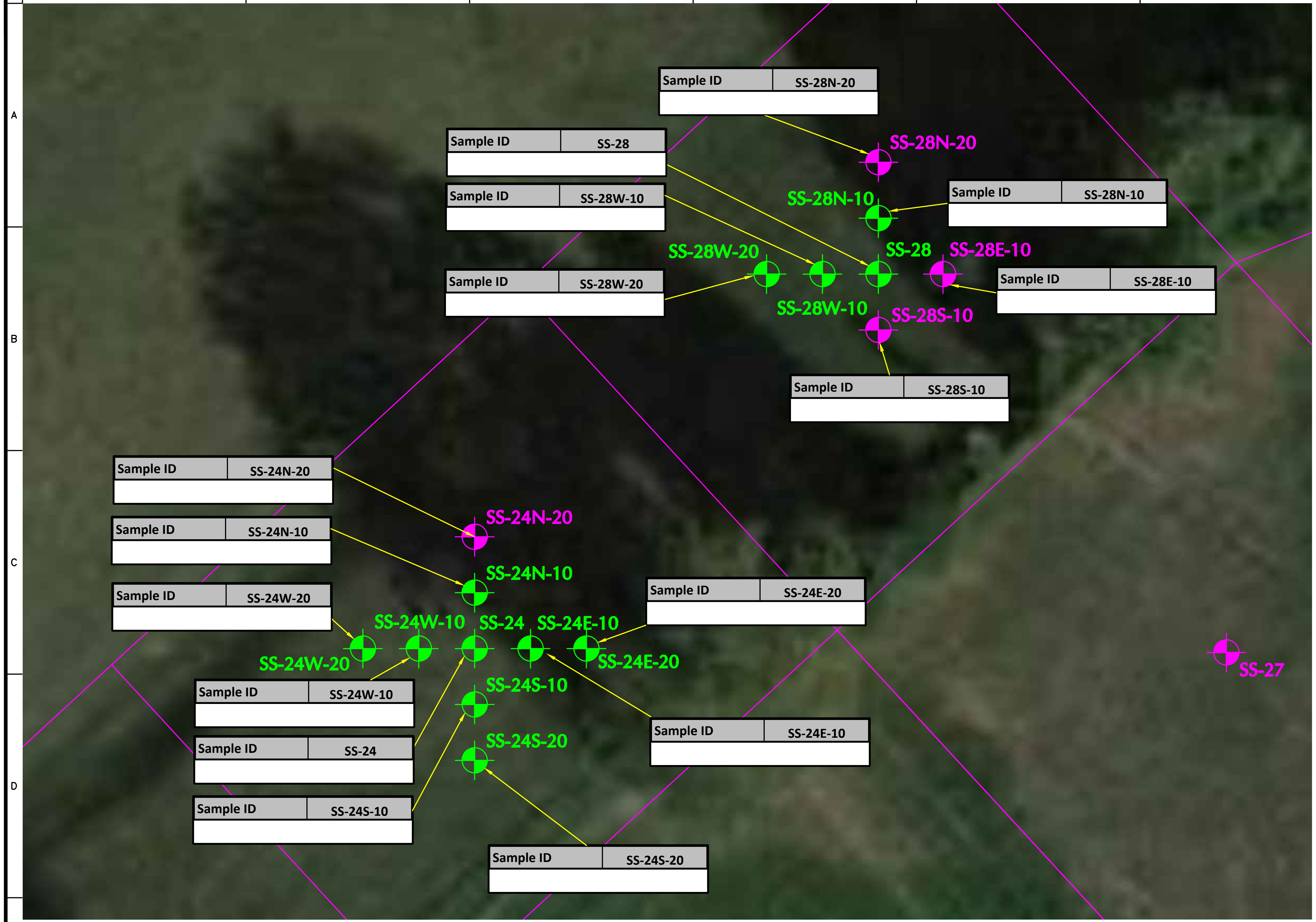
Drawing Title
SOIL ANALYTICAL RESULTS MAP, GRASS FIELDS

Project No. 140131911
Date 8/19/2016
Scale 1"=100'
Drawn By JRF
Checked By RJW
Submission Date SEPTEMBER 2016

Drawing No. 4

Sheet 4 of 5

Filename: \\langan.com\data\NH\data2\140148201\Cadd Data - 140148201\2D-DesignFiles\140148201-Western Middle School_Tag Map JPH.dwg Date: 9/2/2016 Time: 15:18 User: hgriesbach Style Table: Langan.stb Layout: HHRA



LEGEND

SS-## SOIL BORING LOCATION WITH LEAD CONCENTRATION UNDER THE RESIDENTIAL DIRECT EXPOSURE CRITERIA

SS-## SOIL BORING LOCATION WITH LEAD CONCENTRATIONS EXCEEDING RESIDENTIAL DIRECT EXPOSURE CRITERIA

NOTES

1. ALL DELINEATION SOIL SAMPLES WERE COLLECTED 0 TO 3 INCHES BELOW GROUND SURFACE.
2. SHADING INDICATES AN EXCEEDANCE OF THE RDEC AS INDICATED BELOW.

Analyte	Residential Direct Exposure Criteria (mg/kg)
Lead	400

20 0 5 10 20
SCALE IN FEET

LANGAN

555 Long Wharf Drive
New Haven, CT 06511
T: 203.562.5771 F: 203.789.6142 www.langan.com

Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C. S.A.
Langan Engineering, Environmental, Surveying and Landscape Architecture, D.P.C.
Langan Engineering and Environmental Services, Inc.
Langan CT, Inc.
Langan International LLC
Collectively known as Langan

Project: WESTERN MIDDLE SCHOOL
1 WESTERN JUNIOR HIGHWAY
GREENWICH CONNECTICUT

Drawing Title: SOIL DELINEATION RESULTS MAP (LEAD)

Project No. 140131911
Date 8/19/2016
Scale 1"=20'
Drawn By JRF
Checked By RJW
Submission Date SEPTEMBER 2016

Drawing No. 5

Sheet 5 of 5

Filename: \\langan.com\data\NH\data2\140148201\Cadd Data - 140148201\2D-DesignFiles\140148201-Western Middle School_Delineation Tag Map_DRAFT JPH.dwg Date: 9/2/2016 Time: 15:17 User: hgriesbach Style Table: Langan.stb Layout: HHRA

Appendix A

ProUCL Output

	A	B	C	D	E	F	G	H	I	J	K	L
1	UCL Statistics for Uncensored Full Data Sets											
2												
3			User Selected Options									
4			Date/Time of Computation	6/27/2016 11:09:30 AM								
5			From File	WorkSheet.xls								
6			Full Precision	OFF								
7			Confidence Coefficient	95%								
8			Number of Bootstrap Operations	2000								
9												
10												
11	Arsenic											
12												
13	General Statistics											
14					Total Number of Observations	11					Number of Distinct Observations	10
15											Number of Missing Observations	0
16					Minimum	2.36					Mean	12.03
17					Maximum	37					Median	7.79
18					SD	11.55					Std. Error of Mean	3.483
19					Coefficient of Variation	0.961					Skewness	1.427
20												
21	Normal GOF Test											
22					Shapiro Wilk Test Statistic	0.8	Shapiro Wilk GOF Test					
23					5% Shapiro Wilk Critical Value	0.85	Data Not Normal at 5% Significance Level					
24					Lilliefors Test Statistic	0.279	Lilliefors GOF Test					
25					5% Lilliefors Critical Value	0.267	Data Not Normal at 5% Significance Level					
26	Data Not Normal at 5% Significance Level											
27												
28	Assuming Normal Distribution											
29	95% Normal UCL						95% UCLs (Adjusted for Skewness)					
30					95% Student's-t UCL	18.34					95% Adjusted-CLT UCL (Chen-1995)	19.36
31											95% Modified-t UCL (Johnson-1978)	18.59
32												
33	Gamma GOF Test											
34					A-D Test Statistic	0.426	Anderson-Darling Gamma GOF Test					
35					5% A-D Critical Value	0.744	Detected data appear Gamma Distributed at 5% Significance Level					
36					K-S Test Statistic	0.213	Kolmogrov-Smirnoff Gamma GOF Test					
37					5% K-S Critical Value	0.26	Detected data appear Gamma Distributed at 5% Significance Level					
38	Detected data appear Gamma Distributed at 5% Significance Level											
39												
40	Gamma Statistics											
41					k hat (MLE)	1.423					k star (bias corrected MLE)	1.095
42					Theta hat (MLE)	8.452					Theta star (bias corrected MLE)	10.98
43					nu hat (MLE)	31.3					nu star (bias corrected)	24.1
44					MLE Mean (bias corrected)	12.03					MLE Sd (bias corrected)	11.49
45											Approximate Chi Square Value (0.05)	13.92
46					Adjusted Level of Significance	0.0278					Adjusted Chi Square Value	12.68
47												
48	Assuming Gamma Distribution											
49					95% Approximate Gamma UCL (use when n>=50)	20.81					95% Adjusted Gamma UCL (use when n<50)	22.86
50												

	A–E	F	G–K	L
51	Lognormal GOF Test			
52	Shapiro Wilk Test Statistic	0.946	Shapiro Wilk Lognormal GOF Test	
53	5% Shapiro Wilk Critical Value	0.85	Data appear Lognormal at 5% Significance Level	
54	Lilliefors Test Statistic	0.155	Lilliefors Lognormal GOF Test	
55	5% Lilliefors Critical Value	0.267	Data appear Lognormal at 5% Significance Level	
56	Data appear Lognormal at 5% Significance Level			
57				
58	Lognormal Statistics			
59	Minimum of Logged Data	0.859	Mean of logged Data	2.096
60	Maximum of Logged Data	3.611	SD of logged Data	0.923
61				
62	Assuming Lognormal Distribution			
63	95% H-UCL	28.66	90% Chebyshev (MVUE) UCL	22.28
64	95% Chebyshev (MVUE) UCL	27	97.5% Chebyshev (MVUE) UCL	33.56
65	99% Chebyshev (MVUE) UCL	46.45		
66				
67	Nonparametric Distribution Free UCL Statistics			
68	Data appear to follow a Discernible Distribution at 5% Significance Level			
69				
70	Nonparametric Distribution Free UCLs			
71	95% CLT UCL	17.75	95% Jackknife UCL	18.34
72	95% Standard Bootstrap UCL	17.41	95% Bootstrap-t UCL	24.43
73	95% Hall's Bootstrap UCL	22.14	95% Percentile Bootstrap UCL	17.93
74	95% BCA Bootstrap UCL	19.54		
75	90% Chebyshev(Mean, Sd) UCL	22.47	95% Chebyshev(Mean, Sd) UCL	27.21
76	97.5% Chebyshev(Mean, Sd) UCL	33.78	99% Chebyshev(Mean, Sd) UCL	46.68
77				
78	Suggested UCL to Use			
79	95% Adjusted Gamma UCL	22.86		
80				
81	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
82	These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)			
83	and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.			
84	For additional insight the user may want to consult a statistician.			
85				

	A	B	C	D	E	F	G	H	I	J	K	L
1	UCL Statistics for Data Sets with Non-Detects											
2												
3	User Selected Options											
4	Date/Time of Computation			ProUCL 5.18/25/2016 10:00:15 AM								
5	From File			ProUCL_Input.xls								
6	Full Precision			OFF								
7	Confidence Coefficient			95%								
8	Number of Bootstrap Operations			2000								
9												
10												
11	Arsenic											
12												
13	General Statistics											
14	Total Number of Observations					40	Number of Distinct Observations					35
15							Number of Missing Observations					0
16	Minimum					2.35	Mean					7.303
17	Maximum					37	Median					6.87
18	SD					5.502	Std. Error of Mean					0.87
19	Coefficient of Variation					0.753	Skewness					4.182
20												
21	Normal GOF Test											
22	Shapiro Wilk Test Statistic					0.603	Shapiro Wilk GOF Test					
23	5% Shapiro Wilk Critical Value					0.94	Data Not Normal at 5% Significance Level					
24	Lilliefors Test Statistic					0.262	Lilliefors GOF Test					
25	5% Lilliefors Critical Value					0.139	Data Not Normal at 5% Significance Level					
26	Data Not Normal at 5% Significance Level											
27												
28	Assuming Normal Distribution											
29	95% Normal UCL						95% UCLs (Adjusted for Skewness)					
30	95% Student's-t UCL					8.769	95% Adjusted-CLT UCL (Chen-1995)					9.348
31							95% Modified-t UCL (Johnson-1978)					8.865
32												
33	Gamma GOF Test											
34	A-D Test Statistic					1.319	Anderson-Darling Gamma GOF Test					
35	5% A-D Critical Value					0.754	Data Not Gamma Distributed at 5% Significance Level					
36	K-S Test Statistic					0.167	Kolmogorov-Smirnov Gamma GOF Test					
37	5% K-S Critical Value					0.14	Data Not Gamma Distributed at 5% Significance Level					
38	Data Not Gamma Distributed at 5% Significance Level											
39												
40	Gamma Statistics											
41	k hat (MLE)					3.3	k star (bias corrected MLE)					3.07
42	Theta hat (MLE)					2.213	Theta star (bias corrected MLE)					2.379
43	nu hat (MLE)					264	nu star (bias corrected)					245.6
44	MLE Mean (bias corrected)					7.303	MLE Sd (bias corrected)					4.168
45							Approximate Chi Square Value (0.05)					210.3
46	Adjusted Level of Significance					0.044	Adjusted Chi Square Value					209.1
47												
48	Assuming Gamma Distribution											
49	95% Approximate Gamma UCL (use when n>=50))					8.528	95% Adjusted Gamma UCL (use when n<50)					8.578
50												

	A–E	F	G–K	L
51	**Lognormal GOF Test**			
52	Shapiro Wilk Test Statistic	0.923	**Shapiro Wilk Lognormal GOF Test**	
53	5% Shapiro Wilk Critical Value	0.94	Data Not Lognormal at 5% Significance Level	
54	Lilliefors Test Statistic	0.154	**Lilliefors Lognormal GOF Test**	
55	5% Lilliefors Critical Value	0.139	Data Not Lognormal at 5% Significance Level	
56	**Data Not Lognormal at 5% Significance Level**			
57				
58	**Lognormal Statistics**			
59	Minimum of Logged Data	0.854	Mean of logged Data	1.829
60	Maximum of Logged Data	3.611	SD of logged Data	0.54
61				
62	**Assuming Lognormal Distribution**			
63	95% H-UCL	8.535	90% Chebyshev (MVUE) UCL	9.121
64	95% Chebyshev (MVUE) UCL	10	97.5% Chebyshev (MVUE) UCL	11.22
65	99% Chebyshev (MVUE) UCL	13.62		
66				
67	**Nonparametric Distribution Free UCL Statistics**			
68	**Data do not follow a Discernible Distribution (0.05)**			
69				
70	**Nonparametric Distribution Free UCLs**			
71	95% CLT UCL	8.734	95% Jackknife UCL	8.769
72	95% Standard Bootstrap UCL	8.677	95% Bootstrap-t UCL	9.963
73	95% Hall's Bootstrap UCL	15.24	95% Percentile Bootstrap UCL	8.924
74	95% BCA Bootstrap UCL	9.413		
75	90% Chebyshev(Mean, Sd) UCL	9.913	95% Chebyshev(Mean, Sd) UCL	11.1
76	97.5% Chebyshev(Mean, Sd) UCL	12.74	99% Chebyshev(Mean, Sd) UCL	15.96
77				
78	**Suggested UCL to Use**			
79	95% Chebyshev (Mean, Sd) UCL	11.1		
80				
81	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
82	Recommendations are based upon data size, data distribution, and skewness.			
83	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
84	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
85				

	A	B	C	D	E	F	G	H	I	J	K	L
1	UCL Statistics for Data Sets with Non-Detects											
2												
3			User Selected Options									
4			Date/Time of Computation	ProUCL 5.18/25/2016 9:54:38 AM								
5			From File	ProUCL_Input.xls								
6			Full Precision	OFF								
7			Confidence Coefficient	95%								
8			Number of Bootstrap Operations	2000								
9												
10	Chlordane											
11												
12	General Statistics											
13					Total Number of Observations	32					Number of Distinct Observations	31
14					Number of Detects	21					Number of Non-Detects	11
15					Number of Distinct Detects	21					Number of Distinct Non-Detects	10
16					Minimum Detect	0.155					Minimum Non-Detect	0.0104
17					Maximum Detect	6.76					Maximum Non-Detect	0.0138
18					Variance Detects	3.475					Percent Non-Detects	34.38%
19					Mean Detects	2.562					SD Detects	1.864
20					Median Detects	2.02					CV Detects	0.728
21					Skewness Detects	0.794					Kurtosis Detects	-0.0964
22					Mean of Logged Detects	0.6					SD of Logged Detects	0.97
23												
24	Normal GOF Test on Detects Only											
25					Shapiro Wilk Test Statistic	0.931	Shapiro Wilk GOF Test					
26					5% Shapiro Wilk Critical Value	0.908	Detected Data appear Normal at 5% Significance Level					
27					Lilliefors Test Statistic	0.138	Lilliefors GOF Test					
28					5% Lilliefors Critical Value	0.188	Detected Data appear Normal at 5% Significance Level					
29	Detected Data appear Normal at 5% Significance Level											
30												
31	Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs											
32					KM Mean	1.685					KM Standard Error of Mean	0.346
33					KM SD	1.908					95% KM (BCA) UCL	2.233
34					95% KM (t) UCL	2.271					95% KM (Percentile Bootstrap) UCL	2.232
35					95% KM (z) UCL	2.254					95% KM Bootstrap t UCL	2.379
36					90% KM Chebyshev UCL	2.722					95% KM Chebyshev UCL	3.192
37					97.5% KM Chebyshev UCL	3.844					99% KM Chebyshev UCL	5.124
38												
39	Gamma GOF Tests on Detected Observations Only											
40					A-D Test Statistic	0.18	Anderson-Darling GOF Test					
41					5% A-D Critical Value	0.757	Detected data appear Gamma Distributed at 5% Significance Level					
42					K-S Test Statistic	0.0852	Kolmogorov-Smirnov GOF					
43					5% K-S Critical Value	0.193	Detected data appear Gamma Distributed at 5% Significance Level					
44	Detected data appear Gamma Distributed at 5% Significance Level											
45												
46	Gamma Statistics on Detected Data Only											
47					k hat (MLE)	1.614					k star (bias corrected MLE)	1.415
48					Theta hat (MLE)	1.588					Theta star (bias corrected MLE)	1.811
49					nu hat (MLE)	67.78					nu star (bias corrected)	59.43
50					Mean (detects)	2.562						

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	1.685
Maximum	6.76	Median	0.893
SD	1.939	CV	1.151
k hat (MLE)	0.387	k star (bias corrected MLE)	0.371
Theta hat (MLE)	4.357	Theta star (bias corrected MLE)	4.538
nu hat (MLE)	24.75	nu star (bias corrected)	23.76
Adjusted Level of Significance (β)	0.0416		
Approximate Chi Square Value (23.76, α)	13.67	Adjusted Chi Square Value (23.76, β)	13.26
95% Gamma Approximate UCL (use when n>=50)	2.929	95% Gamma Adjusted UCL (use when n<50)	3.02

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	1.685	SD (KM)	1.908
Variance (KM)	3.641	SE of Mean (KM)	0.346
k hat (KM)	0.78	k star (KM)	0.728
nu hat (KM)	49.91	nu star (KM)	46.57
theta hat (KM)	2.161	theta star (KM)	2.316
80% gamma percentile (KM)	2.766	90% gamma percentile (KM)	4.192
95% gamma percentile (KM)	5.656	99% gamma percentile (KM)	9.142

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (46.57, α)	31.91	Adjusted Chi Square Value (46.57, β)	31.26
95% Gamma Approximate KM-UCL (use when n>=50)	2.459	95% Gamma Adjusted KM-UCL (use when n<50)	2.51

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.931	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.138	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	1.757	Mean in Log Scale	-0.13
SD in Original Scale	1.876	SD in Log Scale	1.29
95% t UCL (assumes normality of ROS data)	2.32	95% Percentile Bootstrap UCL	2.302
95% BCA Bootstrap UCL	2.372	95% Bootstrap t UCL	2.36
95% H-UCL (Log ROS)	3.863		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-1.176	KM Geo Mean	0.309
KM SD (logged)	2.571	95% Critical H Value (KM-Log)	4.725
KM Standard Error of Mean (logged)	0.466	95% H-UCL (KM -Log)	74.47
KM SD (logged)	2.571	95% Critical H Value (KM-Log)	4.725
KM Standard Error of Mean (logged)	0.466		

	A	B	C	D	E	F	G	H	I	J	K	L
101												
102	**DL/2 Statistics**											
103	**DL/2 Normal**						**DL/2 Log-Transformed**					
104	Mean in Original Scale					1.684	Mean in Log Scale					-1.362
105	SD in Original Scale					1.94	SD in Log Scale					2.863
106	95% t UCL (Assumes normality)					2.265	95% H-Stat UCL					222.8
107	**DL/2 is not a recommended method, provided for comparisons and historical reasons**											
108												
109	**Nonparametric Distribution Free UCL Statistics**											
110	**Detected Data appear Normal Distributed at 5% Significance Level**											
111												
112	**Suggested UCL to Use**											
113	95% KM (t) UCL					2.271						
114												
115	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
116	Recommendations are based upon data size, data distribution, and skewness.											
117	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
118	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
119												

Outlier Tests for Selected Uncensored Variables

User Selected Options

Date/Time of Computation	ProUCL 5.18/25/2016 10:01:30 AM
From File	ProUCL_Input.xls
Full Precision	OFF

Rosner's Outlier Test for Arsenic

Mean	**7.303**
Standard Deviation	**5.502**
Number of data	**40**
Number of suspected outliers	**1**

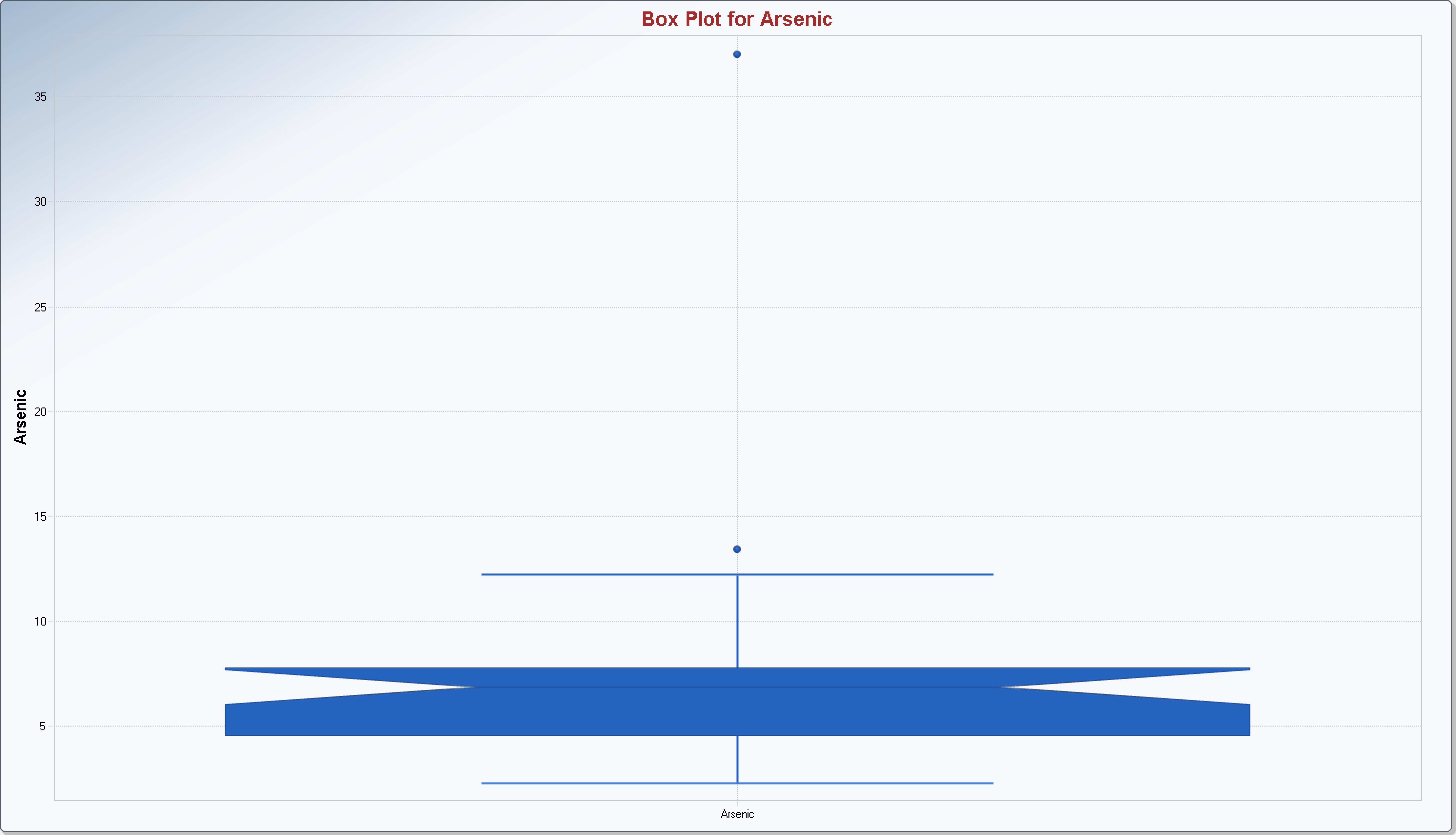
#	Mean	sd	Potential outlier	Obs. Number	Test value	Critical value (5%)	Critical value (1%)
1	7.303	5.433	37	37	5.466	3.04	3.38

For 5% Significance Level, there is 1 Potential Outlier

Potential outliers is: 37

For 1% Significance Level, there is 1 Potential Outlier

Potential outliers is: 37


Box Plot for Arsenic
Arsenic
35
30
25
20
15
10
5
Arsenic

Appendix B

Chlordane Standards

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
TR (target cancer risk) unitless	1.0E-6
THQ (target hazard quotient) unitless	1
SA_{rec-c} (skin surface area - child) cm^2/day	0
SA_{rec-a} (skin surface area - adult) cm^2/day	6520
SA_{0-2} (skin surface area - mutagenic) cm^2/day	0
SA_{2-6} (skin surface area - mutagenic) cm^2/day	0
SA_{6-16} (skin surface area - mutagenic) cm^2/day	6520
SA_{16-30} (skin surface area - mutagenic) cm^2/day	0
LT (lifetime - recreator) year	70
$IFS_{rec-adj}$ (age-adjusted soil ingestion factor) mg/kg	1636.364
$DFS_{rec-adj}$ (age-adjusted soil dermal factor) mg/kg	10669.091
$IFSM_{rec-adj}$ (mutagenic age-adjusted soil ingestion factor) mg/kg	4909.091
$DFSM_{rec-adj}$ (mutagenic age-adjusted soil dermal factor) mg/kg	32007.273
EF_{0-2} (exposure frequency) day/year	0
EF_{2-6} (exposure frequency) day/year	0
EF_{6-16} (exposure frequency) day/year	180
EF_{16-30} (exposure frequency) day/year	0
EF_{rec-c} (exposure frequency - child) day/year	0
EF_{rec-a} (exposure frequency - adult) day/year	180
EF_{rec} (exposure frequency - recreator) day/year	180
IRS_{0-2} (soil intake rate) mg/day	0
IRS_{2-6} (soil intake rate) mg/day	0
IRS_{6-16} (soil intake rate) mg/day	200
IRS_{16-30} (soil intake rate) mg/day	0
IRS_{rec-c} (soil intake rate - child) mg/day	0
IRS_{rec-a} (soil intake rate - adult) mg/day	200
ED_{0-2} (exposure duration) year	0
ED_{2-6} (exposure duration) year	0
ED_{6-16} (exposure duration) year	1
ED_{16-30} (exposure duration) year	0
ED_{rec-c} (exposure duration - child) year	0
ED_{rec-a} (exposure duration - adult) year	1
ED_{rec} (exposure duration - recreator) year	1

Output generated 01SEP2016:16:53:30

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
ET_{0-2} (exposure time) hr/day	0
ET_{2-6} (exposure time) hr/day	0
ET_{6-16} (exposure time) hr/day	8
ET_{16-30} (exposure time) hr/day	0
ET_{rec-c} (exposure time - child) hr/day	0
ET_{rec-a} (exposure time - adult) hr/day	8
ET_{rec} (exposure time - recreator) hr/day	8
BW_{0-2} (body weight) kg	0
BW_{2-6} (body weight) kg	0
BW_{6-16} (body weight) kg	22
BW_{16-30} (body weight) kg	0
BW_{rec-c} (body weight - child) kg	0
BW_{rec-a} (body weight - adult) kg	22
AF_{0-2} (skin adherence factor) mg/cm^2	0
AF_{2-6} (skin adherence factor) mg/cm^2	0
AF_{6-16} (skin adherence factor) mg/cm^2	0.2
AF_{16-30} (skin adherence factor) mg/cm^2	0
AF_{rec-c} (skin adherence factor - child) mg/cm^2	0
AF_{rec-a} (skin adherence factor - adult) mg/cm^2	0.2
City (Climate Zone) PEF Selection	12
A_s (acres)	6.9
Q/C_{wp} (g/m^2-s per kg/m^3)	48.910518917183
PEF (particulate emission factor) m^3/kg	104966799.84195
A (PEF Dispersion Constant)	13.6482
B (PEF Dispersion Constant)	18.1754
C (PEF Dispersion Constant)	206.7273
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	5.9
U_t (equivalent threshold value)	11.32
F(x) (function dependant on U_m/U_t) unitless	0.6582086037705
City (Climate Zone) VF Selection	12
A_s (acres)	6.9
Q/C_{vol} (g/m^2-s per kg/m^3)	48.910518917183

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
foc (fraction organic carbon in soil) g/g	0.006
ρ$_b$ (dry soil bulk density) g/cm ^{3}	1.5
ρ$_s$ (soil particle density) g/cm ^{3}	2.65
n (total soil porosity) L_{pore}/L_{soil}	0.43396
θ$_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.28396
θ$_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	819936000
A (VF Dispersion Constant)	13.6482
B (VF Dispersion Constant)	18.1754
C (VF Dispersion Constant)	206.7273
City (Climate Zone) VF_{ml} Selection	12
VF_s (volitization factor) m^3/kg	175430.86281224
Q/C_{vol} (g/m^2-s per kg/m^3)	48.910518917183
A_s (acres)	6.9
T (exposure interval) yr	26
d_s (depth of source) m	0.1524
ρ$_b$ (dry soil bulk density) g/cm ^{3}	1.5
A (VF Dispersion Constant - Mass Limit)	13.6482
B (VF Dispersion Constant - Mass Limit)	18.1754
C (VF Dispersion Constant - Mass Limit)	206.7273

Site-specific

Recreator Screening Levels (RSL) for Soil

ca=Cancer, nc=Noncancer, ca* (Where nc SL < 100 x ca SL),
ca** (Where nc SL < 10 x ca SL), max=SL exceeds ceiling limit (see User's Guide), sat=SL exceeds csat,
Smax=Soil SL exceeds ceiling limit and has been substituted with the max value (see User's Guide),
Ssat=Soil inhalation SL exceeds csat and has been substituted with the csat

Chemical	CAS Number	Mutagen?	VOC?	Ingestion SF (mg/kg-day)$^{-1}$	SFO Ref	Inhalation Unit Risk (ug/m^3)$^{-1}$	IUR Ref	Subchronic RfD (mg/kg-day)	Subchronic RfD Ref	Subchronic RfC (mg/m^3)	Subchronic RfC Ref	GIABS	ABS	RBA
Chlordane	12789-03-6	No	Yes	3.50E-01	I	1.00E-04	I	6.00E-04	A	2.00E-04	A	1	0.04	1

Chemical	Volatilization Factor (m^3/kg)	Henry's Law Constant	Soil Saturation Concentration (mg/kg)	Particulate Emission Factor (m^3/kg)	Ingestion SL TR=1.0E-6 (mg/kg)	Dermal SL TR=1.0E-6 (mg/kg)	Inhalation SL TR=1.0E-6 (mg/kg)	Carcinogenic SL TR=1.0E-6 (mg/kg)	Ingestion SL Child THQ=1 (mg/kg)	Dermal SL Child THQ=1 (mg/kg)	Inhalation SL Child THQ=1 (mg/kg)
Chlordane	1.75E+05	0.0019869	-	1.05E+08	4.46E+01	1.71E+02	7.46E+02	3.38E+01	-	-	-

Chemical	Noncarcinogenic SL Child THI=1 (mg/kg)	Ingestion SL Adult THQ=1 (mg/kg)	Dermal SL Adult THQ=1 (mg/kg)	Inhalation SL Adult THQ=1 (mg/kg)	Noncarcinogenic SL Adult THI=1 (mg/kg)	Screening Level (mg/kg)
Chlordane	-	1.34E+02	5.13E+02	2.13E+02	7.09E+01	3.38E+01 ca**

Output generated 01SEP2016:16:53:30

Chemical	CASNUM	Inhalation Unit Risk (µg/m ³)-1	Toxicity Source	EPA Cancer Classification	Inhalation Unit Risk Tumor Type	Inhalation Unit Risk Target Organ	Inhalation Unit Risk Species	Inhalation Unit Risk Method	Inhalation Unit Risk Route	Inhalation Unit Risk Treatment Duration	Inhalation Unit Risk Study Reference	Inhalation Unit Risk Study Date
Chlordane	12789-03-6	1.00E-04	IRIS	Known/likely human carcinogen	Hepatocellular carcinoma	Liver	Mouse	Linearized multistage procedure, extra risk	NA	NA	IRDC 1973, NCI 1977, Khasawinah and Grutsch 1989b	NA

Chemical	CASNUM	Oral Slope Factor (mg/kg-day) $^{-1}$	Toxicity Source	EPA Cancer Classification	Oral Slope Factor Tumor Type	Oral Slope Factor Target Organ	Oral Slope Factor Species	Oral Slope Factor Method	Oral Slope Factor Route	Oral Slope Factor Treatment Duration	Oral Slope Factor Study Reference	Oral Slope Factor Study Date
Chlordane	12789-03-6	3.50E-01	IRIS	Known/likely human carcinogen	Carcinoma	Liver	Mouse	Linearized multistage procedure, extra risk	NA	NA	IRDC 1973, NCI 1977, Khasawinah and Grutsch 1989b	NA

Chemical	CASNUM	Subchronic Oral Reference Dose (mg/kg-day)	Toxicity Source	Oral Subchronic Reference Dose Basis	Oral Subchronic Reference Dose Confidence Level	Oral Subchronic Reference Dose Critical Effect	Oral Subchronic Reference Dose Target Organ	Oral Subchronic Reference Dose Modifying Factor
Chlordane	12789-03-6	0.0006	ATSDR	LOAEL: 0.125 mg/kg-day	NA	Centrilobular hypertrophy, cytoplasmic inclusion bodies	Hepatic	NA

Oral Subchronic Reference Dose Uncertainty Factor	Oral Subchronic Reference Dose Species	Oral Subchronic Reference Dose Route	Oral Subchronic Reference Dose Study Duration	Oral Subchronic Reference Dose Study Date	Oral Subchronic Reference Dose Study Reference
100	Rat	Hepatic	2-9 months	1994	Ortega et al. 1957

Chemical	CASNUM	Subchronic Inhalation Reference Concentration (mg/m³)	Toxicity Source	Inhalation Subchronic Reference Concentration Basis	Inhalation Subchronic Reference Concentration Confidence Level	Inhalation Subchronic Reference Concentration Critical Effect	Inhalation Subchronic Reference Concentration Target Organ	Inhalation Subchronic Reference Concentration Modifying Factor
Chlordane	12789-03-6	0.0002	ATSDR	LOAEL: 0.125 mg/kg-day	NA	Centrilobular hypertrophy, cytoplasmic inclusion bodies	Hepatic	NA

Inhalation Subchronic Reference Concentration Uncertainty Factor	Inhalation Subchronic Reference Concentration Species	Inhalation Subchronic Reference Concentration Route	Inhalation Subchronic Reference Concentration Study Duration	Inhalation Subchronic Reference Concentration Study Date	Inhalation Subchronic Reference Concentration Study Reference
100	Rat	Hepatic	2-9 months	1994	Ortega et al. 1957

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
TR (target cancer risk) unitless	1.0E-6
THQ (target hazard quotient) unitless	1
SA_{rec-c} (skin surface area - child) cm^2/day	0
SA_{rec-a} (skin surface area - adult) cm^2/day	9600
SA_{0-2} (skin surface area - mutagenic) cm^2/day	0
SA_{2-6} (skin surface area - mutagenic) cm^2/day	0
SA_{6-16} (skin surface area - mutagenic) cm^2/day	9600
SA_{16-30} (skin surface area - mutagenic) cm^2/day	0
LT (lifetime - recreator) year	70
$IFS_{rec-adj}$ (age-adjusted soil ingestion factor) mg/kg	2250
$DFS_{rec-adj}$ (age-adjusted soil dermal factor) mg/kg	21600
$IFSM_{rec-adj}$ (mutagenic age-adjusted soil ingestion factor) mg/kg	6750
$DFSM_{rec-adj}$ (mutagenic age-adjusted soil dermal factor) mg/kg	64800
EF_{0-2} (exposure frequency) day/year	0
EF_{2-6} (exposure frequency) day/year	0
EF_{6-16} (exposure frequency) day/year	180
EF_{16-30} (exposure frequency) day/year	0
EF_{rec-c} (exposure frequency - child) day/year	0
EF_{rec-a} (exposure frequency - adult) day/year	180
EF_{rec} (exposure frequency - recreator) day/year	180
IRS_{0-2} (soil intake rate) mg/day	0
IRS_{2-6} (soil intake rate) mg/day	0
IRS_{6-16} (soil intake rate) mg/day	200
IRS_{16-30} (soil intake rate) mg/day	0
IRS_{rec-c} (soil intake rate - child) mg/day	0
IRS_{rec-a} (soil intake rate - adult) mg/day	200
ED_{0-2} (exposure duration) year	0
ED_{2-6} (exposure duration) year	0
ED_{6-16} (exposure duration) year	3
ED_{16-30} (exposure duration) year	0
ED_{rec-c} (exposure duration - child) year	0
ED_{rec-a} (exposure duration - adult) year	3
ED_{rec} (exposure duration - recreator) year	3

Output generated 01SEP2016:16:50:34

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
ET_{0-2} (exposure time) hr/day	0
ET_{2-6} (exposure time) hr/day	0
ET_{6-16} (exposure time) hr/day	8
ET_{16-30} (exposure time) hr/day	0
ET_{rec-c} (exposure time - child) hr/day	0
ET_{rec-a} (exposure time - adult) hr/day	8
ET_{rec} (exposure time - recreator) hr/day	8
BW_{0-2} (body weight) kg	0
BW_{2-6} (body weight) kg	0
BW_{6-16} (body weight) kg	48
BW_{16-30} (body weight) kg	0
BW_{rec-c} (body weight - child) kg	0
BW_{rec-a} (body weight - adult) kg	48
AF_{0-2} (skin adherence factor) mg/cm ^{2}	0
AF_{2-6} (skin adherence factor) mg/cm ^{2}	0
AF_{6-16} (skin adherence factor) mg/cm ^{2}	0.2
AF_{16-30} (skin adherence factor) mg/cm ^{2}	0
AF_{rec-c} (skin adherence factor - child) mg/cm ^{2}	0
AF_{rec-a} (skin adherence factor - adult) mg/cm ^{2}	0.2
City (Climate Zone) PEF Selection	12
A_s (acres)	6.9
Q/C_{wp} (g/m^2-s per kg/m^3)	48.910518917183
PEF (particulate emission factor) m ^{3}/kg	104966799.84195
A (PEF Dispersion Constant)	13.6482
B (PEF Dispersion Constant)	18.1754
C (PEF Dispersion Constant)	206.7273
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	5.9
U_t (equivalent threshold value)	11.32
F(x) (function dependant on U_m/U_t) unitless	0.6582086037705
City (Climate Zone) VF Selection	12
A_s (acres)	6.9
Q/C_{vol} (g/m^2-s per kg/m^3)	48.910518917183

Output generated 01SEP2016:16:50:34

Site-specific

Recreator Equation Inputs for Soil

Variable	Value
foc (fraction organic carbon in soil) g/g	0.006
ρ$_b$ (dry soil bulk density) g/cm^3	1.5
ρ$_s$ (soil particle density) g/cm^3	2.65
n (total soil porosity) L_{pore}/L_{soil}	0.43396
θ$_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.28396
θ$_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	819936000
A (VF Dispersion Constant)	13.6482
B (VF Dispersion Constant)	18.1754
C (VF Dispersion Constant)	206.7273
City (Climate Zone) VF_{ml} Selection	12
VF_s (volitization factor) m^3/kg	175430.86281224
Q/C_{vol} (g/m^2-s per kg/m^3)	48.910518917183
A_s (acres)	6.9
T (exposure interval) yr	26
d_s (depth of source) m	0.1524
ρ$_b$ (dry soil bulk density) g/cm^3	1.5
A (VF Dispersion Constant - Mass Limit)	13.6482
B (VF Dispersion Constant - Mass Limit)	18.1754
C (VF Dispersion Constant - Mass Limit)	206.7273

Output generated 01SEP2016:16:50:34

Site-specific

Recreator Screening Levels (RSL) for Soil

ca=Cancer, nc=Noncancer, ca* (Where nc SL < 100 x ca SL),
ca** (Where nc SL < 10 x ca SL), max=SL exceeds ceiling limit (see User's Guide), sat=SL exceeds csat,
Smax=Soil SL exceeds ceiling limit and has been substituted with the max value (see User's Guide),
Ssat=Soil inhalation SL exceeds csat and has been substituted with the csat

Chemical	CAS Number	Mutagen?	VOC?	Ingestion SF (mg/kg-day)$^{-1}$	SFO Ref	Inhalation Unit Risk (ug/m^3)$^{-1}$	IUR Ref	Subchronic RfD (mg/kg-day)	Subchronic RfD Ref	Subchronic RfC (mg/m^3)	Subchronic RfC Ref	GIABS	ABS	RBA
Chlordane	12789-03-6	No	Yes	3.50E-01	I	1.00E-04	I	6.00E-04	A	2.00E-04	A	1	0.04	1

Chemical	Volatilization Factor (m^3/kg)	Henry's Law Constant	Soil Saturation Concentration (mg/kg)	Particulate Emission Factor (m^3/kg)	Ingestion SL TR=1.0E-6 (mg/kg)	Dermal SL TR=1.0E-6 (mg/kg)	Inhalation SL TR=1.0E-6 (mg/kg)	Carcinogenic SL TR=1.0E-6 (mg/kg)	Ingestion SL Child THQ=1 (mg/kg)	Dermal SL Child THQ=1 (mg/kg)	Inhalation SL Child THQ=1 (mg/kg)
Chlordane	1.75E+05	0.0019869	-	1.05E+08	3.24E+01	8.45E+01	2.49E+02	2.14E+01	-	-	-

Chemical	Noncarcinogenic SL Child THI=1 (mg/kg)	Ingestion SL Adult THQ=1 (mg/kg)	Dermal SL Adult THQ=1 (mg/kg)	Inhalation SL Adult THQ=1 (mg/kg)	Noncarcinogenic SL Adult THI=1 (mg/kg)	Screening Level (mg/kg)
Chlordane	-	2.92E+02	7.60E+02	2.13E+02	1.06E+02	2.14E+01 ca**

Output generated 01SEP2016:16:50:34

Chemical	CASNUM	Inhalation Unit Risk (µg/m ^{3})$^{-1}$	Toxicity Source	EPA Cancer Classification	Inhalation Unit Risk Tumor Type	Inhalation Unit Risk Target Organ	Inhalation Unit Risk Species	Inhalation Unit Risk Method	Inhalation Unit Risk Route	Inhalation Unit Risk Treatment Duration	Inhalation Unit Risk Study Reference	Inhalation Unit Risk Study Date
Chlordane	12789-03-6	1.00E-04	IRIS	Known/likely human carcinogen	Hepatocellular carcinoma	Liver	Mouse	Linearized multistage procedure, extra risk	NA	NA	IRDC 1973, NCI 1977, Khasawinah and Grutsch 1989b	NA

Chemical	CASNUM	Oral Slope Factor (mg/kg-day) $^{-1}$	Toxicity Source	EPA Cancer Classification	Oral Slope Factor Tumor Type	Oral Slope Factor Target Organ	Oral Slope Factor Species	Oral Slope Factor Method	Oral Slope Factor Route	Oral Slope Factor Treatment Duration	Oral Slope Factor Study Reference	Oral Slope Factor Study Date
Chlordane	12789-03-6	3.50E-01	IRIS	Known/likely human carcinogen	Carcinoma	Liver	Mouse	Linearized multistage procedure, extra risk	NA	NA	IRDC 1973, NCI 1977, Khasawinah and Grutsch 1989b	NA

Chemical	CASNUM	Subchronic Oral Reference Dose (mg/kg-day)	Toxicity Source	Oral Subchronic Reference Dose Basis	Oral Subchronic Reference Dose Confidence Level	Oral Subchronic Reference Dose Critical Effect	Oral Subchronic Reference Dose Target Organ	Oral Subchronic Reference Dose Modifying Factor
Chlordane	12789-03-6	0.0006	ATSDR	LOAEL: 0.125 mg/kg-day	NA	Centrilobular hypertrophy, cytoplasmic inclusion bodies	Hepatic	NA

Oral Subchronic Reference Dose Uncertainty Factor	Oral Subchronic Reference Dose Species	Oral Subchronic Reference Dose Route	Oral Subchronic Reference Dose Study Duration	Oral Subchronic Reference Dose Study Date	Oral Subchronic Reference Dose Study Reference
100	Rat	Hepatic	2-9 months	1994	Ortega et al. 1957

Chemical	CASNUM	Subchronic Inhalation Reference Concentration (mg/m³)	Toxicity Source	Inhalation Subchronic Reference Concentration Basis	Inhalation Subchronic Reference Concentration Confidence Level	Inhalation Subchronic Reference Concentration Critical Effect	Inhalation Subchronic Reference Concentration Target Organ	Inhalation Subchronic Reference Concentration Modifying Factor
Chlordane	12789-03-6	0.0002	ATSDR	LOAEL: 0.125 mg/kg-day	NA	Centrilobular hypertrophy, cytoplasmic inclusion bodies	Hepatic	NA

Inhalation Subchronic Reference Concentration Uncertainty Factor	Inhalation Subchronic Reference Concentration Species	Inhalation Subchronic Reference Concentration Route	Inhalation Subchronic Reference Concentration Study Duration	Inhalation Subchronic Reference Concentration Study Date	Inhalation Subchronic Reference Concentration Study Reference
100	Rat	Hepatic	2-9 months	1994	Ortega et al. 1957

Site-specific

Outdoor Worker Equation Inputs for Soil

Variable	Value
TR (target cancer risk) unitless	1.0E-6
THQ (target hazard quotient) unitless	1
AT_{ow} (averaging time - outdoor worker)	365
EF_{ow} (exposure frequency - outdoor worker) day/yr	250
ED_{ow} (exposure duration - outdoor worker) yr	25
ET_{ow} (exposure time - outdoor worker) hr	8
LT (lifetime) yr	70
BW_{ow} (body weight - outdoor worker)	80
IR_{ow} (soil ingestion rate - outdoor worker) mg/day	50
SA_{ow} (surface area - outdoor worker) cm^2/day	3527
AF_{ow} (skin adherence factor - outdoor worker) mg/cm^2	0.12
City (Climate Zone) PEF Selection	12
A_s (acres)	6.9
Q/C_{wp} (g/m^2-s per kg/m^3)	48.910518917183
PEF (particulate emission factor) m^3/kg	32408433629.741
A (PEF Dispersion Constant)	13.6482
B (PEF Dispersion Constant)	18.1754
C (PEF Dispersion Constant)	206.7273
V (fraction of vegetative cover) unitless	0.5
U_m (mean annual wind speed) m/s	3.49
U_t (equivalent threshold value)	11.32
F(x) (function dependant on U_m/U_t) unitless	0.0103
City (Climate Zone) VF Selection	12
A_s (acres)	6.9
Q/C_{vol} (g/m^2-s per kg/m^3)	48.910518917183
foc (fraction organic carbon in soil) g/g	0.006
ρ$_b$ (dry soil bulk density) g/cm^3	1.5
ρ$_s$ (soil particle density) g/cm^3	2.65
n (total soil porosity) L_{pore}/L_{soil}	0.43396
θ$_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.28396
θ$_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	819936000
A (VF Dispersion Constant)	13.6482

Site-specific

Outdoor Worker Equation Inputs for Soil

Variable	Value
B (VF Dispersion Constant)	18.1754
C (VF Dispersion Constant)	206.7273
City (Climate Zone) VF $_{ml}$ Selection	12
VF_s (volitization factor) m^3/kg	175430.86281224
Q/C_{vol} (g/m^2-s per kg/m^3)	48.910518917183
A_c (acres)	6.9
T (exposure interval) yr	26
d_c (depth of source) m	0.1524
ρ$_b$ (dry soil bulk density) g/cm^3	1.5
A (VF Dispersion Constant - Mass Limit)	13.6482
B (VF Dispersion Constant - Mass Limit)	18.1754
C (VF Dispersion Constant - Mass Limit)	206.7273

Site-specific

Outdoor Worker Screening Levels (RSL) for Soil

ca=Cancer, nc=Noncancer, ca* (Where nc SL < 100 x ca SL),
ca** (Where nc SL < 10 x ca SL), max=SL exceeds ceiling limit (see User's Guide), sat=SL exceeds csat,
Smax=Soil SL exceeds ceiling limit and has been substituted with the max value (see User's Guide),
Ssat=Soil inhalation SL exceeds csat and has been substituted with the csat

Chemical	CAS Number	Mutagen?	VOC?	Ingestion SF (mg/kg-day)$^{-1}$	SFO Ref	Inhalation Unit Risk (ug/m^3)$^{-1}$	IUR Ref	Chronic RfD (mg/kg-day)	Chronic RfD Ref	Chronic RfC (mg/m^3)	Chronic RfC Ref	GIABS	ABS	RBA	Volatilization Factor (m^3/kg)	Henry's Law Constant
Chlordane	12789-03-6	No	Yes	3.50E-01	I	1.00E-04	I	5.00E-04	I	7.00E-04	I	1	0.04	1	1.75E+05	0.0019869

Chemical	Soil Saturation Concentration (mg/kg)	Particulate Emission Factor (m^3/kg)	Ingestion SL TR=1.0E-6 (mg/kg)	Dermal SL TR=1.0E-6 (mg/kg)	Inhalation SL TR=1.0E-6 (mg/kg)	Carcinogenic SL TR=1.0E-6 (mg/kg)	Ingestion SL THQ=1 (mg/kg)	Dermal SL THQ=1 (mg/kg)	Inhalation SL THQ=1 (mg/kg)	Noncarcinogenic SL THI=1 (mg/kg)	Screening Level (mg/kg)
Chlordane	-	3.24E+10	1.87E+01	5.52E+01	2.15E+01	8.47E+00	1.17E+03	3.45E+03	5.38E+02	3.33E+02	8.47E+00 ca*

Output generated 01SEP2016:16:46:51

Chemical	CASNUM	Inhalation Unit Risk (µg/m 3)-1	Toxicity Source	EPA Cancer Classification	Inhalation Unit Risk Tumor Type	Inhalation Unit Risk Target Organ	Inhalation Unit Risk Species	Inhalation Unit Risk Method	Inhalation Unit Risk Route	Inhalation Unit Risk Treatment Duration	Inhalation Unit Risk Study Reference	Inhalation Unit Risk Study Date
Chlordane	12789-03-6	1.00E-04	IRIS	Known/likely human carcinogen	Hepatocellular carcinoma	Liver	Mouse	Linearized multistage procedure, extra risk	NA	NA	IRDC 1973, NCI 1977, Khasawinah and Grutsch 1989b	NA

Chemical	CASNUM	Oral Slope Factor (mg/kg-day) $^{-1}$	Toxicity Source	EPA Cancer Classification	Oral Slope Factor Tumor Type	Oral Slope Factor Target Organ	Oral Slope Factor Species	Oral Slope Factor Method	Oral Slope Factor Route	Oral Slope Factor Treatment Duration	Oral Slope Factor Study Reference	Oral Slope Factor Study Date
Chlordane	12789-03-6	3.50E-01	IRIS	Known/likely human carcinogen	Carcinoma	Liver	Mouse	Linearized multistage procedure, extra risk	NA	NA	IRDC 1973, NCI 1977, Khasawinah and Grutsch 1989b	NA

Oral Chronic Toxicity Metadata

Chemical	CASNUM	Chronic Oral Reference Dose (mg/kg-day)	Toxicity Source	Oral Chronic Reference Dose Basis	Oral Chronic Reference Dose Confidence Level	Oral Chronic Reference Dose Critical Effect	Oral Chronic Reference Dose Target Organ
Chlordane	12789-03-6	5.00E-04	IRIS	NOAEL: 0.15 mg/kg-day	Medium	Hepatic Necrosis	Liver

Oral Chronic Reference Dose Modifying Factor	Oral Chronic Reference Dose Uncertainty Factor	Oral Chronic Reference Dose Species	Oral Chronic Reference Dose Route	Oral Chronic Reference Dose Study Duration	Oral Chronic Reference Dose Study Date	Oral Chronic Reference Dose Study Reference
1	300	Mouse	NA	NA	1994	Khasawinch and Grutsch 1989a

Chemical	CASNUM	Chronic Inhalation Reference Concentration (mg/m³)	Toxicity Source	Inhalation Chronic Reference Concentration Basis	Inhalation Chronic Reference Concentration Confidence Level	Inhalation Chronic Reference Concentration Critical Effect	Inhalation Chronic Reference Concentration Target Organ
Chlordane	12789-03-6	0.0007	IRIS	NOAEL (HEC): 0.65 mg/m3	Low	Hepatic effects	Liver

Inhalation Chronic Reference Concentration Modifying Factor	Inhalation Chronic Reference Concentration Uncertainty Factor	Inhalation Chronic Reference Concentration Species	Inhalation Chronic Reference Concentration Route	Inhalation Chronic Reference Concentration Study Duration	Inhalation Chronic Reference Concentration Study Date	Inhalation Chronic Reference Concentration Study Reference
1	1000	Rat	NA	NA	1994	Khasawinah et al. 1989a