Toxicity Testing of Soils Contaminated with Gasoline, Diesel, and Heavy Oil

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Contact information

For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600, Olympia, WA 98504-7600
Phone: (360) 407-6764

Washington State Department of Ecology - www.ecy.wa.gov

o	Headquarters, Olympia	(360) 407-6000
o	Northwest Regional Office, Bellevue	(425) 649-7000
o	Southwest Regional Office, Olympia	(360) 407-6300
o	Central Regional Office, Union Gap	(509) 575-2490
o	Eastern Regional Office, Spokane	(509) 329-3400

Cover photo: *Lactuca sativa* (lettuce) bioassay test. Picture taken by CH2M HILL – Applied Science Laboratory.

Toxicity Testing of Soils Contaminated with Gasoline, Diesel, and Heavy Oil

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by

Patti Sandvik and Siana Wong

Toxics Studies Unit
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

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Abstract

The purpose of this study was to collect data to support development of numeric values under Washington's Model Toxic Control Act (MTCA) for ecological screening of soils contaminated with petroleum products. The Washington State Department of Ecology (Ecology) is the lead agency responsible for the implementation and enforcement of MTCA.

Ecology's Toxics Cleanup Program specifies procedures for establishing cleanup levels at sites where there has been a release of petroleum and its associated hazardous substances. Complex mixtures of petroleum hydrocarbons can be grouped into fractions containing hydrocarbons with similar chemical, physical, and toxicological characteristics. When released to the environment, different fractions break down (termed *weathering*) at different rates so that the properties of the mixture are different both physically and chemically than the composition at the time of the release.

To support the development of ecological screening values for gasoline, diesel, and heavy oil contamination in weathered soils, Ecology collected toxicity data from laboratory bioassay tests on soils collected around Washington State. These screening values, or *benchmarks*, are considered protective of soil biota and wildlife.

Results from gasoline and diesel range organics analysis support using 120 mg/kg for Gasoline Range Organics and 260 mg/kg Diesel Range Organics for soil screening levels under MTCA for soil biota. Screening levels of 120 mg/kg for Gasoline Range Organics and 1,600 mg/kg for Diesel Range Organics were considered appropriate for plants.

Recommendations include conducting:

- Additional bioassay tests using soils collected from the east side of Washington State.
- Additional research for developing methods to define screening levels and fractions.
- Bioaccumulation tests to support a bioaccumulation factor for worm tissue.

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Introduction

The purpose of this study was to collect data for establishing numeric values for ecological screening of petroleum products under Washington's Model Toxic Control Act (MTCA). This act is a comprehensive regulatory scheme to protect human health and the environment from hazardous waste contamination. Washington State Department of Ecology (Ecology) is the lead agency responsible for the implementation and enforcement of MTCA. MTCA classifies petroleum as a regulated hazardous substance.

MTCA regulations can be found in Chapter 173-340 WAC (www.ecy.wa.gov/biblio/9406.html). Various policy documents and technical memoranda that help explain how Ecology interprets and applies the MTCA are at www.ecy.wa.gov/programs/tcp/policies/tcppoly.html.

Petroleum products, such as gasoline, diesel, and heavy fuel oils, originally come from crude oil and consist of complex mixtures of hundreds of compounds, of which petroleum hydrocarbons are one of the principal components. Because of the widespread use of these products, environmental contamination from petroleum hydrocarbons is relatively common. Assessment of petroleum hydrocarbon-contaminated sites involves analysis for total petroleum hydrocarbons (TPH). TPH represents the total mass of hydrocarbons rather than the identification of individual components.

When released to the environment, the composition of a petroleum product changes due to weathering (i.e., the breakdown of its components), which causes changes in the components' fate and transport. Hydrocarbons with similar physical and chemical properties can be assigned to a specific equivalent carbon range, known as fractions. Some petroleum constituents biodegrade more readily, leaving the relatively non-mobile components (the weathered product) at the original location (ATSDR, 1999). The constituents that biodegrade quickly or volatilize in the vapor phase are less of a concern than the remaining constituents that are more likely to impact ecological populations.

Ecology's Toxics Cleanup Program (TCP) specifies procedures for establishing cleanup levels at sites where there has been a release of petroleum and its associated hazardous substances. Testing for TPH is required for most types of petroleum releases. For soil contamination, the potential impact of TPH on terrestrial ecological receptors must be evaluated. Specifically, either a Terrestrial Ecological Evaluation (TEE), or an exclusion from the TEE process must be established.

The Terrestrial Ecological Evaluation (TEE)

In a TEE, Ecology requires toxic chemicals to be screened for contaminants of potential concern by:

- Identifying whether a release of hazardous substances to soil may pose a threat to the terrestrial environment.
- Characterizing existing or potential threats to soil biota and terrestrial plants and animals exposed to hazardous substances in soil.

- Establishing soil concentrations that are protective of soil biota and terrestrial plants and animals.
- Facilitating evaluation of cleanup action alternatives by developing necessary information for a feasibility study.

Part of the TEE screening process entails comparing reported ambient concentrations to a set of toxicological screening levels. These screening levels (benchmarks) are described in WAC 173-340 in Tables 749-2 and 749-3(WAC 173-340, 2013; Ecology, 2012; Ecology, 2001). If the screening levels are exceeded, they may be used as a conservative cleanup level for the site, or additional site-specific evaluations may be performed.

Currently, the MTCA lists soil concentration screening levels for gasoline range organics (GRO) and diesel range organics (DRO) in Table 749-2 (for the simplified terrestrial evaluation) and Table 749-3 (for the site-specific evaluation). However, the MTCA does not list screening levels for heavy oils. Ecology directs heavy oils to be summed with DRO in *Guidance for Remediation of Petroleum Contaminated Sites* (Ecology, 2011).

Simplified terrestrial evaluation screening levels for unrestricted land use allow 200 mg/kg for GRO and 460 mg/kg for DRO. Screening levels for the site-specific TEE are presented separately for plants, soil biota, and wildlife. The screening levels for soil biota (including earthworms, other micro and macro invertebrates, and heterotrophic bacteria and fungi) are 100 for GRO and 200 mg/kg for DRO (WAC 173-340, 2013; Ecology, 2011; Ecology, 2012). The screening levels for wildlife are substantially higher: 5,000 mg/kg for GRO and 6,000 mg/kg for DRO. No screening levels are provided for plants.

Additionally, for a site-specific evaluation, a wildlife model must be conducted to determine if bioaccumulation levels of the contaminant of concern will harm animals. The Wildlife Exposure Model for Site-specific Evaluations uses toxicity reference values listed in Table 749-5 (Default Values for Selected Hazardous Substances for use with the Wildlife Exposure Model in Table 749-4). However, since values for GRO and DRO are not listed in Table 749-5, the logarithm of the octanol-water partition coefficient (log K_{ow}) is used for obtaining the GRO and DRO wildlife screening levels. These levels are 5,000 mg/kg and 6,000 mg/kg respectively (WAC 173-340, 2013; Ecology, 2011; Ecology, 2012).

These screening levels are based on literature surveys of laboratory tests using spiked soils[1] or studies of fresh gasoline and diesel products rather than weathered contamination in soil (Ecology, 2001; Ecology, 2011; Efroymson et al., 1997a,b). Furthermore, no screening levels have been developed for the protection of plants.

[1] Clean field-collected or laboratory-created soils are spiked with solutions at different concentrations of the contaminant of interest. The spiked soil is then used to test the toxicity of the contaminant to various organisms.

Objectives

This study assessed plant and soil biota toxicity of weathered petroleum products from contaminated soils located within Washington State. Soil samples were analyzed for gas, diesel, and heavy oil concentrations, and the effects on biota were quantified using lettuce and earthworm bioassay tests.

The primary objective of this study was to:

- Collect data to support development of ecological screening levels for gas, diesel, and heavy oil contamination in weathered soils within Washington for incorporation into MTCA.

Secondary objectives were to:

- Determine if alternative ecologically relevant screening levels are practical for use in screening contaminated soils by comparing toxicity level concentrations for GRO and DRO from this study to current screening levels for soil biota.
- Assess how much of the petroleum products bioaccumulate in the tissue of soil biota.

To address the objectives of this study, we implemented a triad approach consisting of field assessment, chemical testing, and toxicity testing. Field assessment involved site observation of whether actual harm appeared to have occurred at the site. Chemical testing indicated the presence or absence of contamination at the site. Toxicity tests indicated whether biological impacts from contamination were likely.

Methods

This project was designed to sample soils known to be contaminated with gas, diesel, or heavy oil. A Quality Assurance Project Plan (QAPP) was developed to guide this effort to ensure that the data collected were representative of the environment and acceptable for their intended use to meet the goals and objectives of the project (Sandvik, 2014).

Ten different locations were sampled for gas, diesel, or heavy oil contamination in soils: nine on the west side of the Cascade Range and one on the east side. At one site, two sets of soil samples were collected to obtain a larger range of concentrations. Although this study targeted 12 sites, a malfunction in the cold storage room forced the evacuation and early transport of the samples to the bioassay laboratory before the final site could be sampled making a total of 11 sites.

A total of 54 soil samples representing a range in concentrations of gas, diesel, or heavy oil within Washington were collected. A minimum of five samples were collected per site, except for two locations where only three or four samples were collected due to limitations of substrate or sampling equipment. For this study, the soils that were collected targeted a range of contaminant concentrations while little emphasis was put on the actual site except to represent soils found in Washington. However, site and sample descriptions are included in Appendix A, along with sample identification for finding results from this study in Ecology's Environmental Information Management (EIM) database.

Site Selection

Site Screening

Potential locations were found by searching for reported spills, cleanup sites, and leaking underground storage tanks (USTs). Ecology's EIM, Integrated Site Information System (ISIS), internal databases, and professional staff from TCP helped guide the site selection effort as outlined in the QAPP for this study. Most sites were located using current UST removal notifications and by word of mouth. After obtaining permission from Ecology, site owners, governing agencies, or contractors, we accessed sites as soon as feasible. Most of the locations searched in the database were not available for study for such reasons as the site becoming inactive or completing its cleanup.

We screened all sites for appropriateness for this project by confirming a contaminant was above cleanup levels, the site type was upland, and the petroleum product type was generally homogenous (i.e., only GRO or only DRO). Soils selected using these criteria were expected to meet the objective for defining risks to terrestrial plants and animals. A database search, literature search, and personal communication were used to screen for sites containing gasoline, diesel, or heavy oil contamination in soils. For each site and when available, we reviewed and compiled documents for soil concentrations, background levels, cleanup levels, and bioassay test results of each petroleum product of concern.

Potential sites (sites that were screened appropriate) were chosen based on available access from September to December 2014. Only one site was available east of the Cascades during the sampling period. All soil samples represented contamination that had been present for more than five years.

Target Chemicals

The targeted contaminant concentrations were screened using available historical laboratory reports or professional guidance as noted above. Most sites had previous soil testing results, although many of those results were limited in scope, because sample collectors had targeted areas below criteria levels (bottom or sides of pit) to confirm completion of excavation for cleanup.

On-site soils collected for gas and diesel contamination were screened using a Photoionization Detector (PID) owned and operated by professionals on site. Soil samples with a range of concentrations as indicated by the PID were retained. Professionals on site helped guide soil sample collection.

As another method of screening for targeted contaminant concentrations, a PetroFLAG® field test kit for TPH in soils was used. PetroFLAG® quantifies fuels, oils, and greases as total hydrocarbons but does not distinguish between aromatic and aliphatic hydrocarbons (Dexsil, 2014; EPA, 2007a). Although this screening was targeted for all potential locations, only three of the sites were successfully tested. Most sites could not be tested with this method, since many were sampled during ongoing construction and tank removal. These activities limited access needed for screening before collection of the actual sample. Safety restrictions imposed by contractor or owner and available time during excavation and hauling time-sensitive operations limited screening time. Furthermore, it was found that PetroFLAG® did not perform well in air temperatures below about 54° F, and air temperatures were generally below that level during field sampling. The PetroFLAG® instrument was useful for sites with heavy oil where the PID was not effective and where sample collection was not restricted by a construction schedule. PetroFLAG® results are listed in Appendix B.

Since the goal of this project was to test soils for individual petroleum products (i.e., gas, diesel, or heavy oil), it was important to avoid sites with multiple contaminants. The screening was conducted while searching the ISIS database. Potential sites contained fewer than three other suspicious (not confirmed) contaminants in soil or groundwater. These sites showed no results for metals, pesticides, radioactive wastes, or any other substance that may interfere with bioassay testing. Potential sites that were not in the database but available through UST removal notices were screened for multiple contaminants using guidance from professional or experienced stakeholders on site, who generally provided background reports for the individual sites.

XRF

All soil samples were tested for metals and other elements using an X-ray Fluorescence Instrument (XRF) to identify confounding contaminants. The XRF identified relative amounts of metals present in samples by measuring the unique fluorescent x-rays emitted by the different

metals (EPA, 2007b). Results are evaluated as [Total] rather than [Total Recoverable] and may not be directly comparable with screening levels. Although not directly comparable, element screening levels and XRF results are listed in Appendix C for a broad assessment of contaminant levels.

Most results were below MTCA Ecological Screening Levels for plants, soil biota, and wildlife (Appendix C). Exceptions are shown in Table 1. Arsenic and lead XRF results on field samples may be biased slightly low, based on evidence that moisture in soils produces lower XRF results when compared with laboratory analysis (Sloan, 2010). The budget did not allow for additional laboratory analyses.

Table 1. XRF results summary statistics and percent samples that exceeded screening levels.

Element	**Benchmarks**			**XRF Summary Stats (ppm)**			**Percent Results Exceeding Screening Levels**		
	Ecological Indicator (mg/kg)[a]	MTCA Cleanup Levels		Min	Max	Med	Ecological Indicator (%)	MTCA Cleanup Levels	
		Method B (ppm)	Method A (ppm)					Method A or B (%)	Method A (%)
As	10	24	20	2.8	41	6.4	17	4	4
Cr	42	240	19	30	710	80	72	74	74
Pb	50	-	250	3.2	400	7.5	9	2	2
Hg	0.1	-	2	3.8	7.5	4.5	17	17	17
Sb	5	-	-	16	23	21	6	-	-
Ba	102	16,000	-	250	1,600	560	85	-	-
Cu	50	3,200	-	6.5	540	17	4	-	-
Mo	2	400	-	1.3	2.9	2.2	4	-	-
Ni	30	-	-	12	92	36	61	-	-
Se	0.3	400.0	-	1.6	1.6	1.6	2	-	-
Zn	86	24,000	-	33	420	56	11	-	-

[a] Ecological Indicator Soil Concentrations for Plant, Soil Biota, and Wildlife (mg/kg dry soil). The conservative (lowest) of the three values for each element are reported in this table.
Arsenic (As)
Chromium (Cr)
Lead (Pb)
Mercury (Hg)
Antimony (Sb)
Barium (Ba)
Copper (Cu)
Molybdenum (Mo)
Nickel (Ni)
Selenium (Se)
Zinc (Zn)

Most bioassay test results with elevated XRF results (above screening levels) showed no significant adverse effects in soil bioassays when compared to the control. The toxicity found in the bioassay tests that were significant compared to the control are shown to be associated with factors relating to the petroleum contamination within the sample. Further discussion for toxicity associations are discussed with the earthworm and lettuce survival results section.

It is notable that the chromium XRF results may be biased high when compared to screening levels because of analytical method differences. XRF results reported Total concentration, whereas some screening values, such as for chromium, are based on Total Recoverable analysis, which extracts less metal than does the Total method.

Although many chromium results were above the screening level of 42 mg/kg, they were similar to levels found for western Washington. Ames and Prych (1995) found chromium ranged from 50 mg/kg to 540 mg/kg using the Total Method for analysis in samples taken from Puget Sound adjacent upland areas, which is similar to where this study's samples were collected. Total Recoverable results ranged from 19.9 mg/kg to 313 mg/kg for the same samples in the background study (Ames and Prych, 1995; San Juan, 1994). Since this current study's results are comparable with the background range for western Washington, toxicity effects found in bioassays would likely be associated with petroleum contamination rather than chromium or other confounding metal contaminants.

Soil Collection

Soil samples were collected from targeted contaminated areas within a known contamination plume, which was determined from current or historical documentation. Most samples were collected after consultation with professionals on site and in consideration of evidence based on PID or PetroFLAG® readings and obvious visual and olfactory evidence. Heavily contaminated soils had an obvious darker or gray color and a notable petroleum smell. Instrument readings and observational evidence were used as a guide to target a range of concentrations.

A variety of methods were used for extracting samples from contaminated soils, including direct push coring, open excavation, sonic boring, and collecting from stockpile and contaminated natural areas. Soils were excavated and shoveled into a five gallon plastic-lined bucket, sealed by twisting the top of the plastic bag, and applying the lid. At least four liters of soil were targeted for each sample.

All sampling equipment (shovel, hand trowel, spoons, and collection buckets) were cleaned before use at each site. The cleaning process followed the QAPP (Sandvik, 2014) for this project, and Standard Operating Procedure (SOP) for decontaminating sampling equipment (Friese, 2014). Cleaning included washing with water and phosphate-free detergent, rinsing with distilled water, and then rinsing with pesticide-grade acetone. Contractors cleaned core equipment following their protocols, which were similar. The backhoe scoops were not cleaned between samples; therefore, care was taken to collect soils from the inside portion of the scoop and to avoid touching its edges.

Sample Processing

Once a soil sample was collected and retained in a sealed plastic-lined five gallon bucket, it was transported to a safe working area near the site for subsampling. Non-soil components such as roots, twigs, and large rocks were removed by hand and noted on field logs. Soils in buckets were then subsampled and divided into the appropriate containers for chemical analyses, bioassay tests, and ancillary analyses. Volatile organic compounds (VOC) were sampled first. The soil in the bucket was kept sealed in plastic bags and covered with the lid between subsampling. Although some VOC may have been lost even with best efforts to retain them, the actual concentrations measured more likely reflect those found in the soils used for bioassay tests. Bioassay test soil concentrations were the intent of this study rather than to measure concentrations of the site where the soils were collected.

Subsamples were taken from different areas within the bucket of soil sample to increase homogeneity. Homogenization was applied once to samples in preparation for and at the time of the bioassay tests to avoid loss of volatiles prematurely.

VOC samples were collected immediately and preserved as directed by laboratories doing the analysis and Ecology's memorandum #5 instructions for *Collecting and Preparing Soil Samples for VOC Analysis* (Nord, 2004). The subsample for VPH was taken using Easy Draw®, a specially designed sealed-tube device that obtains airtight soil samples by extruding directly into the soil. The samples were then put in tubes with premeasured methanol for preservation, which was provided by the contracting laboratory. The subsamples for NWTPH-Gx were collected in a four-ounce jar with a septum, leaving no head space. Both types of VOC samples were immediately put on bottled ice.

The remaining subsamples were collected and chilled in coolers with bottled ice. General soil characteristics were determined following the guidance as described in the QAPP (Sandvik, 2014) and recorded in the field notes. Field measurements of pH were taken following protocols found in EPA's methods for evaluating solid waste (EPA, 2004). This entailed mixing a small subsample (20 g) of soil with 20 mL of distilled water to create slurry and then allowing the slurry to settle before measuring pH. Three pH measurements were recorded for each soil sample and an average pH measurement was obtained. Field measurements, observations, and any other remarks were recorded in field notes.

Analysis Methods

Methods used in this study followed those described in the QAPP (Sandvik, 2014). Tables 2 and 3 list the analyses that were conducted and the associated method. Due to some soil characteristics, the methods specified in the QAPP for the bioassays were adjusted to maintain proper moisture and pH. Sample comparisons were conducted to verify that bioassay results remained valid. See the Bioassay Test Methods below for more discussion.

Table 2. Parameters and methods.

Analysis	Laboratory	Instrument/ Technique	Analytical Method	Reporting Limits/Resolution
Field Measurements				
pH	-	Hach pH meter	EPA Method 9045D	0.01
Various Contaminants (e.g., metals)	-	XRF	EPA Method 6200 & Instrument Manual	10 ppm[a]
Hydrocarbon Range	-	PetroFLAG®	EPA Method 9074	200[b] - Gas 13 - Diesel 18 - Oil ppm ww
Soil Characteristics	-	-	ASTM D 2488 modified	-
Grain Size	-	Ro-TAP	CMAP SOP modified	-
Laboratory Analyses				
TOC	MEL	-	PSEP, 1997	0.10%
Solids	MEL	-	SM2540G	1.0%
NWTPH-Dx	MEL	GC/FID	NWTPH-Dx Ecology, 1997	25 - Diesel 100 - Oil mg/kg dw
NWTPH-Gx[c]	MEL	GC/FID	NWTPH-Gx Ecology, 1997	5 mg/kg dw
EPH	ARI	GC/FID	EPH Ecology, 1997	5 mg/kg dw
VPH[1]	ARI	GC/FID	VPH Ecology, 1997	5 mg/kg dw

[a] Analyte dependent.
[b] Due to the non-linear response curve of Gasoline, quantification below 1,000 ppm may underestimate the true contamination.
[c] Method includes Ecology's Memorandum #7: Soil Moisture Corrected Reporting by EPA Method 8000C (Bradley, 2008).
ARI: Analytical Resources, Inc.
dw: Dry weight
EPH: Extractable Petroleum Hydrocarbons
NWTPH-Dx: Northwest Total Petroleum Hydrocarbon diesel range organics
NWTPH-Gx: Northwest Total Petroleum Hydrocarbon gasoline range organics
MEL: Manchester Environmental Laboratory
TOC: Total Organic Carbon
VPH: Volatile Petroleum Hydrocarbons
ww: Wet weight
XRF: X-ray Fluorescence Instrument

Table 3. Laboratory procedures for bioassay tests

Bioassay	Endpoints Measured	Methods
Lettuce	Survival, Biomass	Norton, 1996a, ASTM E 1963-09 (2009)
Earthworm	Survival, Concentration	Norton, 1996b, ASTM E 1676-12 (2012), EPA 600/3-88/029 (1988)

General soil characteristics were determined following the described plan listed in the QAPP for this project (Sandvik, 2014) and recorded in the field notes. Soil types were characterized by observation in the field for coarse versus fine grain, but determined volumetrically back at Ecology's Headquarters and Operation Center on dry soil (<3 inch, 75 mm). Soil characteristics described in the field notes are included in Appendix A.

Grain size was based on a series of sieves (0.075 mm (No. 200), 0.425 mm (No. 40), and 4.00 mm (No. 5). The sieve No. 5 was used instead of the No. 4 as listed in the QAPP because the No. 4 sieve was not available at the time of the analysis. This substitute does not compromise results since the grain size analysis was for a general determination between gravel, sandy, and silty materials.

Sixteen soil samples (sample numbers 1412041-10 through 1412041-25) contaminated with heavy oil needed to be pre-cleaned before sieving because the heavy oil prevented sifting. Cleaning was conducted using a 75%/25% acetone/hexane solvent mix based on a recent study showing high efficiency to remove heavy oil fractions and petroleum hydrocarbons from contaminated soils (Li et al., 2012). Three of the sixteen pre-cleaned samples (sample numbers 1412041-18, 1412041-19, and 1412041-20) were not successfully cleaned even after multiple rinses and, therefore, no grain size results are available.

Bioassay Test Methods

Acute (germination) and chronic soil bioassays were conducted for 14 days on 54 soil samples collected during this study. These samples contained gas, diesel, or heavy oil contamination. Following the completion of the 14-day bioassay tests, three soil samples containing gas or diesel were tested for bioaccumulation for a duration of 28 days. The organisms tested included lettuce seed (*Lactuca sativa*) for the 14-day bioassays and earthworm (*Eisenia fetida*) for the 14-day bioassay and bioaccumulation tests. The concentration tested was 100 percent sample, with dilution soil for the control.

Acute Bioassays Methods

Soil samples were inspected to remove rocks and large organic material, and then homogenized in a stainless steel bowl. Moisture fraction and pH was determined for each sample. A visual comparison was made between each sample and the 45% hydrated laboratory control to ensure adequate moisture prescribed by Ecology's method (WDOE 96-327). If needed, Milli-Q water was added to the soil to match the appearance of the 45% laboratory control soil.

Several samples (1412041-16, 1412041-17, 1412041-18, 1412041-19, 1412041-20, 1412041-22, and 1412041-24) were very wet with percent hydration levels above the 35% to 45% level required in the method. To address this, an additional laboratory control was prepared with hydration water added to match the appearance of the wettest sample (i.e., the "saturated" control). No attempt was made to dry out these samples.

Five samples (1409070-04, 1409070-05, 1409070-06, 1410045-02, and 1410045-04) had pH values below the preferred level of pH 5.0. Additional aliquots of these samples were prepared and pH was adjusted using calcium carbonate for comparison with the original sample.

To initiate bioassay tests, earthworms were rinsed to remove culturing soil and then ten organisms were randomly selected, weighed to ensure a weight of 0.3 to 0.6 g each, and placed into each test chamber. Lettuce seeds were sized by screening and stored in the dark prior to use. Five seeds were selected and planted into each test chamber for a total of five chambers (25 seeds). Additional water was added via a misting sprayer to ensure the seeds received moisture and the soil was saturated to field capacity as per method WDOE 96-324. Test chambers for the lettuce were hydrated daily. No further hydration was performed for the earthworm chambers.

The effects measured during the earthworm chronic test included survival and normal morphology. Non-normal behavior (i.e., lack of burrowing) or other morphological changes were noted at test termination and normal morphology rates (i.e., percentage of normal behavior and/or appearance of the surviving organisms) were determined as an additional endpoint measurement for comparing with survival results.

The effects measured for the lettuce acute test included germination (for Test Acceptability Criteria assessment only), survival, and both wet and dry weight of surviving seedlings. Wet and dry weights were documented as an additional endpoint measurement to compare with survival results.

A significant effect on survival, growth, reproduction, or behavior is the statistically difference between the test sample compared with the control.

Statistical analyses were performed using CETIS version 1.8.8.3. Homoscedastic (equal variance) T-test was used to compare the survival data between the control and each sample treatment when the assumption of normal distribution was met. Non-parametric tests, such as the Wilcoxon Rank Sum Two-Sample Test were used when the assumptions of normality or homogeneity of variance necessary for the homoscedastic T-test could not be met. All statistics were analyzed at the p (alpha) = 0.05 level.

Chronic Bioaccumulation Methods

After the initial 14-day bioassay tests were completed, samples were selected for three 28-day chronic bioaccumulation tests using earthworms. Soil samples selected for the bioaccumulation tests were from sites that had positive identification of contaminants, as indicated from results of NWTPH-Gx and NWTPH-Dx analyses. In consultation with laboratory and scientific professionals, soil samples were chosen that had high contaminant concentrations and low worm survival from the 14-day bioassay tests (sample numbers 1409070-09 [diesel], 1411036-15 [gas],

and 1412041-05 [gas]). These soil samples were combined with other soil samples with high (>90%) worm survival from the same location and contamination type. The goal was to achieve earthworm survival with as high as possible concentrations of gas or diesel for assessing bioaccumulation of these contaminants.

NWTPH-Gx and NWTPH-Dx analyses were performed on the diluted soil samples (described above) to ensure persistence of the gas or diesel components and to determine the concentrations in the soil samples used for the bioaccumulation tests.

A series of "pre-tests" were conducted in order to ensure organism survival and sufficient earthworm tissue for the bioaccumulation tests. One pre-test was for diesel-contaminated soils and two pre-tests were for gas-contaminated soils. The pre-tests consisted of a soil mixture ratio of 1:1:

- One part sample number 1409070-09 mixed with one part sample number 1409070-08 and assigned 1504063-01 using diesel contaminated soils.
- One part sample number 1411036-15 mixed with one part sample number 1411036-13 and assigned 1504063-02 using gas contaminated soils.
- One part sample number 1412041-05 mixed with one part sample number 1412041-03 and assigned 1504063-03 using gas contaminated soils.

The diesel pre-test showed poor organism behavior (non-normal behavior such as not burrowing), whereas the gas pre-tests showed good organism behavior (normal burrowing). Nevertheless, all organisms died in less than a week. Additional pre-tests were performed for the diesel sample using different dilution ratios: 1:3 and 1:7. The 1:3 ratio showed poor organism behavior but the 1:7 ratio showed good organism behavior and was therefore selected for use. For the gas-contaminated soil samples, a one to one ratio of soil samples from the same site (two different samples) that resulted in high and low worm survival were combined to ensure survival and enough tissue. The final combined samples were:

- One part 1409070-09 mixed with seven parts 1409070-08 and assigned 1504063-07 for the bioaccumulation test using diesel contaminated soils.
- One part 1411036-12 mixed with one part 1411036-13 and assigned sample number 1504063-08 for the bioaccumulation test using gas contaminated soils.
- One part 1412041-01 mixed with one part 1412041-03 and assigned sample number 1504063-09 for the bioaccumulation test using gas contaminated soils.

The effects measured during the earthworm chronic test included survival (number alive at termination / number added at initiation) and growth (average weight of live worms at termination / average weight of live worms at initiation) over the 28-day exposure period. Statistical analysis followed the approach used for the 14-day assays.

Data Quality

All data have been reviewed for completeness, accuracy, and usability. Quality control (QC) procedures were followed as listed in the QAPP for this project (Sandvik, 2014). Additional QC procedures were included as well to address different unforeseen scenarios as the project progressed. A brief summary is presented here. More details are shown in Appendix D.

Sample Collection and Chain of Custody

Sample collection proceeded without incident as planned in the QAPP. All soil samples arrived at their respective laboratories within the proper temperature range of 0°C - 6°C (32°F - 43°F). A couple of laboratory deviations occurred, but these were not expected to compromise the samples. Details of the deviations are explained in Appendix D.

Analyses

NWTPH, VPH, and EPH

Laboratories included QC procedures prescribed by the methods for calibration, precision, and bias to assess the quality of the data produced. If QC results were outside limits, corrective actions (i.e., instruments were recalibrated) were taken or the result was flagged (qualified). Most results were without incident. More details of individual issues and their resolution are described in Appendix D.

In general, the issues involved with petroleum analyses included interference from high concentrations of other compounds of petroleum found in the samples, re-analysis required for calibrations out of limits, and a few qualifiers added to some results to flag uncertainty. Most required no action since these issues were resolved through reanalysis after instrument recalibration or had other acceptable QC results within limits.

There were no concerns for total organic carbon (TOC) analysis or results.

From this assessment, the results described above are considered valid.

Bioassay and Bioaccumulation Tests

Results from the 14-day bioassay tests were considered valid. Tissue collected for the 28-day bioaccumulation tests should be considered valid also. Deviations or interruptions that could have affected the test results were addressed and discussed in more detail in Appendix D.

The *Eisenia fetida* (earthworm) test meets Test Acceptability Criteria of the minimum 90 percent control survival (45% hydrated). No deviations or interruptions that could have affected test results were reported. The testing should be considered “valid”.

The *Lactuca sativ*a (lettuce) test meets Test Acceptability Criteria of a minimum 90 percent control germination. No deviations or interruptions that could have affected test results were reported. The testing should be considered "valid".

Bioaccumulation Tests

The bioaccumulation tests were prepared and initiated without incident. Initial and terminal pH values were all within acceptable range between pH 5.0 – 9.0. During the testing, a laboratory mishap allowed earthworms to escape original chambers. Although most were recaptured and replaced inside the chambers, the event confounded results at the termination of the tests. More details are available in Appendix D.

Because of the uncertainty the escaped earthworms created, the laboratory recommended the survival and growth test results should be interpreted cautiously and these endpoints should be considered "conditionally acceptable". But for this study, survival and growth results for the earthworm bioaccumulation tests are not valid.

Results from the tissue collected for bioaccumulation analysis for gas and diesel concentrations should not have been affected and should be considered "valid" because no contamination was found in the tissue sample collected before the test began (day zero sample). Therefore, any petroleum concentration found in the earthworm tissue would be the result of bioaccumulation from the soil sample.

Results and Discussion

Soil Characteristics

Soil Classification

Soil classification for this study's soil samples were classified using the Unified Soil Classification System (USCS). Only four different categories were found to describe the samples when calculating the coefficients of uniformity and curvature (Pitz, 2016):

1. Poorly-graded gravel
2. Silty sand
3. Poorly-graded sand
4. Well-graded sand

All samples were predominantly a mix of the sand class except one (which was classed with gravel) (Table 4).

Table 4. Soil classification frequencies.

USCS Soil Code	Number of Samples	Frequency (%)
Poorly-graded gravel (GP)	1	2
Silty sand (SM)	23	45
Poorly-graded sand (SP)	22	43
Well-graded sand (SW)	5	10
Total	51	100

Soil classes assigned to these samples should be used with caution since grain size analysis was conducted for the purpose of generalizing each sample in this study as described above in methods (using only four soil sieves for broad categorical characterization). No relationships between grain size and other parameters were analyzed further for this study, only general observations as reported.

Soil classifications are included with TOC and percent solids in Appendix E. Additional soil characteristics are reported in Appendix A.

Total Organic Carbon

TOC ranged from < 0.1% to as high as 62.5%, but most samples collected for this project had low TOC (<1.0%). Most of these samples were collected from pits of removed fuel tanks and/or historical contamination plumes, which are below the ground surface area for plant organism productivity and typically have lower TOC. In comparison, most samples with high TOC were surface samples rather than samples collected in pits.

Low TOC alone does not explain wet- and dry-weight reduction or other effects observed in the bioassay tests since the significant effects for wet- and dry-weight were observed for all samples including those with higher (>1.0%) TOC. Several (twelve) bioassay tests with low TOC (not detected at < 0.1 % reporting limit) did not show significant differences for survival of either worm or lettuce.

Some effects (higher toxic endpoints) may be related to the high organic content found in the soil sample. Increased organic matter content is associated with increased sorption of organic contaminants, which reduces the proportion available to the biota (EPA, 2003). Lansdell and McConnell (2003) found soils with high organic content had toxic endpoints from two to eight times that of soils with low organic content. TOC results can be found in Appendix E.

TOC and toxicity is discussed further below.

Percent Solids

Percent solids ranged from 24.9% to 92.9% in soil samples. There appears to be a weak (R2 = 0.69) relationship between percent solids and TOC. High percent solids (>75%) had lower TOC percentages (<0.1%) in soil samples collected for this study as shown in Figure 1.

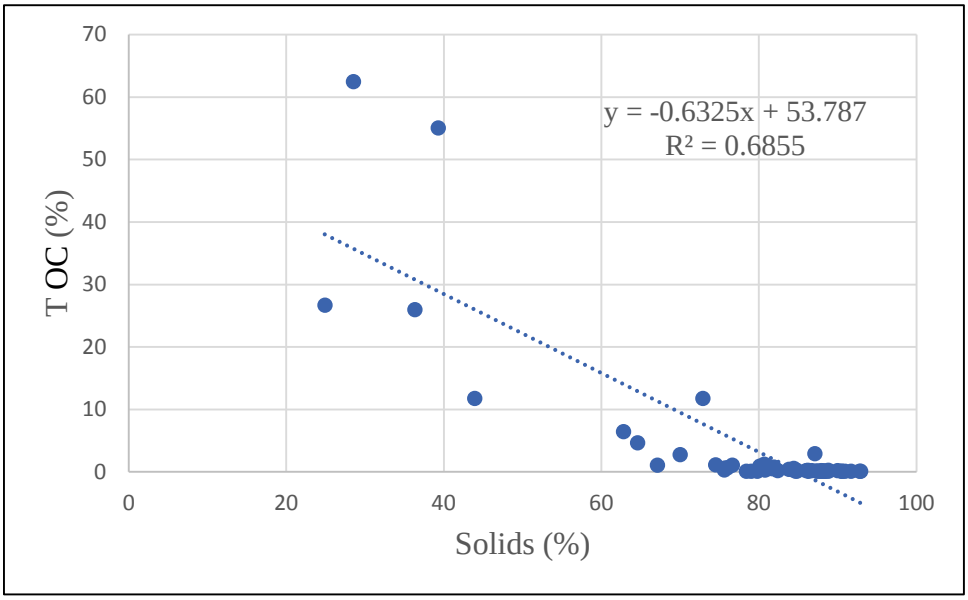

Figure 1. Scatterplot showing relationship between percent solids and TOC.

Percent solids are listed with TOC results in Appendix E.

Chemistry Results

Soil samples were collected and analyzed for gas, diesel, and heavy oil concentration. These samples were collected from sites with known contamination in order to collect a range of contaminant concentrations to be used for toxicity tests. Table 5 provides a basic statistical summary of the gas, diesel, and heavy oil data for this study. Table 6 shows summary statistics for extractable petroleum hydrocarbons (EPH), volatile petroleum hydrocarbons (VPH), and volatile organic compounds (VOC) such as benzene, toluene, ethylbenzene, and xylenes (BTEX). Complete chemistry results are listed in Appendix F.

Table 5. Summary statistics for gasoline, diesel, and heavy oil.

				Detected Results					
Parameter	N	Detected	Detection Frequency (%)	Minimum	Maximum	Median	Mean	Standard Deviation	Unit
Gasoline	54	23	43	5.4	1,900	130	340	500	mg/kg dw
Diesel	54	11	20	35	20,000	1,400	4,000	6,000	mg/kg dw
Heavy Oil	25	13	52	500	500,000	32,000	83,000	140,000	mg/kg dw
Lube Oil	54	8	15	38	1,600	210	400	530	mg/kg dw
Solids	54	54	100	24.9	92.9	84.1	78.4	15.8	%
TOC	54	38	70	0.14	62.5	0.62	5.91	14.1	%

N: Number of samples

Table 6. Summary statistics for extractable and volatile hydrocarbons and volatile organic compounds (BTEX).

					Detected Results (mg/kg dw)				
	Parameter	N	Detected	Detection Frequency (%)	Minimum	Maximum	Median	Mean	Standard Deviation
Aromatics	EPH, C8-C10	54	10	19	2.6	18	4.0	6.4	5.5
	EPH, >C10-C12	54	22	41	2.1	610	14	65	130
	EPH, >C12-C16	54	28	52	3.0	9,700	72	659	1,900
	EPH, >C16-C21	54	29	54	2.6	42,000	100	2,700	8,200
	EPH, >C21-C34	54	23	43	3.4	85,000	85,000	85,000	85,000
Aliphatics	EPH, C8-C10	54	24	44	2.2	54	10.0	16	16
	EPH, >C10-C12	54	36	67	2.3	1,600	30	150	300
	EPH, >C12-C16	54	36	67	3.0	11,000	61	800	1,900
	EPH, >C16-C21	54	31	57	2.3	14,000	140	1,100	2,600
	EPH, >C21-C34	54	33	61	3.1	27,000	32	1,600	4,900
Aromatics	VPH, >C8-C10	54	28	52	13	670	82	160	180
	VPH, >C10-C12	54	34	63	12	1,300	120	190	250
	VPH, >C12-C13	54	29	54	5.2	480	56	95	120
Aliphatics	VPH, C5-C6	54	6	11	84	84	46	46	24
	VPH, >C6-C8	54	14	26	580	580	80	171	200
	VPH, >C8-C10	54	9.0	17	210	210	46	80	78
	VPH, >C10-C12	54	17	31	290	290	98	100	83
BTEX Organic Compounds	Benzene	54	1.0	1.8	0.86	0.86	0.86	0.86	NC
	Toluene	54	2.0	3.7	1.9	2.5	2.2	2.2	0.42
	Ethylbenzene	54	12	22	0.94	27	6.8	10	9.6
	m, p-Xylene	54	8.0	15	3.2	140	41	55	49
	o-Xylene	54	6.0	11	0.95	40	5.55	10	15
	Methyl t-butyl ether	54	1.0	1.9	0.94	0.94	0.94	0.94	NC
	Pentane	54	6.0	11	1.0	15	1.75	5.8	6.8
	Hexane	54	7.0	13	0.87	26	3.0	8.6	9.6
	Octane	54	12	22	1.2	36	8.2	11	10
	Decane	54	13	24	0.9	34	6.0	7.7	8.9
	Dodecane	54	24	44	1.2	51	4.5	8.6	11

N: Number of Samples
NC: Not calculated because only one result
EPH: Extractable Petroleum Hydrocarbons
VPH: Volatile Petroleum Hydrocarbons

The data show a large range of contaminant concentrations for most of the detected analytes, which meets the design of the project to collect samples representing different concentrations of contaminated soils within Washington.

As described in the QAPP for this study (Sandvik, 2014), the products of concern (gasoline, diesel, and heavy oil) overlap each other with respect to chromatographic ranges and are defined slightly differently by other regulators (Figure 2).

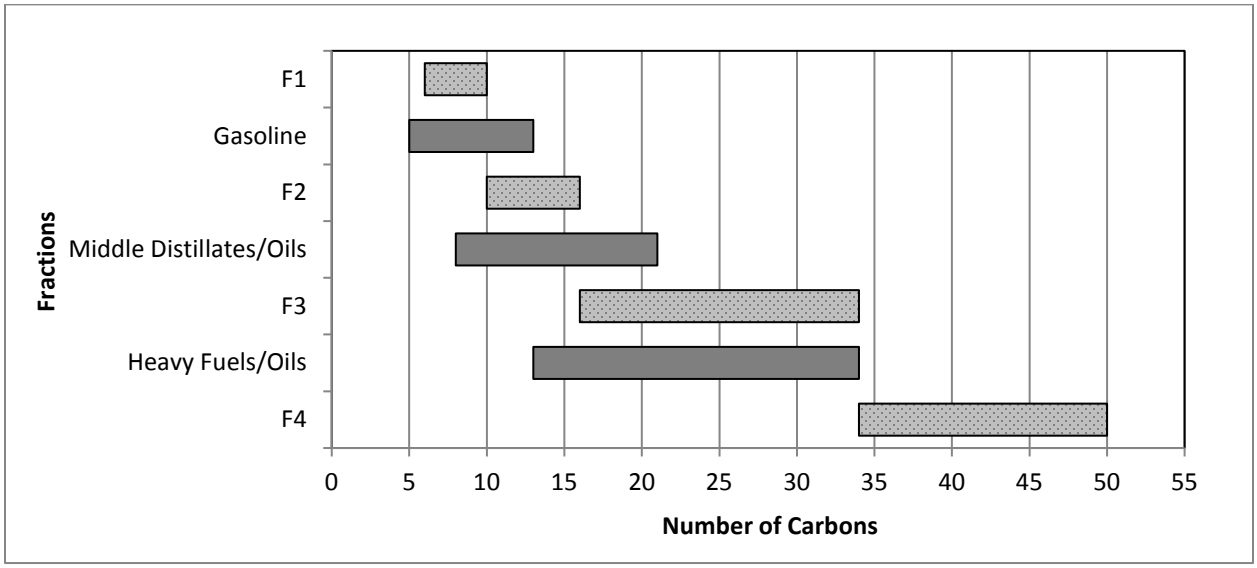

Figure 2. Carbon range comparisons.

Gasoline, Middle and Heavy Fuel Oils categories are from Ecology's categories for Table 830-1 in the MTCA, whereas F1 to F4 are for Canada. F1: C6 to C10, F2: >C10 to C16, F3: >C16 to C34, and F4: C34+.

At least some soil samples for the Gasoline and Middle Distillates/Oils categories targeted concentrations above 9,620 mg/kg and above 87,000 mg/kg for the Heavy Fuel/Oils category to show lethal effects in bioassays as directed in the QAPP. These levels were based on a comprehensive summary by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) in Canada for effective concentrations (CCME, 2008). Maximum concentrations exceeded these levels for diesel and heavy fuel oil (20,000 and 500,000 mg/kg dw respectively) but were below this level for gasoline (1,900 mg/kg dw) for detected results. This is not too surprising since soils were targeted for weathered contamination where the more volatile portions of gasoline may have degraded or dissipated.

Low levels of gasoline contamination in these samples may be explained in part by how these petroleum products are identified in the laboratory. Ecology's laboratory defines #2 diesel, gasoline, heavy fuel oil, and lube oil from a pattern match between the petroleum product found in the samples and the standards of #2 diesel, gasoline, heavy fuel oil, and lube oil. Weathered petroleum product identification becomes more problematic in some cases since the products overlap each other with respect to chromatographic ranges (Carrell, 2015). Special care is taken to not report the early eluting portion of diesel as gasoline or the weathered, late eluting portion of gasoline as diesel.

Bioassay Results

Earthworm and lettuce bioassays were conducted for 54 samples collected from 11 sites, which includes two sets of samples from one location. Toxicity was considered evident if the bioassay results were significantly more impacted than the control. Table 7 shows the results of the bioassays and soil concentrations of the petroleum chemicals of interest. Detailed bioassay results are reported Appendix G.

Table 7. Bioassay results reported with gasoline, diesel, heavy oil, and lube oil soil concentrations.

Result values are mg/kg dw. Bioassay samples with significant effects are designated with an X.

Sample ID	Gas	Gas (MRL)	#2 Diesel	#2 Diesel (MRL)	Heavy Oil	Heavy Oil (MRL)	Lube Oil	Lube Oil (MRL)	Earthworm		Lettuce		
									14-day Survival	Normal Morphology	14-day Survival	Dry Weight	Wet Weight
1409070-01	3.4 U	3.4	5.5 U	5.5	-	-	14 U	14				X	X
1409070-02	81	3.2	11 U	11	-	-	14 U	14			X	X	X
1409070-03	5.4	3.1	5.5 U	5.5	-	-	14 U	14				X	X
1409070-04	730 U	36	4,400	58	-	-	150 U	150	X	NC	X	X	X
1409070-04 pH	730 U	36	4,400	58	-	-	150 U	150	X	NC		X	X
1409070-05	3.2 U	3.2	6.3 U	6.3	-	-	16 U	16				X	X
1409070-05 pH	3.2 U	3.2	6.3 U	6.3	-	-	16 U	16			X	X	X
1409070-06	4.3 U	4.3	6.6 U	6.6	-	-	36 U	17			X	X	X
1409070-06 pH	4.3 U	4.3	6.6 U	6.6	-	-	36 U	17				X	X
1409070-07	3.3 U	3.3	5.8 U	5.8	-	-	15 U	15			X	X	X
1409070-08	3.9 U	3.9	8.1 U	6.2	-	-	16 U	16			X	X	X
1409070-09	1,100 U	35	3,900	58	-	-	150 U	150	X	NC	X	X	X
1410045-01	28	4.6	110 U	35	-	-	260	90			X	X	X
1410045-02	56	4.9	21 U	6	-	-	320	91				X	X
1410045-02 pH	56	4.9	21 U	6	-	-	320	91				X	X
1410045-03	170	4.2	120 U	5.6	-	-	14 U	14				X	X
1410045-04	95	5	360 U	18	-	-	160	47				X	X
1410045-04 pH	95	5	360 U	18	-	-	160	47				X	X
1410045-05	16	4.5	35 U	35	-	-	740	89				X	X
1411036-01	330	42	92 U	5.7	-	-	38	14			X	X	X
1411036-02	150	39	100 U	5	-	-	13 U	13				X	X

Sample ID	Gas	Gas (MRL)	#2 Diesel	#2 Diesel (MRL)	Heavy Oil	Heavy Oil (MRL)	Lube Oil	Lube Oil (MRL)	Earthworm		Lettuce		
									14-day Survival	Normal Morphology	14-day Survival	Dry Weight	Wet Weight
1411036-03	130	21	23 U	5.3	-	-	14 U	14				X	X
1411036-04	29	3.8	14 U	5.1	-	-	13 U	13				X	X
1411036-05	4.2 U	4.2	5.7 U	5.4	-	-	14 U	14				X	X
1411036-06	740 U	48	8,900	180	-	-	450 U	450	X	NC		X	X
1411036-07	800 U	50	4,600	30	-	-	77 U	77	X	NC	X	X	X
1411036-08	96 U	3.8	260	5.3	-	-	14 U	14	X	NC		X	X
1411036-09	15 U	4	80	5.4	-	-	14 U	14				X	X
1411036-10	4.7 U	4.4	35	5.6	-	-	14 U	14				X	X
1411036-11	8.4 U	8.4	5.6 U	5.6	-	-	45	14				X	X
1411036-12	67	9.9	6.3 U	6.3	-	-	16 U	16				X	X
1411036-13	90	8.5	11 U	5.7	-	-	14 U	14				X	X
1411036-14	8.4 U	8.4	5.6 U	5.6	-	-	14 U	14				X	X
1411036-15	1,100	87	140 U	5.7	-	-	91	14	X	NC	X	X	X
1412041-01	300	22	110 U	29	73 U	73	73 U	73				X	X
1412041-02	370	22	280 U	29	73 U	73	73 U	73				X	X
1412041-03	370	21	160 U	29	73 U	73	73 U	73				X	X
1412041-04	120	8.6	150 U	28	72 U	72	72 U	72	X			X	X
1412041-05	1,900	86	1,100 U	28	71 U	71	71 U	71	X	NC		X	X
1412041-06	1,500	94	270	31	77 U	77	77 U	77	X	X	X	X	X
1412041-07	200	10	1,400	62	160 U	160	160 U	160				X	X
1412041-08	750	48	500	31	78 U	78	78 U	78				X	X
1412041-09	54	4.8	60 U	60	150 U	150	150 U	150				X	X
1412041-10	2,100 U	86	17,000 U	3,400	45,000	8,600	8,600 U	8600	X	NC	X	X	X
1412041-11	45 U	5.6	1,400 U	65	3,800	170	170 U	170	X	X		X	X

Sample ID	Gas	Gas (MRL)	#2 Diesel	#2 Diesel (MRL)	Heavy Oil	Heavy Oil (MRL)	Lube Oil	Lube Oil (MRL)	Earthworm		Lettuce		
									14-day Survival	Normal Morphology	14-day Survival	Dry Weight	Wet Weight
1412041-12	5.5 U	5.5	6.6 U	6.6	17 U	17	17 U	17				X	X
1412041-13	120 U	5.6	33 U	33	740	83	83 U	83				X	X
1412041-14	23 U	5.6	65 U	65	500	160	160 U	160				X	X
1412041-15	6.3 U	6.3	71 U	71	3,100	180	180 U	180				X	X
1412041-16	77 U	7.2	1,600 U	1,500	38,000	3,900	12,000 U	3,900	X	NC	X	X	X
1412041-17	44 U	7.5	1,000 U	790	22,000	2,000	7,400 U	2,000	X	NC	X	X	X
1412041-18	150 U	15	8,200 U	5,500	160,000	14,000	51,000 U	14,000	X	NC	X	X	X
1412041-19	450 U	21	34,000 U	28,000	500,000	70,000	150,000 U	70,000	X	NC	X	X	X
1412041-20	25 U	14	1,300 U	1,300	150,000	3,200	83,000 U	3,200				X	X
1412041-21	5 U	5	62 U	62	1,600	160	1,100 U	160			X	X	X
1412041-22	24 U	24	200 U	200	32,000	500	12,000 U	500			X	X	X
1412041-23	500 U	59	8,800 U	5,400	120,000	14,000	23,000 U	14,000	X	NC	X	X	X
1412041-24	210 U	61	20.000	340	38,000 U	860	1,600	860	X	X		X	X
1412041-25	8.6 U	6.7	15 U	15	120 U	37	37 U	37				X	X

MRL: Method Reporting Limit
NC: Not calculated because there were no survivors.
U: not detected, several results had raised reporting limit because of interference.
Samples ID with "pH" were samples that were adjusted for pH for comparison.
- Not reported.

Eleven soil samples showed significant differences for all toxicity endpoints (i.e., survival, normal morphology, wet and dry weight) in earthworm and lettuce bioassay toxicity tests when compared to the controls. Six of these samples had only heavy oil detections, three had diesel, one had gasoline, and one had predominantly gasoline but some diesel was identified in the sample.

Significant normal morphology endpoint (i.e., percentage of normal behavior and/or appearance of the surviving organisms compared to non-normal behavior or appearance) results (n=3) for earthworms coincided with significant earthworm survival results (n=18) except for one (sample 1412041-04). Most normal morphology results failed because there were no survivors and, therefore, could not be calculated (n=14 out of 17).

All wet- and dry-weight endpoints in the lettuce toxicity tests were significantly different compared to the controls. This can suggest sensitivity to the field-collected soil samples that contained petroleum chemical contamination. On the other hand, soil properties and characteristics may affect the toxicity potential towards organisms independent of chemical concentration, which could suggest the control soil was a better-suited environment for plant growth than the field samples. Many field samples likely lacked nutrient concentrations, microbial communities, or other physiological factors (e.g., proper carbon, phosphate, or nitrogen levels) for optimal organism growth and survival.

Soil conditions conducive to biological activity may report toxicity endpoints at higher concentrations because they are likely to have lower proportions of bioavailable components of contaminant hydrocarbons (Lansdell and McConnell, 2003). Well weathered soils loose the low molecular weight hydrocarbons due to higher water solubility and biodegradation. The remaining higher molecular weight hydrocarbons are less available to organisms because they are less soluble in water and more likely to sorb onto soil. Low bioavailability is reflected in the lower toxicity of petroleum hydrocarbons found in higher/fine organic soils, which promotes sorption of hydrocarbons.

Earthworm and Lettuce Survival

The survival endpoint is a good target for evaluating the effective concentrations for Soil Screening Levels (SSLs). Other endpoints either coincide with each other (i.e., the same samples had significant results for earthworm normal morphology and survival) or show no difference between samples (i.e., all lettuce wet- and dry-weight results were significant compared to the control) as stated above.

Traditionally, SSLs for plants and biota are determined by conducting bioassays using soils spiked with the contaminant of interest within a laboratory setting. Although this allows more control for determining the cause of toxicity, laboratory spiked soils do not represent the effects of natural conditions such as weathering, pH, and soil characteristics. Bioassays on contaminated field soils do take into account the effects of natural conditions. However, because field soils combine the effects of all potential toxicants, known or unknown, it may be difficult to say with certainty what caused the toxicity.

The calculated effects concentration or lowest observed adverse effect level (LOAEL) (i.e., the lowest concentration tested where a negative effect was observed) are used as the SSL for plants and soil biota for each of the petroleum categories: gasoline, diesel, and heavy oil.

The LOAEL is appropriate to use as an estimate of the concentration that may have caused adverse effects in the field soils compared to control (WAC 173-340, 2013). Although appropriate, many variables may drive toxicity in the field samples, which can lead to mixed results. This was found to be true in the current study.

Table 8 shows the range of concentrations associated with earthworm and lettuce survival in the bioassay tests with and without significant results (compared to controls). There is an overlap in the results associated with a significant bioassay and those where no significant bioassay result was observed.

Table 8. Concentration range associated with results for survival in bioassay tests (mg/kg dw).

Contaminant	Receptor	Bioassay Test	MTCA SSL[a]	Significant Bioassay Results Associated Concentration Range	NOT Significant Bioassay Results Associated Concentration Range
Gasoline	Soil Biota	Earthworm	100[b]	120 - 1,900	5.4 - 750
	Plant	Lettuce	NA	28 - 1,500	
Diesel	Soil Biota	Earthworm	200	260 - 20,000	35 - 1,400
	Plant	Lettuce	NA	270 - 4,600	
Heavy Oil	Soil Biota	Earthworm	NA	3,800 - 500,000	500 - 150,000
	Plant	Lettuce	NA	1,600 - 500,000	

a. These values are ecological indicator soil concentrations from Table 749-3.
b. 100 mg/kg applies to samples with weathered product; otherwise 30 mg/kg applies taking into account benzene.
NA: Not available.

The categories of gasoline, diesel, and heavy oil are not individual compounds, but rather a summary of the non-specific analytical method used to broadly characterize the petroleum contamination. Factors affecting the impact from the contaminant include the nature of the hydrocarbon itself (source, composition, extent of weathering) and the soil properties and microbial ecosystem surrounding it (Lansdell and McConnell, 2003). To assist identifying the nature of the contaminant in association to the bioassay results, the data were sorted by contaminant type or carbon fraction components (as per EPH and VPH analyses) to screen for any components that would reasonably link with significant results for survival in the bioassays. This approach seemed reasonable because many samples with significant results had 100% mortality, limiting effectiveness of using regression or variance statistical models.

Tables 9 and 10 show the distribution of gasoline, diesel, and heavy oil contaminant concentrations along with the percent reduction in the biota used in the bioassay tests. Percent reduction is the difference between the sample results and the control divided by the control. In the case of the earthworm survival bioassay, several samples had 100% survival whereas the

control mean survival was 96.7%, hence leaving a negative 3.4%. This variation is within the expected error of Test Acceptability Criteria of a minimum 90 percent control survival for the earthworm bioassay test.

Table 9. Gasoline contaminant concentration and percent reduction in the bioassay tests.

Sample ID	Earthworms 14-day Survival (% reduced)	Lettuce 14-day Survival (% reduced)	Gasoline (mg/kg)	#2 Diesel (mg/kg)	Heavy Oil (mg/kg)	Lube Oil (mg/kg)
1412041-05	**100**	12.5	**1,900**			
1411036-15	**100**	**44.0**	**1,100**			91
1412041-02	20.7	4.0	370			
1412041-03	0.0	4.0	370			
1411036-01	-3.4	**12.0**	**330**			**38**
1412041-01	-3.4	8.0	300			
1410045-03	0.0	8.0	170			
1411036-02	6.9	8.0	150			
1411036-03	-3.4	8.0	130			
1412041-04	**31.0**	8.0	**120**			
1410045-04	0.0	4.2	95			160
1410045-04 pH	-3.4	8.0	95			160
1411036-13	0.0	8.0	90			
1409070-02	3.4	**66.7**	**81**			
1411036-12	-3.4	8.0	67			
1410045-02	0.0	0.0	56			320
1410045-02 pH	-3.4	0.0	56			320
1411036-04	-3.4	4.0	29			
1410045-01	-3.4	**24.0**	**28**			**260**
1410045-05	0.0	0.0	16			740
1409070-03	-3.4	0.0	5.4			
1409070-01	-3.4	4.0				
1411036-05	-3.4	4.0				
1411036-11	-3.4	0.0				45
1411036-14	-3.4	4.0				

Bold: significant effects in the bioassay test and contaminant concentration in that sample.

Table 10. Diesel and heavy oil contaminant concentration and percent reduction in the bioassay tests.

Sample ID	Earthworms 14-day Survival (% reduced)	Lettuce 14-day Survival (% reduced)	Gasoline (mg/kg)	#2 Diesel (mg/kg)	Heavy Oil (mg/kg)	Lube Oil (mg/kg)
1412041-19	**100**	**33.3**			**500,000**	
1412041-18	**100**	**25.0**			**160,000**	
1412041-20	-3.4	28.0			150,000	
1412041-23	**100**	**62.5**			**120,000**	
1412041-10	**100**	**66.7**			**45,000**	
1412041-16	**100**	**24.0**			**38,000**	
1412041-22	-3.4	**20.8**			**32,000**	
1412041-17	**100**	**32.0**			**22,000**	
1412041-24	**28**	12.0		**20,000**		1,600
1411036-06	**100**	8.0		**8,900**		
1411036-07	**100**	**40.0**		**4,600**		
1409070-04	**100**	**16.0**		**4,400**		
1409070-04 pH	**93.1**	12.0		**4,400**		
1409070-09	**100**	**12.0**		**3,900**		
1412041-11	**17.2**	0.0			**3,800**	
1412041-15	-3.4	8.0			3,100	
1412041-21	-3.4	**32.0**			**1,600**	
1412041-07	-3.4	0.0	200	1,400		
1412041-13	0.0	0.0			740	
1412041-08	-3.4	4.0	750	500		
1412041-14	-3.4	4.0			500	
1412041-06	**13.8**	**24.0**	**1,500**	**270**		
1411036-08	**75.9**	4.0		**260**		
1411036-09	-3.4	8.0		80		
1411036-10	-3.4	8.0		35		
1409070-05	0.0	4.0				
1409070-05 pH	-3.4	**12.0**				
1409070-06	-3.4	**28.0**				
1409070-06 pH	-3.4	4.0				
1409070-07	-3.4	**12.0**				
1409070-08	6.9	**12.0**				
1412041-09	-3.4	4.0	54			
1412041-12	-3.4	4.0				
1412041-25	6.9	4.0				

Bold: significant effects in the bioassay test and contaminant concentration in that sample.

The variability shown between the samples and bioassay effects is not too surprising since toxicity tests in soils with complex mixtures tend to yield all-or-nothing responses, unlike toxicity tests with single compounds (Greene et al., 1988). Exposures to higher sample concentrations resulted in 100% mortality of the test organisms, whereas exposures at lower concentrations showed minimal or no effects. These soil samples vary with degree of weathering of the contamination, collection locations, and individual soil properties. In these samples, there appears to be greater variability within the gasoline toxicity results than the diesel and heavy oil toxicity results.

TOC and toxicity relationship

All the soil samples targeting gasoline were collected from underground plumes and extracted either by boring or opening a pit. These samples had relatively low TOC (<1.0%). Although these were weathered plumes, many of the lighter fractions may have still persisted because they had been concealed underground. Upon extraction, the lighter fractions began volatizing rather than staying within the soil or bound to organics, even though procedures were taken to minimize releases as described in the Methods section above. This increased variability in concentration at a given site. Although the lighter fractions are unlikely to persist in surface soils, the deeper contamination or more recent releases may have lighter fractions available, increasing the risk of ecological impact (Lansdell and McConnell, 2003). Hydrocarbon fractions are discussed further below.

Samples with TOC nearly three percent and above were the samples with the highest concentrations for heavy oil and were associated with significant effects in bioassay tests, with one exception. Samples with diesel concentrations above 1,600 mg/kg with <1.0% TOC were associated with significant effects in bioassay tests, with one exception. The two exceptions are associated with samples 1412041-20 and 1412041-15, where TOC was elevated (>1.0%), yet no toxic effect was associated with earthworm survival and no significant reductions were seen in lettuce survival bioassay tests even though contaminant concentrations were elevated.

These two samples had high TOC compared to other samples with similar contaminant concentrations as shown in Table 11.

Table 11. Toxicity effect compared to TOC.

Sample ID	Earthworms 14-day Survival (% reduced)	Lettuce 14-day Survival (% reduced)	Heavy Oil (mg/kg)	TOC (%)
1412041-20	-3.4	28.0	150,000	55.1
1412041-23	**100**	**62.5**	**120,000**	11.8
1412041-15	-3.4	8.0	3,100	2.8
1412041-21	-3.4	**32.0**	**1,600**	0.94

Bold: significant effects in the bioassay test and contaminant concentration in that sample.

Toxicity tests showed no effect for sample 1412041-20 with 55.1% TOC and concentration of 150,000 mg/kg of heavy oil, compared to sample 1412041-23 with 11.8% TOC and concentration of 120,000 mg/kg heavy oil, which showed significant effects for both earthworm and lettuce survival. Likewise, sample 1412041-15 with 2.8% TOC and concentration of 3,100 mg/kg heavy oil showed no toxicity effects, compared to sample 1412041-21 with 0.94% TOC and concentration of 1,600 mg/kg associated with significant reduction in lettuce survival. The relationship of the toxic contaminant being bound to TOC and, therefore not available for uptake by the organisms, may explain some of these effects on the bioassay tests.

Figures 3 and 4 compared TOC with the data for the measured hydrocarbon. Figure 3 shows the relationship between TOC and the measured diesel and heavy oil hydrocarbons from these data.

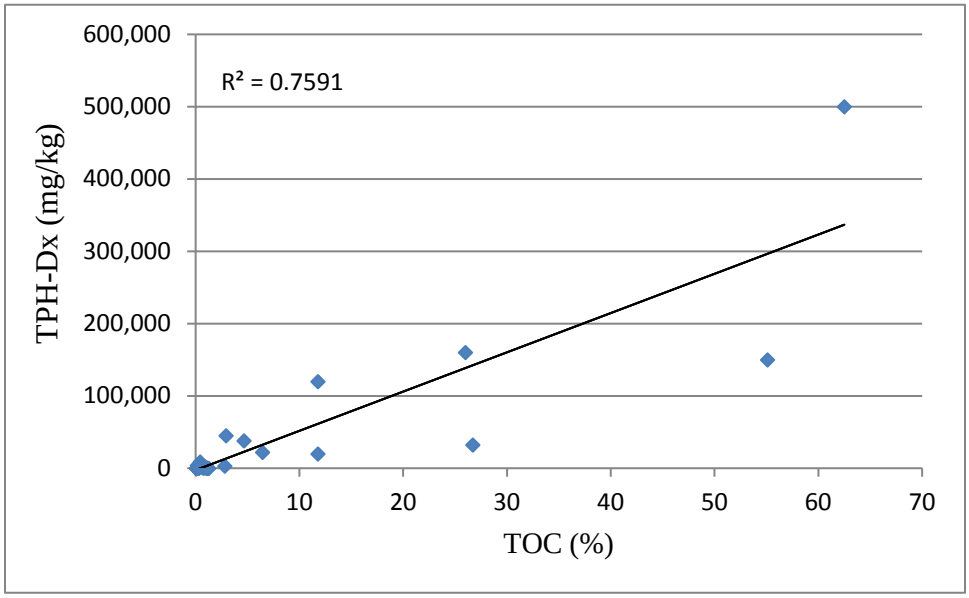

Figure 3. TOC and diesel and heavy oil contamination.

There appears to be a weak relationship between TOC and the measured diesel and heavy oil hydrocarbons from these data, which may reflect incorporation of some of these hydrocarbons in TOC analysis.

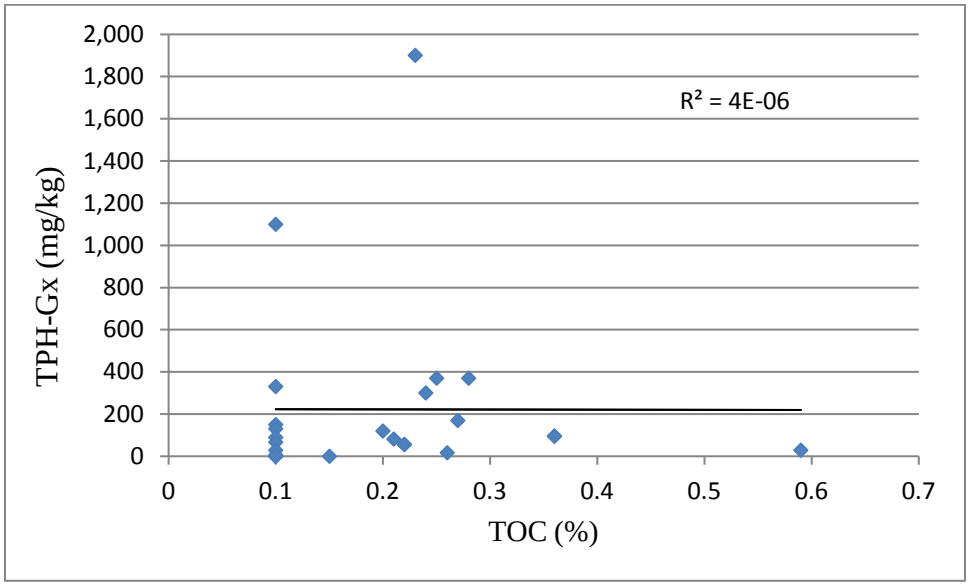

Figure 4. TOC and gasoline contamination.

There appears to be no relationship between the measured gasoline hydrocarbon and TOC from these data.

TOC appears to be an important factor, but this study lacks the data to normalize the results for comparisons.

Screening Levels

The goal of this study was to help define possible screening levels for statewide use based on field-collected samples representing statewide soils contaminated with various levels and types of petroleum products. Yet, in practice, site managers are concerned with specific sites and need to define screening levels from the site of interest. Because there are different methods (use of statewide screening levels and determining site specific levels) used to determine safe petroleum concentrations in soils, it seemed reasonable to compare this study's results several different ways. Below, this study's data are discussed in three ways: (1) individual sites, (2) gasoline and diesel categories, and (3) hydrocarbon fractions.

Individual Sites

Concentration levels associated with toxic bioassay effects (i.e. statistically significant difference of survival between the test sample compared to the control) were compared among the individual samples with the overall distribution of concentrations for all locations as reported in Tables 9 and 10 above.

When comparing the bioassay effects between the individual locations (sites) of collection, a different story emerges. Eleven sets of samples were collected from nine locations. Two locations provided two sets of samples; one location targeted two different types of contaminants

(gasoline and diesel) while the other location targeted two sets of the same type of contaminant (heavy oil).

Gasoline sites

Figure 5 shows five locations targeted for gasoline contamination and their respective concentrations compared to the MTCA screening level under Table 749-3 (100 ppm).

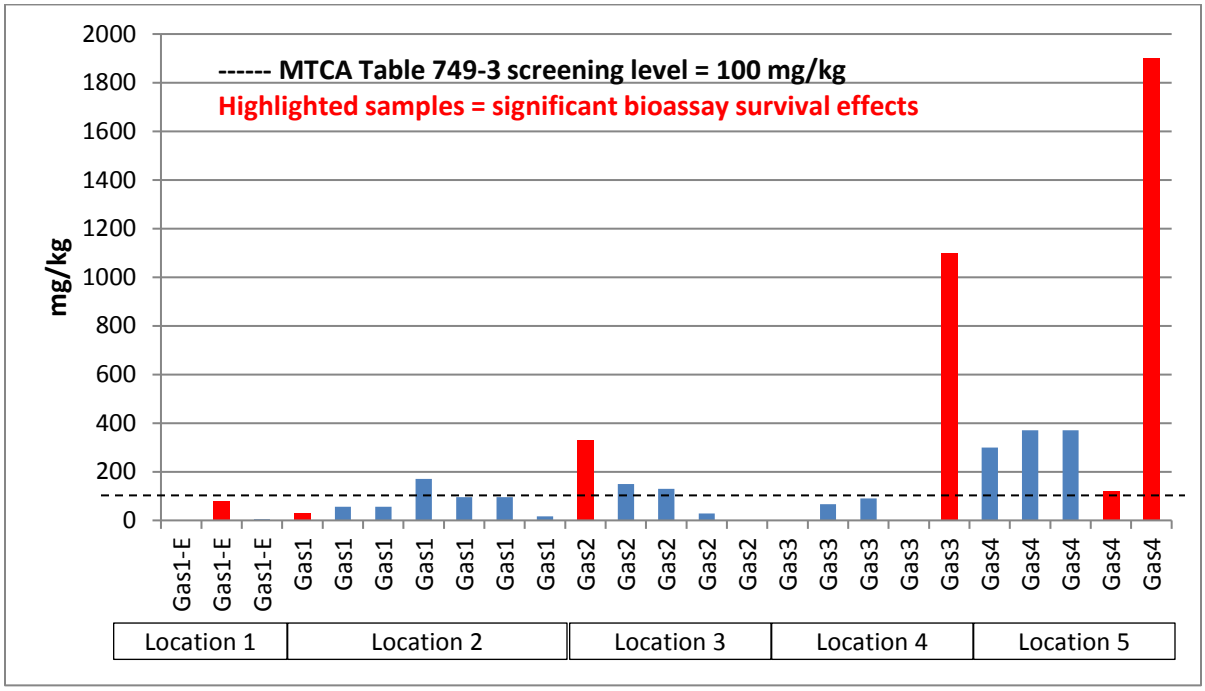

Figure 5. Gasoline concentrations from five locations.

If considered as site-specific, Location 1 (sample name Gas1-E, sample numbers 1409070-01 to -03) would have a more conservative level than the MTCA screening level while the other locations would have much less restrictive cleanup values: up to three times the screening level for the second location (i.e., sample name Gas2 compared to sample name Gas1-E). Location 1 was the only site successfully collected from the east side of the state. The significant bioassay result at low levels from the east side soils (Location 1, sample name Gas1-E) could very well represent the sensitivity to petroleum contamination in those soils with different soil characteristics and low TOC (ranging from not detected to 0.21%). This site (Location 1 or sample name Gas1-E) was also the only sample with benzene detection, which may be the more dominant driver of toxicity effects. Additional testing is needed to confirm observations.

For Location 2 (sample name Gas1, samples 1410045-01 to -05), analytical results showed detected gasoline, but the laboratory reported some uncertainty. The chemist said the "fingerprint" of the product did not resemble that of gasoline but more closely resembled that of mineral spirits (Carrell, 2015). It is recommended that samples in Location 2 not be included when assessing screening level values for gasoline based on the bioassay survival endpoint, but the samples may be considered separately as a case of mixed results.

The other locations (Locations 3, 4, and 5; sample names Gas 2, Gas 3, and Gas 4) targeted for gasoline were reported by the chemist as very weathered gasoline. Since this study targeted weathered petroleum products, the chemist's report affirms the use of these samples in assessing screening levels.

Diesel sites

Although diesel and heavy oil are considered under the same MTCA screening level, they are presented here separately for discussion purposes. Figure 6 shows diesel concentrations for sites targeted for diesel.

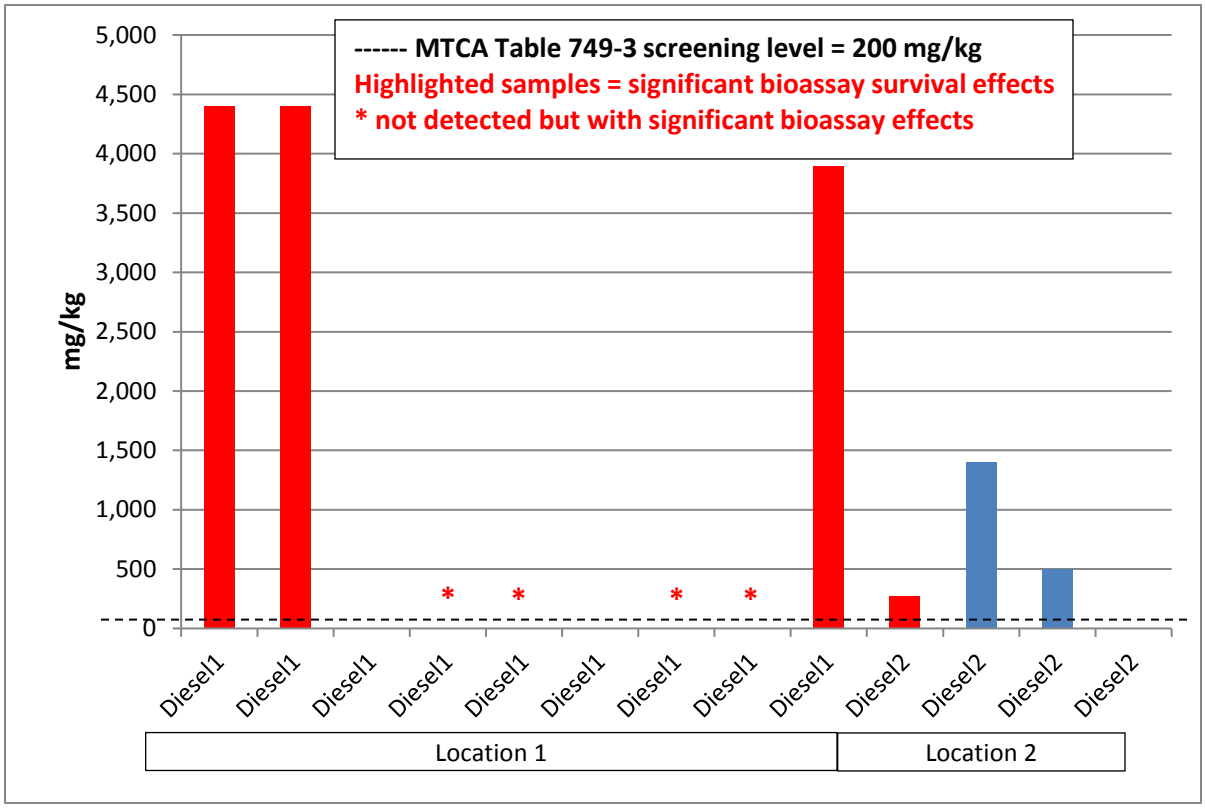

Figure 6. Diesel concentrations from two locations.

Screening levels for diesel in Location 1 (Diesel1, samples 1409070-04 to -09) would not be possible to define by just considering levels reported for that site because of the variability found with the toxicity associations (i.e., toxicity found in samples ranging from not detected to >3500 mg/kg detected concentrations of diesel). The samples with the high concentrations in Location 1 are replicates of each other (field and bioassay pH adjusted). The detected diesel concentrations shown in Location 1 were included in the distribution list for all sites since they are viable results.

The first sample (Diesel2, sample 1412041-06) for diesel Location 2 (samples 1412041-06 to -09) (Figure 6) had low concentrations (270 mg/kg) of diesel and high gasoline concentrations of 1,500 mg/kg. Gasoline was the likeliest driver for the effects (i.e. low survival compared to the control) associated with earthworms and lettuce survival. The other samples in Location 2 also had mixed hydrocarbons, which confound the findings of the bioassay tests. These samples may best be considered separately in evaluation of screening levels based on the bioassay survival endpoint, as suggested above for the set with mixed results from Location 2 in the gasoline group.

The samples from Location 1 (Diesel1) will be combined with heavy oil for evaluation of screening levels.

Heavy oil sites

Heavy oil concentrations from sites targeted for heavy oil are shown in Figure 7.

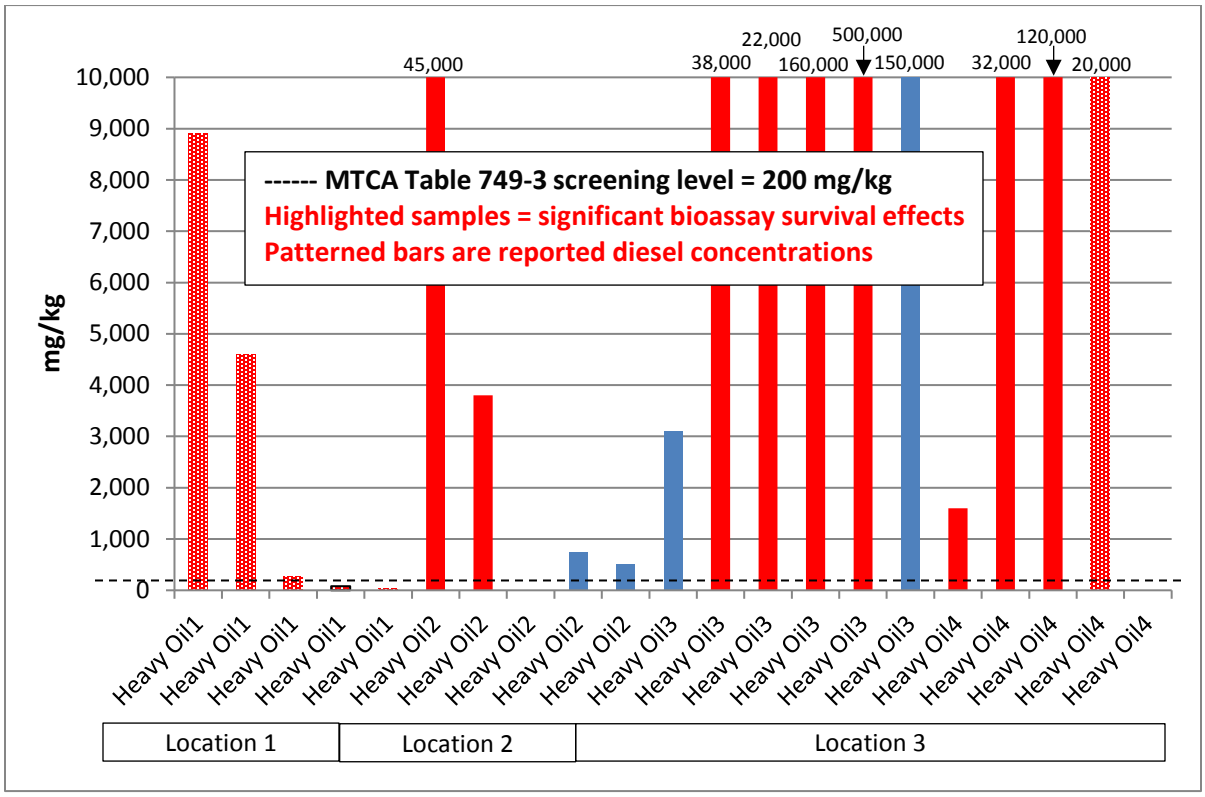

Figure 7. Heavy oil concentrations from three locations.

Although soil samples in Location 1 (Heavy Oil1, samples 1411036-06 to -10) were collected for heavy oil from a pit removal of a large bunker C tank, the analytical results reported diesel rather than heavy oil concentrations (patterned bars in Figure 7). Likewise, one sample in Location 3 (Heavy Oil4, samples 1412041-15 to -20) was reported as having diesel rather than heavy oil. Since MTCA regards diesel and heavy oil in one category, these samples reported as diesel will be included with the heavy oil samples into one category for comparing with screening levels.

One observation to note in Figure 7 is the samples with higher concentrations of heavy oil with insignificant bioassay test effects compared to similar samples with significant bioassay test effects within Location 3. The sample with 3,000 mg/kg concentration of heavy oil (blue bar) did not show significant effects in bioassay tests whereas the sample with 1,600 mg/kg (red bar) had significant effects. Likewise the sample with 150,000 mg/kg concentration (blue bar) did not show significant effects in bioassay tests whereas the sample with 120,000 mg/kg (red bar) did.

The lower heavy oil concentrations with significant bioassay results compared here were samples with higher organic content as discussed previously. The higher organic content appeared to have limited toxicity availability[2] when compared to similar samples (i.e., samples with similar heavy oil concentration levels but with lower organic content). This becomes important when considering screening levels. Since not all samples within a set or location will show the same results, a conservative value should be selected.

Gasoline and Diesel

When toxicity is exhibited, it is difficult to say with certainty what the cause was. The LOAEL has been used in other bioassay tests and is appropriate to use as an estimate of the concentration at which a contaminant may have caused adverse effects in field soils, compared to the control (Ecology, 2012). This study compares the LOAEL derived from lettuce and earthworm survival in bioassay tests on field soils to current MTCA and other screening levels. In addition, we were able to determine concentrations that exhibited no adverse effects on the treatment when compared to the control. This is equally important, because there is no need for cause as described above. No effects remain as such regardless of contaminant load. These no-effects levels help to support decisions in regards to proposed screening levels.

The distribution of screening level concentrations with associated bioassay survival effects are shown in Table 12. Mixed hydrocarbon sets have been removed (samples 14120045-01 to -05 and 1412041-06 to -09) as discussed above (under Gasoline sites and Diesel sites sections respectively), and diesel and heavy oil are combined into one category.

[2] Toxicity availability in soils is the toxicity of the chemical contaminant that is made available to an organism through the complex interaction of physicochemical and biological processes within each soil microenvironment. These processes influence soil toxicity through their effect on microbial degradation, chemical sorption, solubility and availability, and partitioning coefficients.

Table 12. Distribution of gasoline and diesel concentrations using NWTPH-Gx and NWTPH-Dx associated with effects for lettuce and earthworm survival.

Sample ID	Lettuce 14-day Survival (% reduced)	Gas (mg/kg)	#2 Diesel + Heavy Oil (mg/kg)	Sample ID	Earthworms 14-day Survival (% reduced)	Gas (mg/kg)	#2 Diesel + Heavy Oil (mg/kg)
1411036-15	44.0	1,100		1412041-05	100	1,900	
1411036-01	12.0	330		1411036-15	100	1,100	
1409070-02	66.7	81		1412041-04	31.0	120	
1412041-19	33.3		500,000	1412041-19	100		500,000
1412041-18	25.0		160,000	1412041-18	100		160,000
1412041-23	62.5		120,000	1412041-23	100		120,000
1412041-10	66.7		45,000	1412041-10	100		45,000
1412041-16	24.0		38,000	1412041-16	100		38,000
1412041-22	20.8		32,000	1412041-17	100		22,000
1412041-17	32.0		22,000	1412041-24	28		20,000
1411036-07	40.0		4,600	1411036-06	100		8,900
1409070-04	16.0		4,400	1411036-07	100		4,600
1409070-09	12.0		3,900	1409070-04	100		4,400
1412041-21	32.0		1,600	1409070-04 pH	93.1		4,400
1409070-05 pH	12.0			1409070-09	100		3,900
1409070-06	28.0			1412041-11	17.2		3,800
1409070-07	12.0			1411036-08	75.9		260
1409070-08	12.0						

The LOAEL of gasoline associated with effects for lettuce or earthworm survival was 81 mg/kg and 120 mg/kg respectively. As noted above in Gasoline sites section above, sample 1409070-02 with 81 mg/kg of gasoline had detected levels of benzene, which is likely the driver of toxicity shown in the lettuce bioassay result. Therefore, for lettuce survival, the LOAEL would likely be above 81 mg/kg but below 330 mg/kg as shown in this study. As a conservative approach, this study recommends using no higher than 120 mg/kg for protection of plants, which was the level associated with effects from gasoline for earthworms.

The lowest concentration (LOAEL) of diesel and heavy oil associated with effects on lettuce and earthworm survival was 1,600 mg/kg and 260 mg/kg respectively.

The levels from this study agree fairly well with the MTCA ecological indicator soil concentrations of 100 mg/kg for gasoline and 200 mg/kg for diesel (including heavy oil) categories for earthworms. Since no plant screening levels are available for MTCA, based on these findings, a conservative approach for plant screening levels of 120 mg/kg and 1,600 mg/kg may be appropriate for gasoline and diesel respectively.

Hydrocarbon Fractions

Many regulatory agencies have developed screening levels using petroleum fractions. Fractions defined by the US Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG) were subdivided into ranges of equivalent carbon number, which are made up according to their relevant physical and chemical properties and toxicological characteristics. Soil sample composition can be established based on the fraction divisions according to the regulatory agency overseeing the project.

Ecology derived values for MTCA cleanup tables 749-2 and 749-3 using fractional compositions (F1, F2, and F3) with ratios for gasoline and diesel (gasoline 80% F1, 20% F2; diesel 50% F2, 50% F3) (Ecology, 1999). These fractions were derived from support of Canadian soil standards (CCME, 2008; Ecology, 2012) and include:

- F1 = C6–C10
- F2 = C10–C16
- F3 = C16–C34

By establishing sample compositions with fractional data following *Guidance for Remediation of Petroleum Contaminated Sites* (Ecology, 2011), this study's results were compared to the MTCA Table 749-3 screening level. However, no specific aromatic compounds falling into Fraction 1 (i.e., benzene, toluene, ethylbenzene and xylenes, (BTEX)) were subtracted out since this study is targeting terrestrial screening levels. BTEX compounds are assumed to be managed separately for protection of human health, which does not apply for terrestrial biota at this time for Washington State.

Each fraction is composed by summing these sub-fractions as:

A. Fraction 1
    1. Aromatics >C8–C10
    2. Aliphatics >C6–C8, >C8–C10
B. Fraction 2
    1. Aromatics >C10–C12, >C12–C16
    2. Aliphatics >C10–C12, >C12–C16
C. Fraction 3
    1. Aromatics >C16–C21, >C21–C34
    2. Aliphatics >C16–C21, >C21–C34

Distribution among hydrocarbon sub-fractions

The distribution range of the fractions associated with bioassay effects for earthworm and lettuce survival are shown in Table 13. For simplicity in showing the range of each fraction, they are independently ordered from largest to smallest (columns) rather than grouped together per sample (rows).

Table 13. Distribution of fraction results (F1, F2, F3) associated with bioassay toxicity effects for lettuce and earthworm survival.

Plants			Earthworms		
F1 (mg/kg)	F2 (mg/kg)	F3 (mg/kg)	F1 (mg/kg)	F2 (mg/kg)	F3 (mg/kg)
1,100	23,000	170,000	580	23,000	170,000
1,100	6,500	64,000	460	6,500	64,000
580	5,000	31,000	380	5,000	31,000
380	3,800	11,000	290	3,800	11,000
290	3,000	11,000	290	3,500	11,000
160	2,800	11,000	190	3,000	5,200
70	1,300	5,200	160	2,800	4,500
65	1,000	1,200	120	2,800	1,800
62	890	810	120	1,300	1,700
51	760	480	65	1,000	1,200
40	390	430	62	1,000	810
26	280	13	51	900	430
25	170	6.6	40	760	430
14	21	6.5	26	480	150
12	5.0	5.0	24	170	47
12	4.8	4.8	21	170	13
10	4.8	4.8	6.3	120	5.8
10	4.6	4.6			

The fractions show a fairly large range of values, but the screening levels incorporate some portion of the range. For an example, Table 14 presents proportional statistics (Q_{25} and Q_{50}) of these fractions compared with the fraction values that were used for calculating Ecology's screening levels for gasoline and diesel. Ecology's Q_{25} and Median (Q_{50}) values were taken from Canada's soil quality draft guidelines in 2000 (Ecology, 2012).

Table 14. Percentile statistics compared with fraction values used by Ecology in screening levels for hydrocarbon fractions.

Fraction Statistic or Screening Level		Plants			Earthworms		
		F1	F2	F3	F1	F2	F3
Study Results	25th percentile	17	58	6.5	40	760	430
	50th percentile	57	820	640	120	1,300	1,700
Fraction Values	Q_{25}	NA	NA	NA	75	200	250
	Median (Q_{50})	NA	NA	NA	170	300	620

NA: not available.

There is some agreement between this study's results and the fraction values for earthworms for the 25th percentile. The F1 fraction was more sensitive (lower) in this data set whereas the F2 and F3 fractions are higher compared to the Q_{25} and Q_{50} fractions.

Possible reasons for the differences may include earthworm sensitivity and plant variable responses to the contaminated soils. About a third of the samples for earthworms used for these calculations in this study had no survivors (i.e., mortality 100%). Generally, higher contaminant concentrations were in samples that had no earthworm survivors. Plants showed more variability in survival response to the different levels of concentration. Soil characteristics such as coarse or fine may influence survival of plants. As mentioned earlier, all plant bioassay test results showed significant effects for growth (biomass) in this study.

Before assigning a screening level based on this study, risk managers should evaluate the difference between fine and coarse soils. For example, there is evidence that limited effects on field communities of soil invertebrates may occur in coarse soil at or below an F3 value of 400 mg/kg (CCME, 2006). Differentiating between soil texture may be a good fit for Washington State's different soils found on the east versus the west side of the Cascade Mountains. Soil texture evaluation was out of the scope of this study, although some attempt to describe the soil type was made. (See Appendix A for field notes and Appendix E for soil classifications). Furthermore, consideration should be given to using percentiles from a combination of all bioassay endpoints showing effects.

Distribution for gasoline and diesel using proportions of hydrocarbon sub-fractions

Based on the summation of the hydrocarbon fractions, and subsequent calculation of the proportions of 80/20 F1/F2 for gasoline and 50/50 F2/F3 for diesel, the sample concentration associated with bioassay effects for earthworm and lettuce survival are shown in Table 15.

Table 15. Distribution of gasoline and diesel calculated fraction concentrations associated with effects for lettuce and earthworm survival.

Sample ID	Lettuce 14-day Survival (% reduced)	Gas (mg/kg)	#2 Diesel + Heavy Oil (mg/kg)	Sample ID	Earthworms 14-day Survival (% reduced)	Gas (mg/kg)	#2 Diesel + Heavy Oil (mg/kg)
1409070-02	66.7	930		1411036-15	100	500	
1411036-01	12.0	910		1412041-05	100	460	
1411036-15	44.0	500		1412041-04	31.0	180	
1412041-19	33.3		95,000	1412041-19	100		95,000
1412041-18	25.0		35,000	1412041-18	100		35,000
1412041-23	62.5		18,000	1412041-23	100		18,000
1412041-22	20.8		6,000	1412041-17	100		5,900
1412041-17	32.0		5,900	1412041-16	100		5,800
1412041-16	24.0		5,800	1412041-10	100		4,500
1412041-10	66.7		4,500	1412041-24	28		4,000
1409070-09	12.0		1,900	1409070-09	100		1,900
1409070-04	16.0		1,600	1409070-04	100		1,600
1411036-07	40.0		1,100	1409070-04 pH	93.1		1,600
1412041-21	32.0		250	1412041-11	17.2		1,500
1409070-06	28.0		5.6	1411036-06	100.0		1,400
1409070-05 pH	12.0		5.0	1411036-07	100		1,100
1409070-07	12.0		4.8	1411036-08	75.9		140
1409070-08	12.0		4.8				

A large range in values is observed in the concentration range of diesel for both lettuce plants and earthworms (4.8 to 95,000 mg/kg and 140 to 95,000 mg/kg respectively). The gas range is smaller, partly because of limiting number of samples showing toxicity effects for survival: 500 to 930 mg/kg for lettuce plants and 180 to 500 mg/kg for earthworms. The 25th and 50th percentile were calculated and compared to Ecology's screening level for fraction-based concentrations of gasoline and diesel in Table 16.

Table 16. Percentile compared to screening levels for fraction-based concentrations of gasoline and diesel associated with toxicity effects of survival in lettuce and earthworms.

Fraction Statistic or Screening Level		Plants		Earthworms	
		Gasoline	Diesel	Gasoline	Diesel
Results	25 percentile	705	128	320	1,525
	50 percentile	910	1,900	460	2,950
Ecology	Q25	NA	NA	100	225
	Median (Q50)	NA	NA	196	460

It seems evident that more evaluation of fractions defining gasoline or diesel is necessary before assigning statewide screening levels based on hydrocarbon fractions from these samples. These gas and diesel values that were calculated using fraction proportions were elevated compared to screening levels discussed previously. Furthermore, the percentile calculated for the gasoline range should be used with caution since it was based on only three samples.

Overall, the fraction approach method used was valuable to account for contaminants not seen in the NWTPH-Gx and -Dx approach.

Bioaccumulation Results

Three soil samples were used for the earthworm bioaccumulation tests. Each sample was a composite of two other soil samples from the same location; one with low and another with a relatively high concentration of contamination. The target concentration for the bioaccumulation test was set so that the test organisms would burrow into test soils, because avoidance of test soil may decrease bioaccumulation. The soils chosen for the bioaccumulation test were ones where the number of worms in the toxicity screening test were not significantly reduced in the test soil relative to the control soil.

Results of the earthworm bioaccumulation study and confirmation soil sampling were subsequently used to calculate a bioaccumulation factor (BAF) for a specific indicator concentration that is considered protective of potential wildlife receptors using the equations provided in the MTCA guidance using reference Table 749-4 (WAC 173-340. 2013). This study targeted a BAF to be used for the wildlife exposure model and predatory receptors of shrew and robin.

Because of the uncertainty caused by a laboratory mishap, the survival and growth test results are considered unacceptable for this study. However, the tissue collected for bioaccumulation analysis for gasoline and diesel concentrations should not have been affected and are considered "valid". See Data Quality for more details in Appendix D.

Soil concentrations and tissue results are shown in Table 17.

Table 17. Bioaccumulation test results.

Soil Samples				Tissue Samples			
Sample ID	Study Specific Location ID	Parameter	Result (mg/kg)	Sample ID	Study Specific Location ID	Parameter	Result (mg/kg) (ww)
1504063-08	Gas 3-2 Day-1	Gasoline	4.5	1506056-02	WDOE GAS 3-2 A-B-C	Gasoline	3.3 U
1504063-09	Gas 4-2 Day-1	Gasoline	100	1506056-03	WDOE GAS 4-2 A-B-C	Gasoline	3.3 U
1504063-07	Diesel 1-2 Day-1	2 Diesel	350	1506056-04	WDOE DIESEL 1-2 A-B-C	2 Diesel	160
1504063-04	Control Day-1	Gasoline	13 U	1504063-05	45g Worms Day 0	Gasoline	6.8 U
				1506056-01	WDOE CONTROL A-B-C	2 Diesel	15 U
				1506056-01	WDOE CONTROL A-B-C	Gasoline	3.4 U

ww: wet weight.
WDOE: Washington State Department of Ecology.
U: not detected.

There were no detected contaminants in the control soil or control tissue samples. Soil sample concentrations were low (ranging from 4.5 to 350 mg/kg). One tissue sample reported 160 mg/kg ww of diesel. Gasoline was not detected in tissue samples.

A simple comparison of worm concentration to soil concentration to obtain a ratio of uptake at an apparent steady state (BAF) resulted in 0.46 for diesel in worm tissue. No BAF results were available for gasoline. More research on this subject is advised.

Uncertainties

All analytical measurements provide an estimate of toxicity of an analyte within the measured range of this study. Uncertainties exists for petroleum toxicity as seen in this study's variabilities between samples due to different petroleum products, soil characteristics, or weathering. These factors were reduced but not eliminated by following Ecology and laboratory guidance, methods, and protocols.

To reduce imprecision, this study conducted toxicity tests on 54 samples using ten organisms in three replicates of worms and five organisms in five replicates of plants for each testing unit (sample). To test variability in the bioassays, the percent minimum significant difference (PMSD) was calculated (alpha 0.05). The PMSD is the minimum significant difference (MSD) (minimum difference between a control and treatment to be considered significant) divided by the control mean and expressed as a percent. Low (most <20%) PMSD for bioassay test effects indicated good statistical significance for within test variability.

Uncertainties in exposure and effects were generally addressed through the use of conservative assumptions. When evaluating contaminant concentrations associated with bioassay test effects, only samples with significant effects compared to the control were considered for further evaluation. Endpoints which did not delineate patterns that could be evaluated for causative effects were not used when evaluating concentrations associated with bioassay test effects (i.e., normal morphology in earthworms, and wet and dry weight in lettuce).

Conclusions

Earthworm and lettuce bioassays were conducted for 54 samples collected from 11 sites, which includes two sets of samples from one location. Toxicity was considered evident if the bioassay results were significantly more impacted than the control. Eleven soil samples showed significant effects for all toxicity endpoints (i.e., survival, normal morphology, wet and dry weight) in earthworm and lettuce bioassay toxicity tests when compared to the controls. Additional samples showed either significant effects in lettuce or earthworm bioassay tests.

Survival in bioassay tests was associated with contaminant concentration and evaluated for low effect levels. Normal morphology and wet and dry weights for earthworms were all significantly different, therefore they were not used in screening level evaluations for lack of differentiation.

All data results were reviewed to find the best fit for evaluating screening levels. Methods of deriving screening levels included using concentration, hydrocarbon fractions, and percentile proportions of results with significant bioassay effects. Because variability exist in the toxicity results, Ecology takes a conservative approach for protection of plant and biota.

Results from this study support the following conclusions:

- The results from gasoline and diesel range organics using concentrations from NWTPH analysis support using 120 mg/kg for gasoline and 260 mg/kg for diesel soil screening levels under MTCA (Table 749-3) for soil biota (i.e., for Gasoline Range Organics and Diesel Range Organics respectively). Because variability exists in the toxicity results, these proposed values take a conservative approach for protection of plant and biota based on this study.
- Using concentrations from NWTPH analysis, screening levels of 120 mg/kg for Gasoline Range Organics and 1,600 mg/kg for Diesel Range Organics may be appropriate screening levels for plants under MTCA (Table 749-3).
- Use of the fraction approach method were valuable to account for contaminants not seen in the NWTPH-Gx and -Dx approach.
- The F1 fraction values were more sensitive (lower value) and F2 and F3 fraction values were less sensitive (higher) for earthworms in this study compared to the Ecology's previous fraction values used to calculate standards. No plant values were available for comparison.
- Gasoline and diesel screening levels calculated from hydrocarbon fraction data have a large distribution range and were lower (less sensitive) than Ecology's screening levels.
- Insufficient data were generated to calculate a reliable bioaccumulation factor. Limited data suggest that diesel was accumulating in worm tissues, while gasoline was not.

Recommendations

Results of this study support the following recommendations:

- Conduct additional bioassay tests using soils collected from east of the Cascade Mountains to be more representative of statewide soils since this study had limited representation for east side soils.
- Conduct a literature review for defining toxicity screening levels for carbon fraction 3 (>C16 to C34) in fine and coarse soils.
- Consider further defining plant and animal tissue screening level by combining various toxicity endpoints.
- Conduct additional tests to support a bioaccumulation factor for worm tissue.

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Appendices

Appendix A. Site and Sample Descriptions

Table A-1. Sample Site General Descriptions.

Site	Sample ID	General Site Description
East	1409070-01	This site is located in northeast Washington. Previous investigation and groundwater monitoring indicate a plume of petroleum-contamination (gas) in the soil and groundwater. Investigation indicates this site is downstream of historic leaking gasoline tanks. Geologic maps indicate this site consists of clay, silt, and fine sand deposited in glacial lakes and can include localized deposits of sand and gravel. Subsurface conditions encountered in previous borings consisted of an upper layer of sand mixed with silt extending to depths from 17 to 50 feet below ground surface, underlain by low-permeability silt and clay. For this study, samples at this site were collected using direct push (DP) coring.
	1409070-02	
	1409070-03	
West	1409070-04	This site sits in the Puyallup River flood plain located in the south Puget Sound region. Geology of the site is described as a mixture of silts, clayey silts, and silty sands. Groundwater is typically found 4 to 5 feet below ground surface. Upon the development of a mitigated wetland, an underground tank was discovered and soil samples indicated petroleum contamination of diesel range organics. For this study, samples were collected using a shovel in various locations around the pit during excavation and tank removal.
	1409070-05	
	1409070-06	
	1409070-07	
	1409070-08	
	1409070-09	
West	1410045-01	This site sits in the Puyallup River flood plain located in the south Puget Sound region. Geology of the site is described as a mixture of silts, clayey silts, and silty sands. Groundwater is typically found 4 to 5 feet below ground surface. Upon development of this former residential (old farm) property, a leaking underground storage tank was removed. Gasoline and other volatile organic compound contaminated soils were found during the removal of the tank. Samples for this study were collected during road excavation and removal of contaminated soils.
	1410045-02	
	1410045-03	
	1410045-04	
	1410045-05	
West	1411036-01	This site is located in the lowlands of the Puget Sound basin in Tacoma. Surface geology shows glacial and river till interbedded with sands, silts, and gravel. This commercial site was previously operated as a retail gas station followed by other vehicle commercial outlets. Underground storage tanks were removed about 20 years ago, but soil samples from investigative borings found gasoline range organic contamination. Further work proceeded. Samples for this study were collected using Sonic Boring (SB).
	1411036-02	
	1411036-03	
	1411036-04	
	1411036-05	

Table A-1 continued.

Site	Sample ID	General Site Description
West	1411036-06	This site is an active school facility located in western Washington, King County. The school district is demolishing the school and replacing it with a new facility. The plan includes decommissioning and removing two heating oil underground storage tanks. The dominant geological feature is Vashon till made up of fine-grained deposits of unsorted and unstratified glacial sediments from clay to boulders that vary in compaction and composition throughout Puget Sound. Samples for this study were collected from diesel-affected soil encountered under or around the tanks during removal.
	1411036-07	
	1411036-08	
	1411036-09	
	1411036-10	
West	1411036-11	This site is located in the lowlands of the Puget Sound basin in Tacoma. Surface soils were described as fill material that had silt, sand, and gravel matrix underlain by silty sand with gravel to depths of 19 feet below ground surface. This commercial site was historically a hotel at the turn of the 19th century, then operated as a retail gas station followed by other commercial businesses. Petroleum-contaminated soils were found during a city sewer pipe replacement trench next to this site. Soil samples taken during investigation confirmed gasoline range organic contamination. Samples collected for this study were taken during excavation for removal of contaminated soils.
	1411036-12	
	1411036-13	
	1411036-14	
	1411036-15	
West	1412041-01	The dominant geological feature is Vashon till made up of fine-grained deposits of unsorted and unstratified glacial sediments from clay to boulders that vary in compaction and composition throughout Puget Sound. This site has been used for two gasoline stations before current demolitions. Confirmed releases of gasoline and other investigations show gasoline range organic contamination in soil and groundwater. This study collected samples from a stockpile and from the side of a pit during excavation for contaminated soil removal.
	1412041-02	
	1412041-03	
	1412041-04	
	1412041-05	
West	1412041-06	This site is the same location as for samples 1412041-01 through 1412041-05 with historical gasoline stations before current demolitions. Vashon till is the dominant geology consisting of glacial sediments from clay to boulders that vary in compaction and composition throughout Puget Sound. Contamination of diesel range organics were confirmed near the former island dispensers. This study collected samples from the side of the pit during excavation for contaminated soil removal.
	1412041-07	
	1412041-08	
	1412041-09	

Table A-1 continued.

Site	Sample ID	General Site Description
West	1412041-10	This commercial property site is located in northwest Washington in Bellingham. The geology consists of typical Puget Sound Lowland glacial till composed of very well compacted, unsorted mixture of silt, sand, gravel, and boulders. In Whatcom County, an additional type of glacial sediment is commonly referred to as glacial marine drift or Bellingham Drift. This site is underlain by the Bellingham Drift consisting of poorly sorted and unstratified silty clay, gravelly clay, and gravelly, sandy silt, with some cobbles and rare boulders. A 10,000-gallon fuel oil underground tank was closed-in-place and reportedly filled with inert material at the site over 20 years ago. More recent investigation found petroleum hydrocarbons in the diesel range organics contaminating soil and groundwater in the nearby vicinity. Samples collected for this study came from the pit walls during tank removal and excavation of contaminated soils.
	1412041-11	
	1412041-12	
	1412041-13	
	1412041-14	
West	1412041-15	This site is a privately owned wetland undergoing mostly natural restoration on a Puget Sound island. Most of the surface geology consists of glacial till. Deeper sand and gravel outwashes generally house the principal aquifer. In the past, this site housed a lumber mill, millpond, greenhouses, and oil storage and transfer facilities. Requested and granted investigations revealed bunker C oil contamination in the soils and wetland waters. Samples collected at this site targeted the area of heavy fuel oil contamination as shown from previous reports.
	1412041-16	
	1412041-17	
	1412041-18	
	1412041-19	
	1412041-20	
West	1412041-21	This site is the same location as samples 1412041-15 through 1412041-20. A second set of samples were collected for additional research for soils with heavy oil contamination.
	1412041-22	
	1412041-23	
	1412041-24	
	1412041-25	

Table A-2. Site and Sample Descriptions including Field Observed Soil Characteristics.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
East	1409070-01	Gas1E1_DP50	-	-	-	-	-	-	-	No observable organics, mostly sand and small gravel. Sample collected above contaminated area.
	1409070-02	Gas1E2_DP50	-	-	-	-	-	-	-	No observable organics, mostly sand and small gravel. Sample collected within contaminated area next to groundwater.
	1409070-03	Gas1E3_DP52	-	-	-	-	-	-	-	Sample collected within contaminated area next to groundwater.
West	1409070-04	Diesel1-W1	Fine	Black to dark brown	Strong petroleum	H	VS	-	Wet	Several worms spotted in excavation area (within contamination). Also saw a beetle. Oil slick in most of contaminated area. Strong petroleum smell over all area.
	1409070-05	Diesel1-W2	Fine	Dark brownish gray or black	Slight petroleum	H	VS	-	Wet	Sample was flooded earlier in morning- pumped out area. Water level fills pit during night and must be pumped before excavating or collecting samples.
	1409070-06	Diesel1-W3	Coarse	black (coarser) / dark brownish gray (finer)	some organic and mixed odors	H	VS	W	Wet	Creek/groundwater bubbles up in this area. Unless site is steadily pumping, excavated area fills up with water.
	1409070-07	Diesel1-W4	Fine	Dark brownish gray or black	slight organic odor	H	VS	-	Moist	Large ground beetle- dead at sample point. Worms and snails sighted in excavation area- appear to have fallen off edge near creek.
	1409070-08	Diesel1-W5	Fine	dark brown gray or black	slight organic mixed with petroleum	H	VS	-	Moist	Some wood pieces and noticeable tree sticking out of ground next to sample point. Lots of water flushing around contamination in this whole area.
	1409070-09	Diesel1-W1	Fine	Black to dark brown	Strong petroleum	H	VS	-	Wet	Same as sample 1409070-04 because this is a field replicate.
West	1410045-01	Gas1-W1	Fine	dark gray/dark greenish/brown or black	strong petroleum - gas	H	VS	-	Moist	Occasional 3/4 minus size rocks ~ <1% of sample. Sample taken under road after asphalt removed at depths of 13-15 ft.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
	1410045-02	Gas1-W2	Fine	dark gray/dark-greenish/brown or black	strong petroleum - gas	H	VS	-	Moist	Occasional 3/4 " minus size rocks. Same larger rocks ~ <1 - 2%.
	1410045-03	Gas1-3	Fine	dark gray/dark green or black	very strong petroleum	H	VS	-	Moist	Quite sandy. Very few small pebbles and some clumps that break easily.
	1410045-04	Gas1-W4	Fine	dark gray/dark green or black	strong petroleum - gas	H	VS	-	Moist	Granular, but some clay clumps. Soil sandy but dark. Very few larger than 3/4" minus rocks.
	1410045-05	Gas1-W5	Fine	dark gray/dark green- shade of brown or black	slight petroleum - gas and some earthy smell	H	VS	-	Moist	Soil much lighter brown than other samples from this site. Some very scattered (~ <1%) 3/4" minus rocks.
West	1411036-01	Gas2-W1-2-3	Fine	brownish, mostly gray or black	fairly strong petroleum	H	S	-	Wet	Sandy and small gravel.
	1411036-02	Gas2-W1-2-3	Fine	gray and light brown- mostly gray	strong petroleum odor	H	F	-	Dry	Some rocks ~ 3/4" minus. Soil clumps, breaks apart then crumbles.
	1411036-03	Gas2-W1-2-3	Fine	gray/brown-mostly gray	strong petroleum	H	S	-		Some larger rocks ~ 1.5" but <1% of sample. Clumps of hard pack clay. Can break apart.
	1411036-04	Gas2-W4-5	Coarse	Gray- with little brown hue	moderate petroleum	H	-	M	Dry	Contaminated soil at deeper depth at this bore site. Soils above were light brown, organic with some fines. This sample has larger rocks >1" diameter ~ 10% and very clumpy. Rocks very polished and smooth.
	1411036-05	Gas2-W4-5	Fine	gray, slight brownish hue	slight petroleum	H	F	-	Moist	Same as notes on sample 1411036-04.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
West	1411036-06	HOil1-W1	Fine	gray to light gray	strong petroleum	H	VS	W	Wet	Gray in contaminated area, light brown where contamination is now apparent. Rocks >2" ~70%. Rocks > 3/4 to 2" ~15%. Sample taken from around spill/fill area at 10,000 gal tank pit.
	1411036-07	HOil1-W2	Fine	gray to light gray	strong petroleum	H	VS	-	Wet	Rocks>2" ~10% and rocks>3/4 to 2" ~15-20%. Very soupy because mixed with storm drain water nearby. Large tank (~10,000 gal bunker C removed and a small tank (~5000 gal diesel) also removed east of the large tank.
	1411036-08	HOil1-W3	Fine	light brown gray	some-moderate petroleum	B	S	M	Dry	Fines apparent only after broke apart. Rocks>2" ~10% and rock>3/4" to 2" ~15%.
	1411036-09	HOil1-W4	Coarse	dark brown or black	some petroleum - not as strong as other samples	H	-	S	Dry	Very hard clumps. Rocks >2" ~ 15% and rocks 3/4" to 2" ~ 25%. Once clumps broken, crumbles containing rocks with fines.
	1411036-10	HOil1-W5	Fine	dark brown or black	slight petroleum	H	S	-	Dry	Grainy, not clumpy with rocks >2"~10% and rocks >3/4" to 2" ~ 15%. Sample scraped from Northwest side of pit for cleaner soils (hopefully).
West	1411036-11	Gas3-W1	Fine	dark brownish gray	strong petroleum	H	-	W	Moist	Rocks ~3/4" minus ~5% and rocks~>2"~1%. Groundwater seepage at about 15 ft depth.
	1411036-12	Gas3-W2	Coarse	dark brownish gray	strong petroleum	H	VS	-	Wet	Very sandy with rocks ~ <2" ~ 1%. Groundwater seepage at about 15 ft depth. Lots of groundwater seepage at about 15 ft depth making sample very soupy. Observed a noticeable oil-type sheen on water when sampling.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
	1411036-13	Gas3-W3	Coarse	dark brown or very black with some areas of gray	very strong petroleum	H	VS	W		Soil very black with contamination. Rocks >2" ~2% and rocks 3/4" minus to <2" ~20%.
	1411036-14	Gas3-W4	Fine	dark brown or black and somewhat gray	strong petroleum-gasoline	H	VS	-	Moist	Sandy and clumpy silt which can be broken with hand trowel. Rocks >2"~5% and rocks <3/4" minus to 2" ~ 2% or 3%. Mostly sandy/silt. Lots of groundwater invasion at about 15 ft below ground surface. Sump pump installed on south end. Sample taken above groundwater.
	1411036-15	Gas3-W5	Coarse	dark brown or black	strong petroleum-gasoline	H	VS	-	Moist	Small gravely rocks and rocks >2"~25%. Some rocks as large as footballs and baseballs. Rocks <3/4" minus to 2" ~10%. Sample taken above groundwater.
West	1412041-01	Gas4-W1	Fine	darkish brownish gray or black	moderate petroleum odor	H	VS	-	Wet	Sandy. Was informed there is sandstone in the area. Rocks >2" ~ 10% and rocks >3/4" minus to <2" ~20%. Underground storage tank was gone, removed earlier. At the time of sampling, pit was being backfilled. Some contamination expected, mostly diesel or mix of gas and diesel. Samples were not taken directly from pit, but rather from a stockpile near the pit which contained soils from near the center of pit.
	1412041-02	Gas4-W2	Fine	dark brownish gray or black	moderate petroleum	H	VS	-	Wet	Sandy. Was informed there is sandstone in the area. Rocks >2" ~ 15% and rocks >3/4" minus to <2" ~25%. Like sample 1412041-01, this sample taken from stockpile near pit with expected gas, diesel, or mix contamination. Samples 1412041-01 through 1412041-05 share this same information.
	1412041-03	Gas4-W3	Fine	dark brown gray or black	moderate petroleum	H	VS	-	Wet	Sandy. Rocks >2" ~ 15% and rocks >3/4" minus to <2" ~20%. Like sample 1412041-01, this sample taken from stockpile near pit with expected gas, diesel, or mix contamination.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
	1412041-04	Gas4-W4	Fine	dark gray	moderate petroleum	H	VS	-	Wet	Sandy. Rocks >2" ~ 15% and rocks >3/4" minus to <2" ~15-20%. Like sample 1412041-01, this sample taken from stockpile near pit with expected gas, diesel, or mix contamination.
	1412041-05	Gas4-W5	Fine	dark gray- some dark brown	moderate petroleum	H	VS	-	Wet	Sandy. Rocks > 2" ~ 10% and rocks <3/4" minus to <2" ~20-25%. Same as above Like sample 1412041-01, this sample taken from stockpile near pit with expected gas, diesel, or mix contamination.
West	1412041-06	Diesel2-W1	Fine	gray	moderate petroleum	S	VS	-	Moist	Hard packed sandy soil. Rocks >2" ~ 1% and rocks >3/4" minus to <2" ~ 1%.
	1412041-07	Diesel2-W2	Fine	dark gray green	moderate petroleum	H,~ S	VH	-	Moist	Hard sandy clumps but can break with shovel or scoop. Rocks >2"~1% and rocks >3/4" minus to <2"~1%.
	1412041-08	Diesel2-W3	Coarse	Dark brownish gray or black	moderate petroleum	H	-	M	Moist	Sandy soil mixed with fill gravel. Rocks >2"~5% and rocks >3/4" minus to <2"~80%.
	1412041-09	Diesel2-W4	Fine	dark brownish gray or black	moderate petroleum	H	S	-	Moist	Sandy, clumpy soil with some woody debris. Rocks >2"~1% and rocks >3/4" minus to <2"~10%.
West	1412041-10	HOil2-W1	Fine	black/gray or black	strong petroleum	H	-	W	Wet	Very sandy soil sample, if not all sand (medium to fine grain). Rocks = 0% any size except sand. Saw a couple of wood fragments, which appeared to be old and may have been from wood shoring from tank. Sample collected from bottom of pit with some groundwater showing. Sample very dark in color.
	1412041-11	HOil2-W2	Fine	gray to light gray	moderate petroleum and glacier till odor	H	S	-	Moist	Very sticky and clay-like soil. Rocks <2"~ <1% and rocks >2" = 0%. Sample collected in same area as sample 1412041-10 from bottom of pit from dark colored soil area.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
	1412041-12	HOil2-W3	Fine	dark brown with mottled lighter-rust color spots or black	none	H	VS	-	Moist	Sample collected looked like possible native soil in northwest Washington locally called Bellingham till. Rocks >2" = 0% and rocks <2" but >3/4" minus ~ <1%. Some very small organic debris sparsely mixed in sample.
	1412041-13	HOil2-W4	Fine	gray to light gray	mild petroleum	H	F	-	Moist	Very sticky clay locally called Bellingham till. Rocks <2"~9% and rocks >2" = 0%.
	1412041-14	HOil2-W5	Fine	dark brown, slight gray or black	mild petroleum	H	S	-	Moist	Sample consists of somewhat sticky clay, but can still crumble, yet packs well. Rocks >2" = 0% and rocks <2" but >3/4" minus ~ <1%.
West	1412041-15	HOil3-W1	Fine	Dark brownish gray or black	mixed organic and mild petroleum odor	H	VS	-	Wet	Sample has pea gravel/sand mixed with woody fiber debris. Rocks >2" ~<1%. Observed an oily sheen on surface water of this very saturated wetland-type area. Lots of salmonberries and some alder trees.
	1412041-16	HOil3-W2	Fine	dark brown gray or black	moderate to strong petroleum	H	VS	-	Wet	Sample is sandy with peat (spongy) and wood fibers. Rocks >2" ~1% and rocks <2" but >3/4 minus ~2%. Observed an oily sheen on surface water in this wetland area--very wet with groundwater seepage. A couple of worms observed in top 6". Heavy cover of salmonberries, ivy on alder trees, some sword ferns but did not see any cedar trees.
	1412041-17	HOil3-W2	Fine	dark brown gray or black	moderate to strong petroleum	H	VS	-	Wet	Sample is sandy with peat (spongy) and wood fibers. Rocks>2"~1%. Rocks<2">3/4 minus ~2%. Oily sheen observed in this wetland area--very wet with groundwater seepage. Worms observed in top 6". Sample biota/fauna description as with sample 1412041-16.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
	1412041-18	HOil3-W3	fine	dark brown gray or black	strong petroleum	H	VS	-	wet	Soil sample was black mixed with oily and tar-type substance at approximately >8-12" depth. Rocks >3/4" minus ~1% mixed with wood fibers. Sample collected from area that was very mucky. Oily sheen observed and groundwater following a step down to creek. Salmonberries surrounding sampling area but not densely, ivy on downed tree nearby, and lots of woody debris in first 6".
	1412041-19	HOil3-W4	Fine	dark brown or black	strong petroleum	H	VS	-	Wet	Rocks >3/4" minus ~1% mixed with wood fibers. One worm observed in top 2" of cover soil where leaves accumulate. Area of sampling was very gooey and full of an oily substance. Observed few plants growing in sampling spot next to an existing concrete tank. There were a few salmonberries and sparse buttercup on east side of tank and following the flow of seepage draining.
	1412041-20	HOil3-W5	Fine	brown, dark black	mild petroleum	H	VS	-	Moist	Rocks >2"~ <1% and rocks <2" but >3/4 minus ~10%. Woody debris present. One worm observed in the top 6". Some salmonberries, sword ferns, and piggy back plants. Lots of horsetail evident.
West	1412041-21	HOil4-W1	Fine	top soil (<6") dark brown or black	mild petroleum	H	VS	-	Moist	Sandy sample collected from an area about 6" below ground surface. Rocks >2" ~ <2% and rocks <2" but >3/4" minus ~higher percentage but not noted in notes. Woody debris observed mixed in soil. Salmonberry and blackberry and piggy back plants.

Site	Sample ID	Study Specific ID	Grain	Color	Odor	Soil Structure[a]	Consist	Cement	Moisture Content	Comments
	1412041-22	HOil4-W2	Fine	dark brown to black	slight to mild petroleum odor	H	VS	-	Wet	Rocks ~3/4" minus ~15% and >2"~ <1% mixed with woody debris. Soil somewhat spongy. Sampling area very wet from groundwater seepage. Some oily sheen observed on groundwater seeping in sampling hole. Worms observed in top 3". Observed some blackberries, salmonberries, horsetail, ivy and ferns on logs, piggyback or buttercup type ground cover.
	1412041-23	HOil4-W3	Fine	gray black-sample. Soil above sample (0-18") dark brown	strong petroleum	H	VS	-	Wet	Some rocks >2" ~ <1% but mostly sandy mixed with unknown oozy substance. Very little woody debris observed in sample area. Worms observed in the top 6-8" below ground surface. Found large pipe structure that contained oily substance oozing from under pipe structure. Flora observed included blackberries, salmonberries, wetland type of ground cover such as buttercup.
	1412041-24	HOil4-W4	Fine	dark brown, gray or black	mild to moderate petroleum odor	H	VS	-	Wet	Sandy mix. Rocks >2"~1% to 5% and rocks ~3/4" minus ~ 25% mixed with woody debris. No worms observed. Rocks and seepage appear oily with water draining into lower level towards creek. Sparsely populated ground flora near this sample but some salmonberries on banks.
	1412041-25	HOil4-W5	Fine	gray	none	H	VS	-	Wet	Sandy soil with no woody debris or oily sheen observed except above ground where sample as collected on bank of creek. Observed heavy growth of ivy cover on alder tree, salmonberries, and holly tree near sample point. Streamwater appears clear flowing at about 2-3" deep near this sample location.

- no notes or not applicable.

Cement: Cementation of soils measures the strength for soils to hold together (not break or crumble) under pressure. M: Moderate; S: Strong; W: Weak.

Consist: Consistency measures the stickiness of soil or to resist deformation and rupture. F: Firm; S: Soft; VH: Very Hard; VS: Very Soft.

a. Soil Structure: B: blocky; H: homogenous; S: Stratified; H/~S: homogenous but somewhat stratified.

Appendix B. PetroFLAG® Results

Table B-1. PetroFLAG® Results.

Sample ID	Study Specific ID	PetroFLAG® Results (ppm)	PetroFLAG® Measurement Location (S/A)	PID (ppm)	PID Measurement Location (S/A)
1409070-01	Gas1E1_DP50	-	-	-	-
1409070-02	Gas1E2_DP50	-	-	-	-
1409070-03	Gas1E3_DP52	-	-	-	-
1409070-04	Diesel1-W1	128	A	9.3	A
1409070-05	Diesel1-W2	3	A	0.3	A
1409070-06	Diesel1-W3	57	A	0.0	A
1409070-07	Diesel1-W4	52	A	0.0	A
1409070-08	Diesel1-W5	70	A	0.1	A
1409070-09	Diesel1-W1	128	A	9.3	A
1410045-01	Gas1-W1	-	-	900	S
1410045-02	Gas1-W2	-	-	750	S
1410045-03	Gas1-W3	-	-	1,300	S
1410045-04	Gas1-W4	-	-	1,250	S
1410045-05	Gas1-W5	-	-	130	S
1411036-01	Gas2-W1-2-3	-	-	801–1,523	S
1411036-02	Gas2-W1-2-3	-	-	1,180–1,520	S
1411036-03	Gas2-W1-2-3	-	-	571–1,842	S
1411036-04	Gas2-W4-5	-	-	571–1,156	S
1411036-05	Gas2-W4-5	-	-	112.9–164.5	S
1411036-06	HOil1-W1	-	-	20 - 80	S
1411036-07	HOil1-W2	-	-	-	-
1411036-08	HOil1-W3	-	-	43.7	S
1411036-09	HOil1-W4	-	-	6.0	S
1411036-10	HOil1-W5	-	-	4.3	S
1411036-11	Gas3-W1	-	-	35–90	S
1411036-12	Gas3-W2	-	-	-	-
1411036-13	Gas3-W3	-	-	78–197	S
1411036-14	Gas3-W4	-	-	555	S
1411036-15	Gas3-W5	-	-	1,838	S
1412041-01	Gas4-W1	-	-	230	S
1412041-02	Gas4-W2	-	-	239	S
1412041-03	Gas4-W3	-	-	170	S

Sample ID	Study Specific ID	PetroFLAG® Results (ppm)	PetroFLAG® Measurement Location (S/A)	PID (ppm)	PID Measurement Location (S/A)
1412041-04	Gas4-W4	-	-	439	S
1412041-05	Gas4-W5	-	-	472	S
1412041-06	Diesel2-W1	-	-	200	S
1412041-07	Diesel2-W2	-	-	178–>400	S
1412041-08	Diesel2-W3	-	-	220	S
1412041-09	Diesel2-W4	-	-	76	S
1412041-10	HOil2-W1	1,100–1,567	S	-	-
1412041-11	HOil2-W2	650–1,273	S	-	-
1412041-12	HOil2-W3	0.0	S	-	-
1412041-13	HOil2-W4	377	S	-	-
1412041-14	HOil2-W5	303	S	-	-
1412041-15	HOil3-W1	385	A	-	-
1412041-16	HOil3-W2R	1,438	A	-	-
1412041-17	HOil3-W2	1,438	A	-	-
1412041-18	HOil3-W3	734	A	-	-
1412041-19	HOil3-W4	14,340	A	-	-
1412041-20	HOil3-W5	-	A	-	-
1412041-21	HOil4-W1	-	-	-	-
1412041-22	HOil4-W2	-	-	-	-
1412041-23	HOil4-W3	-	-	-	-
1412041-24	HOil4-W4	-	-	-	-
1412041-25	HOil4-W5	-	-	-	-

- no data available
A: area
S: Sample

Appendix C. Element Screening Levels and Results

Table C-1. Element Screening Levels.

Location	As	Pb	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn
Natural (total recoverable)[a]	6.8	12	-	42	680	42,100	-	34	31	80
Natural (total)[b]	13	18	12,000	190	1,320	79,000	36	74	56	140
Ecological Indicator Soil Concentrations for Plant, Soil Biota, and Wildlife (mg/kg)[c]	10	50	-	42	1,100	-	20	30	50	86
MTCA Cleanup Levels – Method B (ppm)	24	-	-	240	11,200	56,000	-	-	3,200	24,000
MTCA Cleanup Levels – Method A (ppm)	20	250	-	19	-	-	-	-	-	-

[a] Values are from San Juan (1994) and Ames and Prych (1995). The conservative (lower) values from the two studies are reported in this table. Values are 90th percentile values in units of mg/kg dry soil.
[b] Values are from Ames and Prych (1995). Values are 90th percentile values in units of mg/kg dry soil.
[c] Ecological Indicator Soil Concentrations for Plant, Soil Biota, and Wildlife (mg/kg dry soil). The conservative (lowest) of the three values for each element are reported in this table.

Table C-1. Element Screening Levels (Continued).

Location	Se	Rb	Sr	Zr	Mo	Ag	Cd	Sn	Sb	Ba	Hg
Natural (total recoverable)[a]	<5.0	-	-	-	-	0.3	<0.2	-	<3.0	-	0.06
Natural (total)[b]	1.0	-	370	-	<2	<2	<2.3	<5	3.8	760	0.4
Ecological Indicator Soil Concentrations for Plant, Soil Biota, and Wildlife (mg/kg)[c]	0.3	-	-	-	2	2	4	50	5	102	0.1
MTCA Cleanup Levels - Method B (ppm)	400	-	48,000	-	400	400	80	48,000	-	16,000	-
MTCA Cleanup Levels - Method A (ppm)	-	-	-	-	-	-	2	-	-	-	2

[a] Values are from San Juan (1994) and Ames and Prych (1995). The conservative (lower) values from the two studies are reported in this table. Values are 90th percentile values in units of mg/kg dry soil.
[b] Values are from Ames and Prych (1995). Values are 90th percentile values in units of mg/kg dry soil.
[c] Ecological Indicator Soil Concentrations for Plant, Soil Biota, and Wildlife (mg/kg dry soil). The conservative (lowest) of the three values for each element are reported in this table.

Table C-2. XRF Results. Shaded values are above Ecological Indicator or MTCA screening levels listed in Table C-1.

Sample ID	Study Specific ID	As	Pb	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn
+/- range	range for specific samples[a]	0.8 - 1.9	1 - 4	59 - 221	10 - 22	7 - 21	0.10 - 176	-	3 - 5	1.7 - 8	1.6 - 3
1409070-01	Gas1E1_DP50	6.4	15.4	2,389		258	14,100		19	9	425
1409070-02	Gas1E2_DP50	6.8	14.3	1,534		239	14,600		35	12	59
1409070-03	Gas1E3_DP52	5.5	12.3	1,067	61	205	8,792		16		33.2
1409070-04	Diesel1-W1	5.3	5.8	4,792	ND	428	29,425	ND	ND	15	57
1409070-05	Diesel1-W2	2.8	5.5	6,879	65	492	36,221	ND	38	12	58
1409070-06	Diesel1-W3	6.1	5.1	2,939	42	454	31,035	ND	28	17	56
1409070-07	Diesel1-W4	4.1	4.3	4,455	69	425	29,394	ND	ND	10	59
1409070-08	Diesel1-W5	4.7	5.8	5,770	69	450	31,722	ND	28	14	58
1409070-09	Diesel1-W1	ND	8.8	4,772	90	448	29,709	ND	30	12	55
1410045-01	Gas1-W1	5.2	12.3	4,945	59	457	35,005	ND	22	18	56
1410045-02	Gas1-W2	6.0	6.1	3,811	73	390	28,787	ND	60	14	53
1410045-03	Gas1-W3	5.6	8.3	5,775	ND	641	51,265	ND	ND	8.0	57
1410045-04	Gas1-W4	5.4	7.1	4,308	73	459	33,285	ND	27	13	49
1410045-05	Gas1-W5	5.2	6.6	13,343	66	261	25,206	ND	34	78	51
1411036-01	Gas2-W1-2-3	4.7	9.2	2,675	98	366	21,536	ND	42	16	49.8
1411036-02	Gas2-W1-2-3	6.1	3.4	2,980	136	335	18,829	ND	32	9.0	38.3
1411036-03	Gas2-W1-2-3	6.3	7.0	2,975	96	352	26,287	ND	48	31	49
1411036-04	Gas2-W4-5	7.2	ND	3,390	101	365	22,903	ND	45	15	43.8
1411036-05	Gas2-W4-5	5.6	4.3	2,426	62	246	17,527	ND	56	14	37.2
1411036-06	HOil1-W1	5.4	6.0	2,074	ND	284	18,915	ND	30	15	39.6
1411036-07	HOil1-W2	8.2	4.5	2,596	121	318	21,555	ND	27	17	43.3
1411036-08	HOil1-W3	7.1	4.2	3,099	65	400	21,708	ND	33	15	44.5
1411036-09	HOil1-W4	6.0	5.3	3,166	711	466	23,202	ND	31	12	52
1411036-10	HOil1-W5	6.3	3.6	2,536	82	351	19,709	ND	42	15	47

Sample ID	Study Specific ID	As	Pb	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn
+/- range	range for specific samples[a]	0.8 - 1.9	1 - 4	59 - 221	10 - 22	7 - 21	0.10 - 176	-	3 - 5	1.7 - 8	1.6 - 3
1411036-11	Gas3-W1	5.0	22.3	2,572	79	297	19,148	ND	39	12	63
1411036-12	Gas3-W2	6.4	14.0	3,880	64	426	31,455	ND	30	30	56
1411036-13	Gas3-W3	6.4	8.0	2,817	81	299	20,850	ND	29	17	42.2
1411036-14	Gas3-W4	6.0	4.6	2,778	53	263	18,660	ND	47	13	38.8
1411036-15	Gas3-W5	6.9	39.4	3,408	73	549	26,851	ND	40	27	81
1412041-01	Gas4-W1	6.4	6.5	2,823	94	311	22,919	ND	92	14	56
1412041-02	Gas4-W2	5.9	6.8	2,713	159	413	22,850	ND	77	18	64
1412041-03	Gas4-W3	6.4	8.1	3,282	85	599	25,279	ND	65	25	63
1412041-04	Gas4-W4	6.3	7.5	3,174	95	313	24,772	ND	80	21	53
1412041-05	Gas4-W5	5.9	11.8	2,969	332	447	26,088	ND	76	17	61
1412041-06	Diesel2-W1	7.4	6.3	3,558	101	426	25,439	ND	40	19	49
1412041-07	Diesel2-W2	7.5	4.5	3,322	79	418	25,458	ND	32	21	41.1
1412041-08	Diesel2-W3	3.8	12.4	3,225	109	600	23,702	ND	50	22	80
1412041-09	Diesel2-W4	6.8	16.6	3,241	133	511	25,473	ND	70	21	104
1412041-10	HOil2-W1	5.1	3.2	1,694	191	301	17,604	ND	62	14	38.8
1412041-11	HOil2-W2	8.9	7.4	3,098	74	365	28,938	ND	39	28	64
1412041-12	HOil2-W3	8.1	5.8	3,422	64	398	28,536	ND	39	27	69
1412041-13	HOil2-W4	8.9	5.5	2,567	60	336	27,440	ND	24	541	66
1412041-14	HOil2-W5	10.4	7.3	3,921	ND	306	30,430	ND	43	30	85
1412041-15	HOil3-W1	13.1	17.7	1,103	30	452	11,867	ND	29	23.2	45.4
1412041-16	HOil3-W2	10.0	39.9	564	ND	126	11,967	ND	12	17.5	63.4
1412041-17	HOil3-W2	8.8	59.7	505	ND	78	8,285	ND	15	14.5	54.7
1412041-18	HOil3-W3	18.3	41.5	463	ND	39	9,960	ND	ND	9.5	98
1412041-19	HOil3-W4	40.7	50.9	322	ND	56	17,282	ND	24	20.3	101
1412041-20	HOil3-W5	ND	395	ND	ND	ND	8,263	ND	ND	20.4	51
1412041-21	HOil4-W1	10.1	36.4	1,457	201	177	14,963	ND	41	19	75

Sample ID	Study Specific ID	As	Pb	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn
+/- range	range for specific samples[a]	0.8 - 1.9	1 - 4	59 - 221	10 - 22	7 - 21	0.10 - 176	-	3 - 5	1.7 - 8	1.6 - 3
1412041-22	HOil4-W2	16.9	109.4	ND	ND	247	6,415	ND	ND	22.1	94
1412041-23	HOil4-W3	11.7	23.6	1,683	145	169	19,584	ND	41	10.9	58.1
1412041-24	HOil4-W4	26.6	141	721	ND	150	12,513	ND	19	27	209
1412041-25	HOil4-W5	4.6	9.0	1,215	ND	224	11,110	ND	26	6.5	39

Table C-2. XRF Results (Continued).

Sample ID	Study Specific ID	Se	Rb	Sr	Zr	Mo	Ag	Cd	Sn	Sb	Ba	Hg
+/- range	range for specific samples[a]	0.5	0.4 - 1.4	0.6 - 13	0.5 - 6	0.4 - 0.7	-	-	5	4 - 7	58 - 121	1.2 - 1.5
1409070-01	Gas1E1_DP50		89.5	282	255						544	
1409070-02	Gas1E2_DP50		114.4	384	178						647	
1409070-03	Gas1E3_DP52	1.6	79.7	315	114.7						483	
1409070-04	Diesel1-W1	ND	33.9	456	167	ND	ND	ND	ND	ND	674	ND
1409070-05	Diesel1-W2	ND	24.7	433	248	ND	ND	ND	ND	ND	775	ND
1409070-06	Diesel1-W3	ND	29.1	416	190	ND	ND	ND	ND	ND	707	4.0
1409070-07	Diesel1-W4	ND	18.7	416	163	ND	ND	ND	ND	ND	628	ND
1409070-08	Diesel1-W5	ND	24.4	424	227	ND	ND	ND	ND	ND	682	ND
1409070-09	Diesel1-W1	ND	36	472	204	2.2	ND	ND	ND	ND	650	ND
1410045-01	Gas1-W1	ND	31	473	183	ND	ND	ND	ND	ND	649	ND
1410045-02	Gas1-W2	ND	26.8	380	176	ND	ND	ND	ND	ND	628	ND
1410045-03	Gas1-W3	ND	26	420	186	ND	ND	ND	ND	ND	692	ND
1410045-04	Gas1-W4	ND	31.2	468	189	ND	ND	ND	ND	ND	705	ND
1410045-05	Gas1-W5	ND	21.7	1,471	596	ND	ND	ND	ND	ND	1,555	7.5
1411036-01	Gas2-W1-2-3	ND	23.8	227	180	ND	ND	ND	ND	ND	488	3.8
1411036-02	Gas2-W1-2-3	ND	20.1	294	137	ND	ND	ND	ND	ND	667	4.5
1411036-03	Gas2-W1-2-3	ND	54.9	363	191	ND	ND	ND	ND	ND	628	4.5
1411036-04	Gas2-W4-5	ND	19.9	278	127	ND	ND	ND	ND	ND	521	ND
1411036-05	Gas2-W4-5	ND	24.4	280	181	ND	ND	ND	ND	ND	604	ND
1411036-06	HOil1-W1	ND	18.2	221	98.2	2.9	ND	ND	ND	ND	356	ND
1411036-07	HOil1-W2	ND	20.7	221	126.2	ND	ND	ND	ND	ND	523	ND
1411036-08	HOil1-W3	ND	23.3	237	144	ND	ND	ND	ND	ND	553	4.5
1411036-09	HOil1-W4	ND	24.4	247	120	ND	ND	ND	ND	23	549	4.6
1411036-10	HOil1-W5	ND	22	243	111.3	ND	ND	ND	ND	ND	400	ND

Sample ID	Study Specific ID	Se	Rb	Sr	Zr	Mo	Ag	Cd	Sn	Sb	Ba	Hg
+/- range	range for specific samples[a]	0.5	0.4 - 1.4	0.6 - 13	0.5 - 6	0.4 - 0.7	-	-	5	4 - 7	58 - 121	1.2 - 1.5
1411036-11	Gas3-W1	ND	23	257	179	ND	ND	ND	ND	ND	429	ND
1411036-12	Gas3-W2	ND	42.1	246	222	ND	ND	ND	ND	ND	463	4.2
1411036-13	Gas3-W3	ND	28	292	157	ND	ND	ND	ND	ND	419	ND
1411036-14	Gas3-W4	ND	24.2	303	137	ND	ND	ND	ND	ND	288	ND
1411036-15	Gas3-W5	ND	27	294	167	ND	ND	ND	ND	ND	798	ND
1412041-01	Gas4-W1	ND	22.8	287	152	ND	ND	ND	ND	ND	587	ND
1412041-02	Gas4-W2	ND	21.8	239	99	ND	ND	ND	ND	ND	414	4.7
1412041-03	Gas4-W3	ND	20.4	259	113.6	ND	ND	ND	ND	ND	509	ND
1412041-04	Gas4-W4	ND	25.7	295	135	ND	ND	ND	ND	ND	691	ND
1412041-05	Gas4-W5	ND	21.9	272	113.4	ND	ND	ND	ND	ND	535	ND
1412041-06	Diesel2-W1	ND	26.1	207	135	ND	ND	ND	ND	ND	578	ND
1412041-07	Diesel2-W2	ND	26	208	127	ND	ND	ND	ND	ND	586	ND
1412041-08	Diesel2-W3	ND	24.3	224	125	ND	ND	ND	ND	ND	523	ND
1412041-09	Diesel2-W4	ND	26	265	131	ND	ND	ND	ND	ND	653	ND
1412041-10	HOil2-W1	ND	20.8	213	66.3	ND	ND	ND	ND	ND	466	ND
1412041-11	HOil2-W2	ND	27.5	180	109.7	ND	ND	ND	ND	ND	444	ND
1412041-12	HOil2-W3	ND	26.1	204	110	ND	ND	ND	ND	ND	614	ND
1412041-13	HOil2-W4	ND	26.9	158	98.9	ND	ND	ND	ND	ND	393	ND
1412041-14	HOil2-W5	ND	32.7	229	140	ND	ND	ND	ND	ND	672	ND
1412041-15	HOil3-W1	ND	13.8	162.5	83.1	ND	ND	ND	ND	ND	ND	ND
1412041-16	HOil3-W2	ND	11	132.9	58.3	ND	ND	ND	ND	ND	ND	ND
1412041-17	HOil3-W2	ND	10.6	121.3	51.6	ND	ND	ND	ND	ND	ND	ND
1412041-18	HOil3-W3	ND	6.3	74.6	50.7	1.3	ND	ND	ND	ND	ND	ND
1412041-19	HOil3-W4	ND	9.8	127.1	49	ND	ND	ND	ND	ND	ND	ND
1412041-20	HOil3-W5	ND	3.3	24.7	8.0	ND	ND	ND	ND	16	ND	ND
1412041-21	HOil4-W1	ND	15.9	189	129.7	ND	ND	ND	26	ND	358	ND

Sample ID	Study Specific ID	Se	Rb	Sr	Zr	Mo	Ag	Cd	Sn	Sb	Ba	Hg
+/- range	range for specific samples[a]	0.5	0.4 - 1.4	0.6 - 13	0.5 - 6	0.4 - 0.7	-	-	5	4 - 7	58 - 121	1.2 - 1.5
1412041-22	HOil4-W2	ND	3.8	70.6	13.9	ND	ND	ND	ND	ND	ND	ND
1412041-23	HOil4-W3	ND	18.6	182.8	110.3	ND	ND	ND	ND	ND	246	ND
1412041-24	HOil4-W4	ND	9.8	146.2	67.7	ND	ND	ND	18	21	ND	ND
1412041-25	HOil4-W5	ND	17.6	212	68	ND	ND	ND	ND	ND	256	ND

[a] Values for accuracy are for individual results but listed here as a range to show variability in the results.

Table C-3. Element Screening Levels and References.

Benchmark	Reference	As	Pb	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn	Se
Natural (ppm)	San Juan (1994)[a]	7	17	-	42	1,100	42,100	-	38	36	86	-
	Ames and Prych (1995)[b]	6.8	12	-	51	680	4.2%[c]	-	34	31	80	<5.0
	Ames and Prych (1995)[d]	13	18	1.2%[c]	190	1,320	7.9%[c]	-	74	56	140	1
Area-Wide (ppm)	Area-Wide Soil Contamination Task Force (2003)[e]	100	500-700	-	-	-	-	-	-	-	-	-
MTCA Cleanup Levels (ppm)	70.105D RCW3 (Method A)[f]	20	250	-	19 | 2000[g]	-	-	-	-	-	-	-
	70.105D RCW3 (Method B Non Cancer)[h]	24	-	-	240 | 120,000[g]	11,200	56,000	-	-	3,200	24,000	400
Ecological Indicator Soil Concentrations for Plant, Soil Biota, and Wildlife (ppm)	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[i]	10	50	-	42	1100	-	20	30	100	86	1
	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[j]	60	500	-	42	-	-	-	200	50	200	70
	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[k]	132	118	-	67	1500	-	-	980	217	360	0.3
Toxicity Reference Value (ppm-d)	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[l]	1.16 | 0.06	0.69 | 0.0047	-	0.49	0.29	-	-	0.78 | 0.047	0.88 | 0.020	3.19 | 0.095	10.5 | 0.0065

Screening Level	Reference	Se	Rb	Sr	Zr	Mo	Ag	Cd	Sn	Sb	Ba	Hg
Natural (ppm)	San Juan (1994)[a]	-	-	-	-	-	-	1	-	-	-	0.07
	Ames and Prych (1995)[b]	<5.0	-	-	-	-	0.3	<0.2	-	<3.0	-	0.06
	Ames and Prych (1995)[d]	1	-	370	-	<2	<2.0	<2.3	<5	3.8	760	0.4
Area-Wide (ppm)	Area-Wide Soil Contamination Task Force (2003)[e]	-	-	-	-	-	-	-	-	-	-	-
MTCA Cleanup Levels (ppm)	70.105D RCW3 (Method A)[f]	-	-	-	-	-	-	2	-	-	-	2
	70.105D RCW3 (Method B Non Cancer)[h]	400	-	48,000	-	400	400	80	480,000	32	16,000	-
Ecological Indicator Soil Concentrations for Plant, Soil Biota, and Wildlife (ppm)	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[i]	1	-	-	-	2	2	4	50	5	500	0.3
	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[j]	70	-	-	-	-	-	20	-	-	-	0.1
	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[k]	0.3	-	-	-	7	-	14	-	-	102	5.5
Toxicity Reference Value (ppm-d)	Toxic Cleanup Program's Policy & Technical Support Unit (1996)[l]	10.5 | 0.0065	-	-	-	0.48 | 1.01	-	4.6 | 0.14	-	-	0.36	1.32 | 0.0854

[a] Natural background concentration based on 90th percentile. Total recoverable method (EPA Method 3050, Acid Digestion of Sediments, Sludges, and Soils).
[b] Natural background concentration based on 90th percentile using total recoverable method.
[c] 10,000 mg/kg = 1%.
[d] Natural background concentration based on 90th percentile using total method.
Smelter areas & orchards had As and Pb over 3000 & 4000 ppm.
[f] Method A Soil Cleanup Levels for Unrestricted Land Uses.
[g] Values are for Chromium VI | Chromium III.
[h] Cleanup Levels and Risk Calculation values for Method B non-carcinogenic effects.
[i] Values are expected protective concentrations for Plant- see p 275.
[j] Values are expected protective concentrations for Soil Biota- see p 275.
[k] Values are expected protective concentrations for Wildlife- see p 275.
[l] Values for BAFworm | Kplant. See p 278.

References for Appendix C

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Appendix D. Data Quality

Analyses

NWTPH, VPH, and EPH

Laboratories included quality control (QC) procedures prescribed in the methods for calibration, precision and bias to assess the quality of the data produced. If QC results were outside limits, additional and corrective actions were taken or the result was flagged (qualified). Most results were without incident.

In general, the issues for NWTPH analyses included interference from high concentrations or other compounds of petroleum found within the sample. These included, for example, co-elution of compounds associated with heavy oil effectively raising the reporting limit for the NWTPH-Gx results or the weathered portion of gas causing interference during the NWTPH-Dx analysis. The main concerns for the NWTPH are outlined here.

NWTPH-Gx

- Many gasoline values reflect the solvent dilution due to water in the sample.

- Surrogate: surrogate percent recoveries biased high due to interference for samples 1412041-07, 1412041-10. No qualification of data was deemed necessary.

- Surrogate: surrogate percent recoveries biased high due to interference from the early diesel compounds for sample 1411036-08. No qualification of data was deemed necessary.

- Comments:
    - Samples 1412041-10 -11, -13, -14, -16 through -20, -23, -25 and duplicates showed the early eluting compounds associated with a Bunker-C heavy fuel oil. These compounds effectively raised the reporting limits for gasoline due to co-elution problems. This required that the amounts be qualified “U”.
    - Very weathered gasoline detected in samples 1411036-01 through -05.

NWTPH-Dx

- Surrogates:
    - Surrogate percent recoveries biased high due to interference for samples 1412041-22 and -24. No qualification was deemed necessary.
    - Surrogate percent recoveries diluted out due to high concentrations of target analytes for samples 1412041-20 and -23. No qualification was deemed necessary.

- LCS: percent recoveries and RPDs were biased high from interference for 1412041-09. No action deemed necessary because the LCS was within acceptable range for associated samples 1409070-04 through 1409070-09.

- LCS: a large dilution in sample 1412041-10 caused the loss of the surrogate. No action deemed necessary.

- Comments:
    - The late eluting portion of the weathered gasoline in 1411041-01 through -05 provided a positive interference for diesel. The quantitated amount was qualified with a "U" effectively raising the reporting limits.
    - Samples 1412041-06 and -08 had both gasoline and diesel present so there was some positive contribution of gasoline components to the diesel's reported value.
    - Samples 1410045-01 through -05: It was suspected that the lube oil reported in sample 1410045-05 may actually be the lube oil fraction of asphalt, given the extremely dark color of the extract for that sample. This may also be true for samples 1410045-01 through -04 but this cannot be confirmed via the analysis that was performed.

VPH

VPH results for samples 1409070-01 through -03 were possibly biased low because the vials containing the sample soil were overfilled. Several samples were reported with two sets of results because they had been re-analyzed due to calibration or surrogates being outside limits. To determine which result to use for VPH re-analyzed samples, results were compared between the first and second (re-analysis) and the reason for re-analysis was access. Which set of VPH results used are described for:

- Samples 1409070-02 and 1409070-04: first analysis results were used since both analyses had detected results nearly the same (RPDs < 21% except for one fraction at 54%) even though the first had a low percent surrogate recovery. Furthermore, there were more results detected because of lower reporting limits in the first (undiluted) sample.

- Sample 1412041-15 through 1412041-18: second analysis results were used since the second sample had control calibration (CCAL) within limits and used a smaller dilution than the first resulting in lower reporting limits and more analytes and fractions detected.

- Sample 1412041-19: second analysis results were used since the second sample had control calibration (CCAL) within limits. Reporting limits, analytes, and fractions detected were the same.

- Sample 1412041-23: first analysis results used since both analyses had results nearly the same (RPDs < 5% except for one fraction at 73%) even though in the first analysis 1,3,5-trimethylbenzene was high for CCAL. Furthermore, the reporting limits were lower in the first analysis resulting in more analytes and fractions detected.

EPH

A few samples were qualified “B” by the laboratory and changed to “J” (result is an estimate) by Ecology for C8-C10 aliphatic fractions results less than five times that found in a blank during EPH analysis. These samples include 1409070-05 through 1409070-08 and 1410045-01 through 1410045-03, and 1410045-05. No other samples or fractions were affected.

Other quality assurance (QA) issues for VPH and EPH were resolved through additional reanalysis or had other acceptable QC results within limits so no corrective actions were taken and one set of results were reported.

From this assessment, these results described above are accepted as valid.

TOC and Solids

There were no concerns for TOC or Solid analyses or results.

Bioassay and Bioaccumulation Tests

Laboratory precision and organism sensitivity tests were performed prior to the bioassay and bioaccumulation tests using a reference toxicant (Potassium chloride [KCL]). Test results (4.29 mg/kg) were within the control chart limits (2.0 – 7.6 mg/kg) for LC_{25} for earthworms and 49.3 mg/kg LC_{25} for lettuce within the control chart limits of 27.2 – 72.3 mg/kg. These results demonstrate acceptable laboratory performance for precision and test organism sensitivity.

In recognition that Ecology’s methods specify different reference toxicants than those used above; additional reference tests were conducted. Result showed LC_{25} for earthworms using 2-chloroacetamide at >77.0 mg/kg and for lettuce survival, wet weight, and dry weight using boric acid at >640 mg/kg. Control chart limits are not available.

Bioassay Tests

During test preparation of the soil samples, the laboratory noted the samples were saturated (standing water) when strict adherence to the protocol requirement of Ecology for hydrating soil samples between 35% and 45% of the bulk soil weight. The hydration was modified to follow the visual comparison to the 45% hydrated laboratory control soil process outlined in the last paragraph of page 8 of Ecology’s 96-327 method. This complies with the method for “achieving a comparable friable condition" (Norton, 1996b). The laboratory added Milli-Q equivalent water to the control soil at a rate of 45 ml water per 100 g (dry weight) of soil to achieve 45% hydration as outlined in the earthworm protocol.

Several samples (1412041-16 through 1412041-20, 1412041-22, and 1412041-24) had percent hydration levels above the 45% level required in the earthworm protocol. No attempt to dry out samples was made. But to access the impact of this excessive moisture on earthworms, an additional control sample was prepared by hydrating to match the appearance of the wettest sample noted. The saturated control showed no statistically significant difference in survival or

normal morphology (both had 100% normal morphology and 97% survival) when compared to the 45% hydrated control.

Five soil samples (1409070-04 through 1409070-06, 1410045-02, and 1410045-04) had pH below the lower end of the preferred range of pH 5.0 – 9.0 for earthworms and pH 5.0 – 10.0 for plants. Additional aliquots of these samples were prepared and pH adjusted using calcium carbonate for comparison. Sample 1409070-09 was just under pH 5.0 but was not included in this comparison. One termination pH value of pH 4.9 was reported in sample 1410045-03.

Generally, there was little difference between original and pH adjusted samples for earthworm and lettuce 14-day bioassay tests. Exceptions included one earthworm test (sample 1409070-04) having 0% survival for the original sample and 7% survival for the pH adjusted sample. The differences found in this sample (1409070-04) did not affect results overall because both results (original and pH adjusted) were already significantly reduced compared to the control ($p=0.05$). All other end point results were not significant at $p < 0.05$ using Equal Variance *t* Two-Sample test to compare the original and the pH adjusted samples.

Two separate incubators were utilized during the lettuce seedling tests. Each incubator had a laboratory control associated with it and were set up similarly. An evaluation of the two controls showed no statistical significant difference in the survival or wet weight endpoints, but did show a reduction in the dry weight endpoint in Incubator #9 control compared to the Incubator #11 control. Again, overall, effects from the contamination in the test soil compared with control samples dominated results rather than between incubators.

Sample 1410045-04 original and pH adjusted samples were performed in differing incubators. Results showed no difference in survival but some difference in survival weight: Incubator #9 with pH adjusted had 92% survival, 24.1 wet and 1.91 dry mg/seedling survival compared to Incubator #11 with the original had 92% survival, 10.7 wet and 1.01 dry mg/seedling survival.

Both the earthworm and lettuce bioassays met test acceptability criteria of a minimum 90% control germination for each of the controls. The tests proceeded without any other noted deviations or interruptions that could have affected test results and those referenced above have evidence as to no effect. Therefore, the tests results should be considered “valid”.

Bioaccumulation Tests

The bioaccumulation tests were prepared and initiated without incident. Initial and terminal pH values were all within acceptable range between pH 5.0 – 9.0. During the testing, a number of earthworms were observed outside but near the bottom of the testing chambers. These were collected and replaced into the testing chambers and chambers were reinforced to prevent further escapes. This event confounded results at the termination of the tests. The control sample resulted in 88.8% survival (11.2% mortality), which is just under the maximum allowed rate of 10% mortality. It is possible that not all the worms were recaptured. As few as four additional worms found inside the test chamber would have made the survival limits (mortality 9.9%) acceptable, but these and maybe more may have escaped recapture.

Because of the uncertainty the escaped earthworms created, the laboratory recommended the survival and growth test results should be interpreted cautiously and these endpoints should be considered “conditionally acceptable”. But for this study, these results are not valid.

Results from the tissue collected for bioaccumulation analysis for gas and diesel concentrations should not have been affected and should be considered “valid” because no contamination was found in the tissue sample collected before the test began (day zero sample).

Data Quality Results and MQOs

Data quality was assessed by the measurement quality objectives (MQO) outlined in the Quality Assurance Project Plan (Sandvik, 2014). Project objectives and quality assurance results are shown in the tables below.

Table D-1. Laboratory Blanks.

Analyte	Matrix	QC Result	Qualifier
Gasoline (mg/kg dw)	Soil	3.2—7.0	all U
2 Diesel (mg/kg dw)	Soil	5.0—15	all U
Lube Oil (mg/kg dw)	Soil	13—38	all U
Heavy Fuel Oil (mg/kg dw)	Soil	all 14	all U
EPH	Soil	all 2,000	most[a] U
VPH Varied Analytes (µg/kg dw)	Soil	450—1,800	all U
VPH Carbon Ranges (µg/kg dw)	Soil	4,500—9,000	all U
VPH Trip Blanks (µg/kg dw)	Soil	varied	all U
Solids (MEL) (%)	Soil	all 0.001	all U
TOC (%)	Soil	all 0.1	all U
Gasoline (mg/kg ww)	Tissue	3.4—6.7	all U
2 Diesel (mg/kg ww)	Tissue	15	all U
Lipids (%)	Tissue	0.1	all U

[a] Affected results from samples 1409070-04 through 1409070-08 and samples 1410045-01 through 1410045-03 and 1410045-05 were qualified "J" because they were less than five times concentration found in the Method Blank for EPH C8 - C10 aliphatic.

ARI=Analytical Resources, Incorporated
EPH=Extractable Petroleum Hydrocarbons
MEL=Manchester Environmental Laboratory
MQO=Measurement Quality Objectives
QC=Quality Control
TOC=Total Organic Carbon
U=not detected
VPH=Volatile Petroleum Hydrocarbons

Table D-2. Laboratory Duplicates.

Analyte	Matrix	Sample ID	MQO (RPD %)	Sample Result	Sample Qualifier	Duplicate Result	Duplicate Qualifier	RPD (%)
Gasoline (mg/kg dw)	Soil	1409070-04	50	730	U	700	U	4
Gasoline (mg/kg dw)	Soil	1412041-16	50	77	U	67	U	14
Gasoline (mg/kg dw)	Soil	1412041-17	50	44	U	63	U	35
Gasoline (mg/kg dw)	Soil	1504063-02	50	140		220		45
Gasoline (mg/kg dw)	Soil	1504063-04	50	13	U	12	U	NC
Gasoline (mg/kg dw)	Soil	1504063-08	50	4.5		4.6		2
Diesel (mg/kg dw)	Soil	1409070-04	50	4,400		5,200		18
Diesel (mg/kg dw)	Soil	1412041-16	50	1,600	U	1,800	U	8
Diesel (mg/kg dw)	Soil	1412041-17	50	1,000	U	1,300	U	23
Diesel (mg/kg dw)	Soil	1504063-01	50	2,000		2,100		5
Diesel (mg/kg dw)	Soil	1504063-07	50	270		350		26
Lube Oil (mg/kg dw)	Soil	1409070-04	50	150	U	150	U	NC
Lube Oil (mg/kg dw)	Soil	1412041-16	50	12,000	U	12,000	U	7
Lube Oil (mg/kg dw)	Soil	1412041-17	50	7,400	U	8,200	U	10
Lube Oil (mg/kg dw)	Soil	1504063-01	50	230	U	240	U	NC
Lube Oil (mg/kg dw)	Soil	1504063-07	50	30	U	30	U	NC
Heavy Fuel Oil (mg/kg dw)	Soil	1409070-04	50	15	U	15	U	NC

Analyte	Matrix	Sample ID	MQO (RPD %)	Sample Result	Sample Qualifier	Duplicate Result	Duplicate Qualifier	RPD (%)
Heavy Fuel Oil (mg/kg dw)	Soil	1412041-16	50	38,000		35,000		7
Heavy Fuel Oil (mg/kg dw)	Soil	1412041-17	50	22,000		26,000		15
Solids (MEL) (%)	Soil	1409070-01	20	90.5		90		0.6
Solids (MEL) (%)	Soil	1409070-07	20	84.8		86.7		2
Solids (MEL) (%)	Soil	1409070-09	20	84.6		84		0.7
Solids (MEL) (%)	Soil	1410045-03	20	88.8		88.2		0.7
Solids (MEL) (%)	Soil	1411036-11	20	88.2		88.3		0.2
Solids (MEL) (%)	Soil	1411036-08	20	92.8		92.8		0.02
Solids (MEL) (%)	Soil	1412041-04	20	87.3		87.4		0.1
Solids (MEL) (%)	Soil	1412041-15	20	70		64.7		8
Solids (MEL) (%)	Soil	1412041-25	20	67.1		66.3		1
Solids (MEL) (%)	Soil	1504063-01	20	80		79		1
TOC (%)	Soil	1409070-04	20	0.28		0.276		2
TOC (%)	Soil	1409070-04	20	0.28		0.224		23
TOC (%)	Soil	1412041-16	20	4.65		4.67		0.3
TOC (%)	Soil	1412041-16	20	4.65		4.65		0.06
TOC (%)	Soil	1412041-17	20	6.45		5.98		7
TOC (%)	Soil	1412041-17	20	6.45		6.5		0.8
Gasoline (mg/kg ww)	Tissue	1504063-05	50	6.8	U	6.8	U	NC
Gasoline (mg/kg ww)	Tissue	1506056-02	50	3.2	U	3.2	U	NC
2 Diesel (mg/kg ww)	Tissue	1506056-04	50	160		220		37
Lipids (%)	Tissue	1506056-03	20	0.4	U	0.4	U	0

MEL=Manchester Environmental Laboratory
MQO=Measurement Quality Objectives
TOC=Total Organic Carbon

Table D-3. Field Replicates.

Analyte	Matrix	Sample ID	Replicate Sample ID	Sample Result	Sample Qualifier	Replicate Result	Replicate Qualifier	RPD (%)
Gasoline (mg/kg dw)	Soil	1409070-04	1409070-09	730	U	1,100	U	40
	Soil	1412040-17	1412041-16	44	U	77	U	54
Diesel (mg/kg dw)	Soil	1409070-04	1409070-09	4,400		3,900		12
	Soil	1412040-17	1412041-16	1,000	U	1,600	U	46
Lube Oil (mg/kg dw)	Soil	1409070-04	1409070-09	150	U	150	U	0
Lube Oil (mg/kg dw)	Soil	1412040-17	1412041-16	7,400	U	12,000	U	47
Heavy Fuel Oil (mg/kg dw)	Soil	1409070-04	1409070-09	15	U	15	U	0
Heavy Fuel Oil (mg/kg dw)	Soil	1412040-17	1412041-16	22,000		38,000		53
EPH	Soil	1409070-04	1409070-09					
EPH	Soil	1412040-17	1412041-16					
VPH	Soil	1409070-04	1409070-09					
VPH	Soil	1412040-17	1412041-16					
Solids (MEL) (%)	Soil	1409070-04	1409070-09	84.8		84.6		0.2
Solids (MEL) (%)	Soil	1412040-17	1412041-16	62.8		64.6		3
Solids (ARI) (%)	Soil	1409070-04	1409070-09					
Solids (ARI) (%)	Soil	1412040-17	1412041-16					
TOC (%)	Soil	1409070-04	1409070-09	0.28		0.15		60
TOC (%)	Soil	1412040-17	1412041-16	6.45		4.65		32

ARI=Analytical Resources, Incorporated
EPH=Extractable Petroleum Hydrocarbons
MEL=Manchester Environmental Laboratory
TOC=Total Organic Carbon
VPH=Volatile Petroleum Hydrocarbons

Table D-4. Laboratory Control Standards.

Lab	Analyte	Matrix	MQO (% REC)	MQO (% RPD)	Number of LCS Samples	Spike Level (mg/kg)	DUP Flag	QC Result (mg/kg)	REC (%)	RPD (%)
MEL	Gasoline	Soil	70 - 130	50	9	0.64 - 1.4		0.6 - 1.4	92 - 113	
							Dup	0.6 - 1.3	90 - 103	0.7 - 9
		Tissue	70 - 130	50	5	0.329 - 69.6		0.4 - 67	85 - 119	
							Dup	0.3 - 66	86 - 102	2 - 15
	Diesel	Soil	70 - 130	40	7	100 - 300		106 - 357	106 - 119	
							Dup	107 - 405	107 - 135	2 - 16
		Tissue	70 - 130	40	3	300		287 - 302	96 - 101	
							Dup	244 - 285	81 - 95	4 - 16
ARI - EPH	C8 - C10 Aliphatics	Soil	30 - 120	30	9	75		34.0 - 100	45.3 - 133	
							Dup	30.0 - 124	40.0 - 165	1.7 - 37.2
	C10 - C12 Aliphatics	Soil	31 - 120	30	9	75		33.0 - 50.0	44.7 - 64.0	
							Dup	33.0 - 50.0	44.0 - 64.0	0.0 - 14.1
	C12 - C16 Aliphatics	Soil	48 - 120	30	9	75		42.0 - 83.0	56.0 - 111	
							Dup	44.0 - 76.0	58.7 - 101	1.7 - 33.3
	C16 - C21 Aliphatics	Soil	58 - 120	30	9	75		51.0 - 70.0	68.0 - 93.3	
							Dup	56.0 - 69.0	74.7 - 103	1.8 - 12.4
	C21 - C34 Aliphatics	Soil	30 - 160	30	9	75		35.0 - 51.0	46.7 - 68.0	
							Dup	37.0 - 57.0	49.3 - 76.0	0.0 - 11.1
	C10 - C12 Aromatics	Soil	26 - 120	30	9	75		31.0 - 45.0	41.3 - 60.0	
							Dup	29.0 - 46.0	38.7 - 61.3	0.0 - 21.6
	C12 - C16 Aromatics	Soil	35 - 120	30	9	75		37.0 - 63.0	49.3 - 84.0	
							Dup	36.0 - 63.0	48.0 - 84.0	0.0 - 16.5
	C16 - C21 Aromatics	Soil	33 - 121	30	9	150		105 - 133	70.0 - 88.7	
							Dup	96.0 - 126	64.0 - 84.0	2.5 - 16.3
	C21 - C34 Aromatics	Soil	55 - 120	30	9	150		90.0 - 130	60.0 - 86.7	
							Dup	72.0 - 127	48.0 - 84.7	2.1 - 31.1
ARI - VPH	Benzene	Soil	70 - 130	30	11	18 - 36		19.0 - 39.4	80.0 - 109	
							Dup	15.8 - 39.1	87.8 - 109	0.0 - 30.3
	Toluene	Soil	70 - 130	30	11	18 - 36		19.4 - 38.7	81.4 - 108	
							Dup	16.0 - 39.1	88.9 - 109	0.6 - 29.7
	Ethylbenzene	Soil	70 - 130	30	11	18 - 36		19.4 - 38.5	85.6 - 108	
							Dup	16.6 - 40.5	93.6 - 112	0.0 - 27.2
	m, p-Xylene	Soil	70 - 130	30	11	36 - 71.9		37.8 - 76.9	81.6 - 107	
							Dup	32.4 - 76.7	83.3 - 107	1.5 - 26.6
	o-Xylene	Soil	70 - 130	30	11	18 - 36		19.4 - 38.0	80.0 - 108	
							Dup	15.9 - 37.6	88.3 - 104	0.6 - 24.7

Lab	Analyte	Matrix	MQO (% REC)	MQO (% RPD)	Number of LCS Samples	Spike Level (mg/kg)	DUP Flag	QC Result (mg/kg)	REC (%)	RPD (%)
	Methyl tert-butyl Ether	Soil	70 - 130	30	11	18 - 36		18.4 - 38.2	71.1 - 106	
							Dup	16.3 - 40.5	68.9 - 112	0.0 - 30.0
	Naphthalene	Soil	70 - 130	30	11	18 - 36		19.2 - 41.0	87.5 - 114	
							Dup	17.8 - 42.3	83.6 - 118	3.7 - 30.7
	1, 2, 3-Trimethyl-benzene	Soil	70 - 130	30	11	18 - 36		19.5 - 39.4	58.6 - 109	
							Dup	15.6 - 40.7	66.9 - 113	3.9 - 22.7
	1-Methyl-naphthalene	Soil	70 - 130	30	11	18 - 36		19.1 - 45.7	91.1 - 127	
							Dup	15.8 - 45.0	87.8 - 125	1.5 - 20.7
	n-Pentane	Soil	70 - 130	30	11	18 - 36		21.8 - 52.6	79.4 - 146	
							Dup	19.3 - 49.3	78.1 - 137	1.0 - 28.6
	n-Hexane	Soil	70 - 130	30	11	18 - 36		19.4 - 43.6	76.4 - 121	
							Dup	16.7 - 40.7	85.6 - 113	0.0 - 28.7
	n-Octane	Soil	70 - 130	30	11	18 - 36		19.3 - 41.0	76.1 - 114	
							Dup	17.0 - 37.1	85.0 - 103	0.0 - 25.8
	n-Decane	Soil	70 - 130	30	11	18 - 36		17.5 - 37.8	71.4 - 105	
							Dup	16.0 - 34.2	83.6 - 96.4	0.0 - 29.8
	n-Dodecane	Soil	70 - 130	30	11	18 - 36		20.3 - 43.7	83.6 - 121	
							Dup	18.3 - 43.2	96.4 - 120	0.5 - 28.6

ARI=Analytical Resources, Incorporated
DUP=Duplicate
EPH=Extractable Petroleum Hydrocarbons
MEL=Manchester Environmental Laboratory
MQO=Measurement Quality Objectives
QC=Quality Control
REC=Recovery
RPD=Relative Percent Difference
TOC=Total Organic Carbon
VPH=Volatile Petroleum Hydrocarbons

Table D-5. Matrix Spikes.

Sample ID	Analyte (EPH)	Matrix	MQO (% REC)	MQO (% RPD)	Spike Level MS/MSD (mg/kg)	DUP Flag	QC Result (mg/kg)	REC (%)	RPD (%)
1412041-16	C8 - C10 Aliphatics	Soil	30 - 120	30	586/586		258	44	
						Dup	172	29.4	40
	C10 - C12 Aliphatics	Soil	31 - 120	30	586/586		727	58.2	
						Dup	648	44.7	11.5
	C12 - C16 Aliphatics	Soil	48 - 120	30	586/586		5,450	NA	
						Dup	4,670	NA	15.4
	C16 - C21 Aliphatics	Soil	58 - 120	30	586/586		7,300	NA	
						Dup	7,070	NA	3.2
	C21 - C34 Aliphatics	Soil	30 - 160	30	586/586		13,800	NA	
						Dup	12,500	NA	9.9
	C10 - C12 Aromatics	Soil	26 - 120	30	586/586		492	84.0	
						Dup	484	82.6	1.6
	C12 - C16 Aromatics	Soil	35 - 120	30	586/586		3,330	NA	
						Dup	3,230	NA	3.0
	C16 - C21 Aromatics	Soil	33 - 121	30	1,170/1,170		28,800	NA	
						Dup	28,100	NA	2.5
	C21 - C34 Aromatics	Soil	55 - 120	30	1,170/1,170		69,600	NA	
						Dup	69,100	NA	0.7

Table D-5. Matrix Spikes (continued).

Sample ID	Analyte (EPH)	Matrix	MQO (% REC)	MQO (% RPD)	Spike Level MS/MSD (mg/kg)	DUP Flag	QC Result (mg/kg)	REC (%)	RPD (%)
1412041-17	C8 - C10 Aliphatics	Soil	30 - 120	30	591/577		268	45.3	
						Dup	238	41.2	11.9
	C10 - C12 Aliphatics	Soil	31 - 120	30	591/577		1,000	65.3	
						Dup	915	52.2	8.9
	C12 - C16 Aliphatics	Soil	48 - 120	30	591/577		6,530	NA	
						Dup	5,630	NA	14.8
	C16 - C21 Aliphatics	Soil	58 - 120	30	591/577		8,350	NA	
						Dup	6,860	NA	19.6
	C21 - C34 Aliphatics	Soil	30 - 160	30	591/577		16,500	NA	
						Dup	13,300	NA	21.5
	C10 - C12 Aromatics	Soil	26 - 120	30	591/577		551	93.2	
						Dup	477	82.7	14.4
	C12 - C16 Aromatics	Soil	35 - 120	30	591/577		6,750	NA	
						Dup	3,370	NA	10.7
	C16 - C21 Aromatics	Soil	33 - 121	30	1,180/1,150		30,500	NA	
						Dup	28,800	NA	5.7
	C21 - C34 Aromatics	Soil	55 - 120	30	1,180/1,150		75,000	NA	
						Dup	69,600	NA	7.5

Table D-5. Matrix Spikes (continued).

Sample ID	Analyte (VPH)	Matrix	MQO (% REC)	MQO (% RPD)	Spike Level MS/MSD (mg/kg)	DUP Flag	QC Result (mg/kg)	REC (%)	RPD (%)
1412041-16	Benzene	Soil	70 - 130	30	396/356		396	100	
						Dup	334	93.8	17.0
	Toluene	Soil	70 - 130	30	396/356		413	104	
						Dup	356	100	14.8
	Ethylbenzene	Soil	70 - 130	30	396/356		423	107	
						Dup	357	100	16.9
	m, p-Xylene	Soil	70 - 130	30	792/712		760	96.0	
						Dup	646	90.7	16.2
	o-Xylene	Soil	70 - 130	30	396/356		453	114	
						Dup	375	105	18.8
	Methyl tert-butyl Ether	Soil	70 - 130	30	396/356		427	108	
						Dup	359	101	17.3
	Naphthalene	Soil	70 - 130	30	396/356		396	100	
						Dup	338	94.9	15.8
	1, 2, 3-Trimethyl-benzene	Soil	70 - 130	30	396/356		376	94.9	
						Dup	318	89.3	16.7
	1-Methyl-naphthalene	Soil	70 - 130	30	396/356		540	136	
						Dup	422	119	24.5
	n-Pentane	Soil	70 - 130	30	396/356		437	110	
						Dup	318	89.3	31.5
	n-Hexane	Soil	70 - 130	30	396/356		370	93.4	
						Dup	302	84.8	20.2
	n-Octane	Soil	70 - 130	30	396/356		392	99.0	
						Dup	318	89.3	20.8
	n-Decane	Soil	70 - 130	30	396/356		441	111	
						Dup	379	106	15.1
	n-Dodecane	Soil	70 - 130	30	396/356		495	125	
						Dup	425	119	15.2

Table D-5. Matrix Spikes (continued).

Sample ID	Analyte (VPH)	Matrix	MQO (% REC)	MQO (% RPD)	Spike Level MS/MSD (mg/kg)	DUP Flag	QC Result (mg/kg)	REC (%)	RPD (%)
1412041-17	Benzene	Soil	70 - 130	30	382/382		372	97.4	
						Dup	360	94.2	3.3
	Toluene	Soil	70 - 130	30	382/382		385	101	
						Dup	383	100	0.5
	Ethylbenzene	Soil	70 - 130	30	382/382		395	103	
						Dup	389	102	1.5
	m, p-Xylene	Soil	70 - 130	30	763/763		702	92.0	
						Dup	698	91.5	0.6
	o-Xylene	Soil	70 - 130	30	382/382		418	109	
						Dup	401	105	4.2
	Methyl tert-butyl Ether	Soil	70 - 130	30	382/382		401	105	
						Dup	387	101	3.6
	Naphthalene	Soil	70 - 130	30	382/382		370	96.9	
						Dup	349	91.4	5.8
	1, 2, 3-Trimethyl-benzene	Soil	70 - 130	30	382/382		338	88.5	
						Dup	343	89.8	1.5
	1-Methyl-naphthalene	Soil	70 - 130	30	382/382		477	125	
						Dup	397	104	18.3
	n-Pentane	Soil	70 - 130	30	382/382		355	92.9	
						Dup	349	91.4	1.7
	n-Hexane	Soil	70 - 130	30	382/382		336	88.0	
						Dup	334	87.4	0.6
	n-Octane	Soil	70 - 130	30	382/382		343	89.8	
						Dup	341	89.3	0.6
	n-Decane	Soil	70 - 130	30	382/382		420	110	
						Dup	406	106	3.4
	n-Dodecane	Soil	70 - 130	30	382/382		469	123	
						Dup	481	126	2.5

ARI=Analytical Resources, Incorporated
DUP=Duplicate
EPH=Extractable Petroleum Hydrocarbons
MQO=Measurement Quality Objectives
NA=No recovery due to high concentration of analyte in original sample and/or calculated negative recovery
QC=Quality Control
REC=Recovery
RPD=Relative Percent Difference: calculated using sample concentrations per SW846.
VPH=Volatile Petroleum Hydrocarbons

Table D-6. Standard Reference Material.

Analyte	Matrix	SRM Value	QC Result	MQO (% REC)	REC (%)
TOC	Soil	2.99	3.05	75 - 125	102
TOC	Soil	2.99	3.12	75 - 125	104
TOC	Soil	2.99	3.09	75 - 125	103

MQO=Measurement Quality Objectives
QC=Quality Control
REC=Recovery
SRM=Standard Reference Material
TOC=Total Organic Carbon

Appendix E. Total Organic Carbon, Solids, and Grain Size Data

Table E-1. Total Organic Carbon, solids, and grain size data.

Sample ID	Total Organic Carbon					Solids			Predominant Soil Characteristics	
	Result (%)	TOC RL	TOC RL Type	TOC DL	TOC DL Type	Results (%)	Solids RL	Solids RL Type	USCS Soil Name	USCS Soil Code
1409070-01	0.1 U	0.1	MRL	0.03	MDL	90.5	0.001	MRL	Silty sand	SM
1409070-02	0.21	0.1	MRL	0.03	MDL	90	0.001	MRL	Well-graded sand	SW
1409070-03	0.1 U	0.1	MRL	0.03	MDL	90.5	0.001	MRL	Well-graded sand	SW
1409070-04	0.28	0.1	MRL	0.03	MDL	84.8	0.001	MRL	Poorly-graded sand	SP
1409070-05	0.1 U	0.1	MRL	0.03	MDL	79	0.001	MRL	Poorly-graded sand	SP
1409070-06	1.14	0.1	MRL	0.03	MDL	74.5	0.001	MRL	Silty sand	SM
1409070-07	0.1 U	0.1	MRL	0.03	MDL	84.8	0.001	MRL	Silty sand	SM
1409070-08	0.14	0.1	MRL	0.03	MDL	79.8	0.001	MRL	Silty sand	SM
1409070-09	0.15	0.1	MRL	0.03	MDL	84.6	0.001	MRL	Poorly-graded sand	SP
1410045-01	0.59	0.1	MRL	0.03	MDL	84.4	0.001	MRL	Silty sand	SM
1410045-02	0.22	0.1	MRL	0.03	MDL	82.4	0.001	MRL	Silty sand	SM
1410045-03	0.27	0.1	MRL	0.03	MDL	88.8	0.001	MRL	Silty sand	SM
1410045-04	0.36	0.1	MRL	0.03	MDL	80.7	0.001	MRL	Silty sand	SM
1410045-05	0.26	0.1	MRL	0.03	MDL	84.7	0.001	MRL	Poorly-graded sand	SP
1411036-01	0.1 U	0.1	MRL	0.03	MDL	88	0.001	MRL	Silty sand	SM
1411036-02	0.1 U	0.1	MRL	0.03	MDL	91.7	0.001	MRL	Silty sand	SM
1411036-03	0.1 U	0.1	MRL	0.03	MDL	88.4	0.001	MRL	Silty sand	SM
1411036-04	0.1 U	0.1	MRL	0.03	MDL	92.9	0.001	MRL	Poorly-graded sand	SP
1411036-05	0.1 U	0.1	MRL	0.03	MDL	88.8	0.001	MRL	Silty sand	SM
1411036-06	0.44	0.1	MRL	0.03	MDL	83.8	0.001	MRL	Poorly-graded sand	SP
1411036-07	0.52	0.1	MRL	0.03	MDL	81.7	0.001	MRL	Poorly-graded sand	SP

Sample ID	Total Organic Carbon					Solids			Predominant Soil Characteristics	
	Result (%)	TOC RL	TOC RL Type	TOC DL	TOC DL Type	Results (%)	Solids RL	Solids RL Type	USCS Soil Name	USCS Soil Code
1411036-08	0.1 U	0.1	MRL	0.03	MDL	92.8	0.001	MRL	Poorly-graded sand	SP
1411036-09	0.1 U	0.1	MRL	0.03	MDL	90.9	0.001	MRL	Well-graded sand	SW
1411036-10	0.1 U	0.1	MRL	0.03	MDL	87.9	0.001	MRL	Poorly-graded sand	SP
1411036-11	0.15	0.1	MRL	0.03	MDL	88.2	0.001	MRL	Poorly-graded sand	SP
1411036-12	0.1 U	0.1	MRL	0.03	MDL	78.4	0.001	MRL	Poorly-graded sand	SP
1411036-13	0.1 U	0.1	MRL	0.03	MDL	87.5	0.001	MRL	Silty sand	SM
1411036-14	0.1 U	0.1	MRL	0.03	MDL	88.3	0.001	MRL	Silty sand	SM
1411036-15	0.1 U	0.1	MRL	0.03	MDL	86.3	0.001	MRL	Silty sand	SM
1412041-01	0.24	0.1	MRL	0.03	MDL	86.7	0.001	MRL	Poorly-graded sand	SP
1412041-02	0.25	0.1	MRL	0.03	MDL	86	0.001	MRL	Poorly-graded gravel	GP
1412041-03	0.28	0.1	MRL	0.03	MDL	86.2	0.001	MRL	Poorly-graded sand	SP
1412041-04	0.2	0.1	MRL	0.03	MDL	87.3	0.001	MRL	Poorly-graded sand	SP
1412041-05	0.23	0.1	MRL	0.03	MDL	87.9	0.001	MRL	Poorly-graded sand	SP
1412041-06	0.79	0.1	MRL	0.03	MDL	81.9	0.001	MRL	Silty sand	SM
1412041-07	0.34	0.1	MRL	0.03	MDL	80.8	0.001	MRL	Silty sand	SM
1412041-08	0.83	0.1	MRL	0.03	MDL	80.7	0.001	MRL	Silty sand	SM
1412041-09	1.27	0.1	MRL	0.03	MDL	80.7	0.001	MRL	Silty sand	SM
1412041-10	2.95	0.1	MRL	0.03	MDL	87.1	0.001	MRL	Poorly-graded sand	SP
1412041-11	0.65	0.1	MRL	0.03	MDL	75.7	0.001	MRL	Well-graded sand	SW
1412041-12	0.33	0.1	MRL	0.03	MDL	75.6	0.001	MRL	Silty sand	SM
1412041-13	0.67	0.1	MRL	0.03	MDL	76	0.001	MRL	Well-graded sand	SW
1412041-14	1.08	0.1	MRL	0.03	MDL	76.6	0.001	MRL	Silty sand	SM
1412041-15	2.8	0.1	MRL	0.03	MDL	70	0.001	MRL	Poorly-graded sand	SP
1412041-16	4.65	0.1	MRL	0.03	MDL	64.6	0.001	MRL	Silty sand	SM
1412041-17	6.45	0.1	MRL	0.03	MDL	62.8	0.001	MRL	Poorly-graded sand	SP

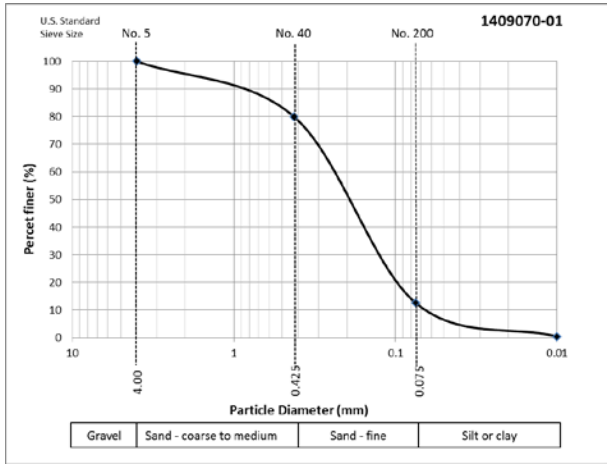
Sample ID	Total Organic Carbon					Solids			Predominant Soil Characteristics	
	Result (%)	TOC RL	TOC RL Type	TOC DL	TOC DL Type	Results (%)	Solids RL	Solids RL Type	USCS Soil Name	USCS Soil Code
1412041-18	26	0.1	MRL	0.03	MDL	36.3	0.001	MRL	NA	NA
1412041-19	62.5	0.1	MRL	0.03	MDL	28.5	0.001	MRL	NA	NA
1412041-20	55.1	0.1	MRL	0.03	MDL	39.3	0.001	MRL	NA	NA
1412041-21	0.94	0.1	MRL	0.03	MDL	80.1	0.001	MRL	Poorly-graded sand	SP
1412041-22	26.7	0.1	MRL	0.03	MDL	24.9	0.001	MRL	Silty sand	SM
1412041-23	11.8	0.1	MRL	0.03	MDL	72.9	0.001	MRL	Poorly-graded sand	SP
1412041-24	11.8	0.1	MRL	0.03	MDL	43.9	0.001	MRL	Poorly-graded sand	SP
1412041-25	1.07	0.1	MRL	0.03	MDL	67.1	0.001	MRL	Poorly-graded sand	SP

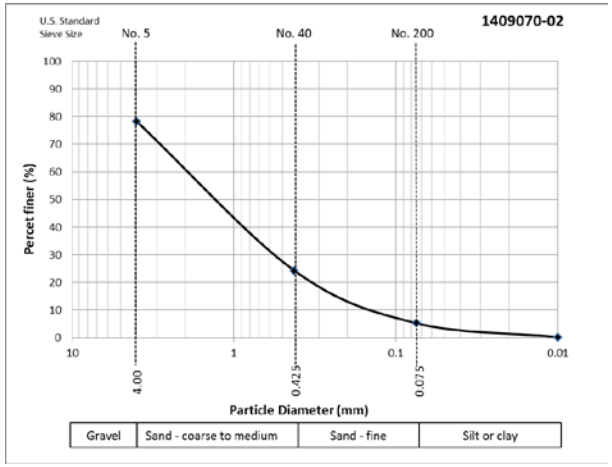
DL=Detection Limit
MDL=Method Detection Limit
MRL=Method Reporting Limit
NA=not analyzed because removal of heavy oil contamination was not possible before all fines were removed.
RL=Reporting Limit
TOC=Total Organic Carbon
USCS=Unified Soil Classification System

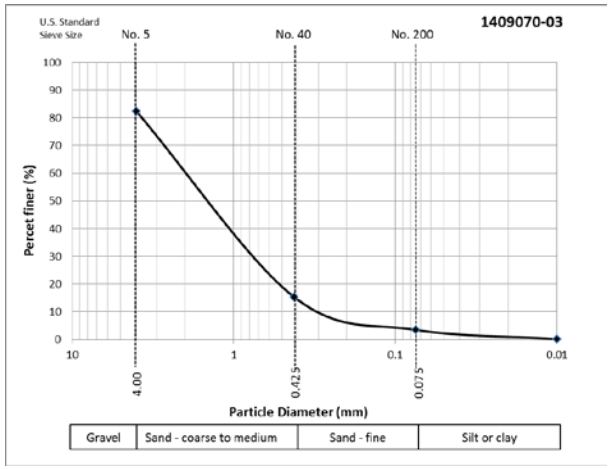
Note: Samples 1412041-10 through -25 may be biased low for Silt or Clay due to solvent rinsing to remove heavy oil contamination.

Figure E-1. Grain size distribution charts. Grouped together per sample site.

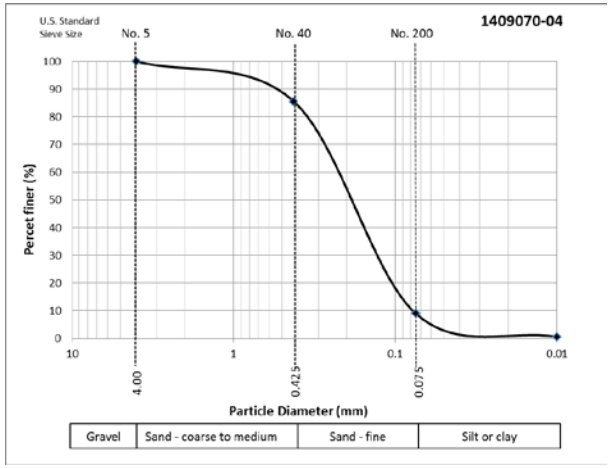
Study Specific ID: Gas1-E1_DP50 through –E3_DP52

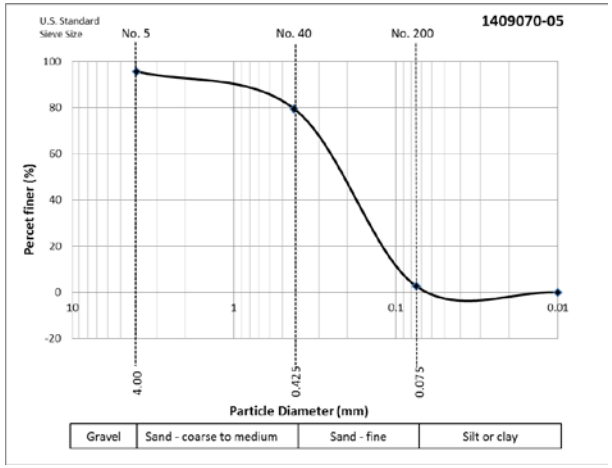


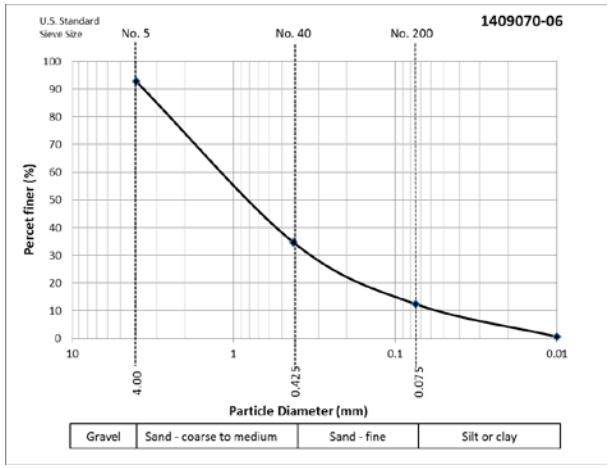


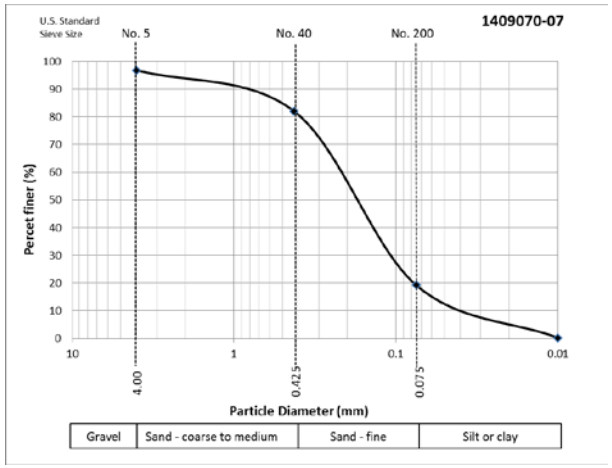


Study Specific ID: Diesel1-W1 through –W5 (1409070-09 if a field replicate of 1409070-04)

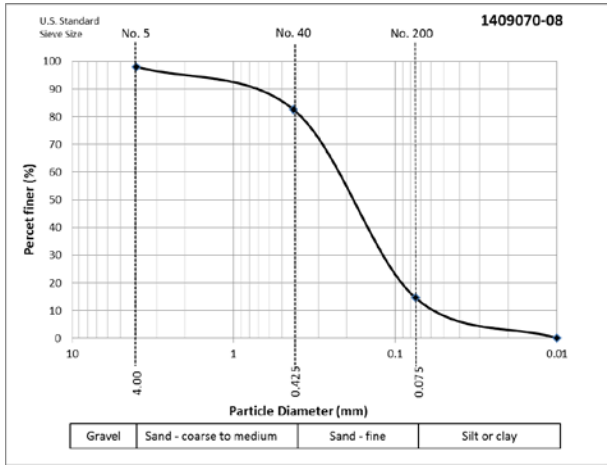


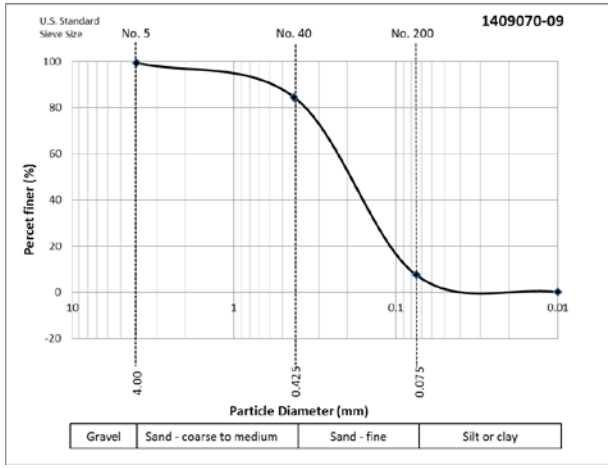




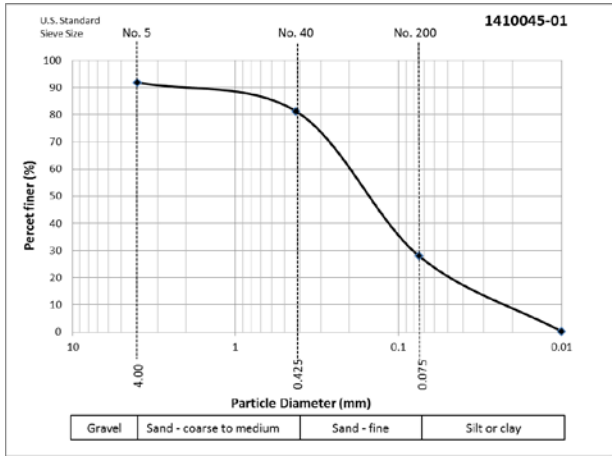


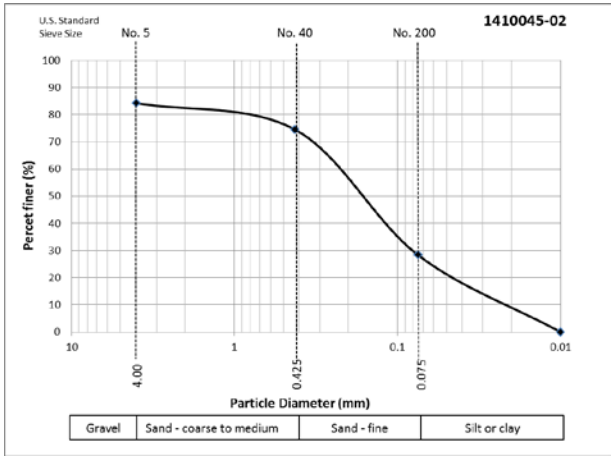
Field replicate of Sample 1409070-04

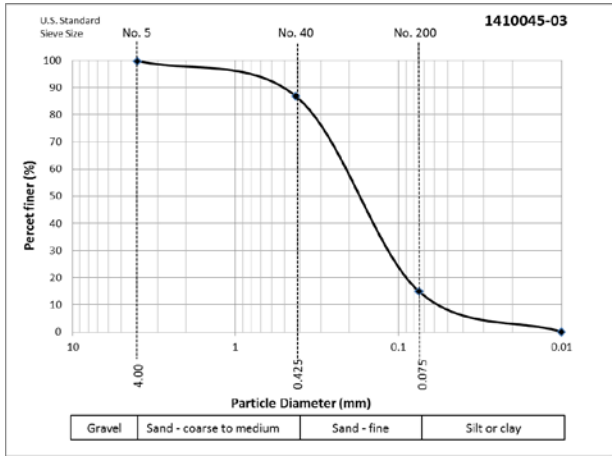


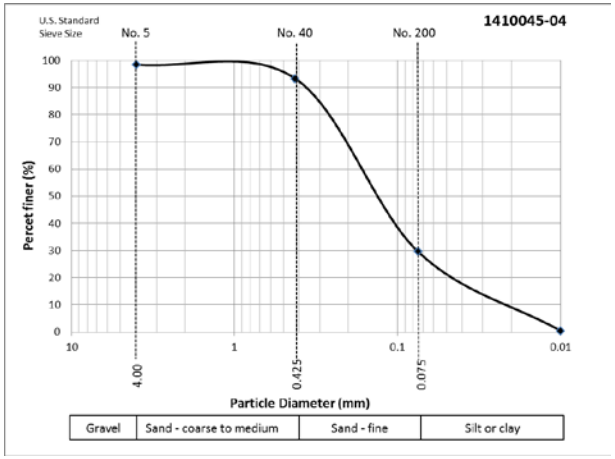


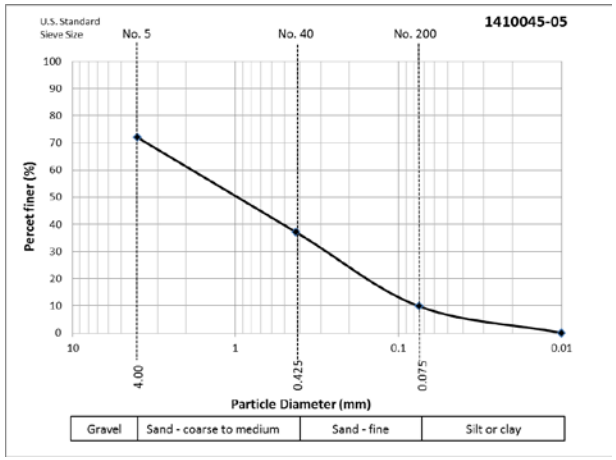
Study Specific ID: Gas1-W1 through –W5



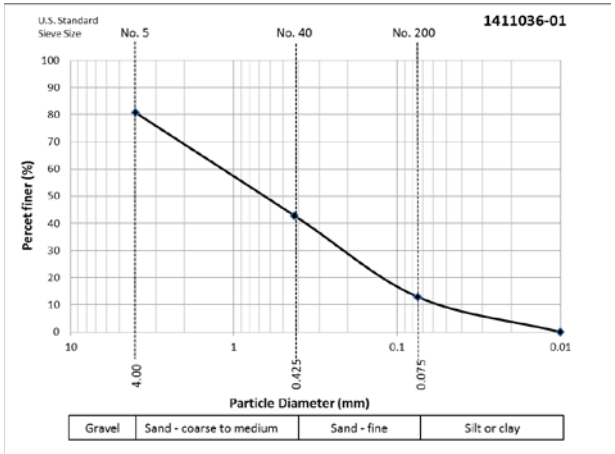


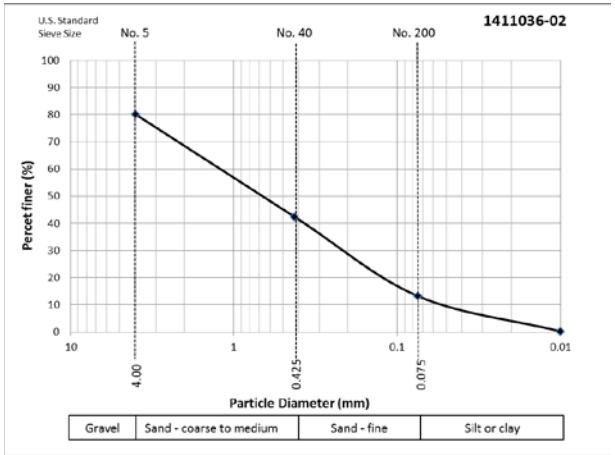

1410045-03
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

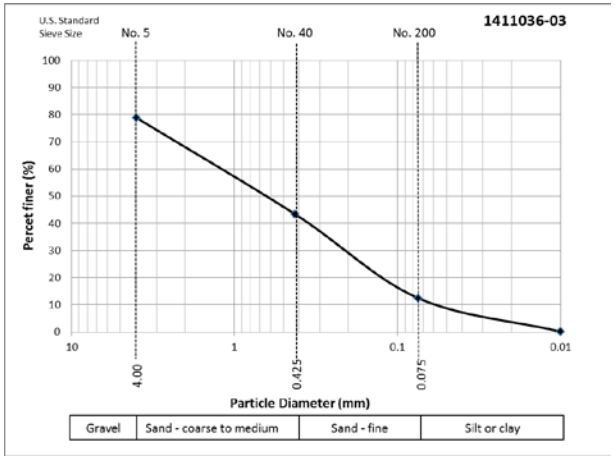

1410045-04
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

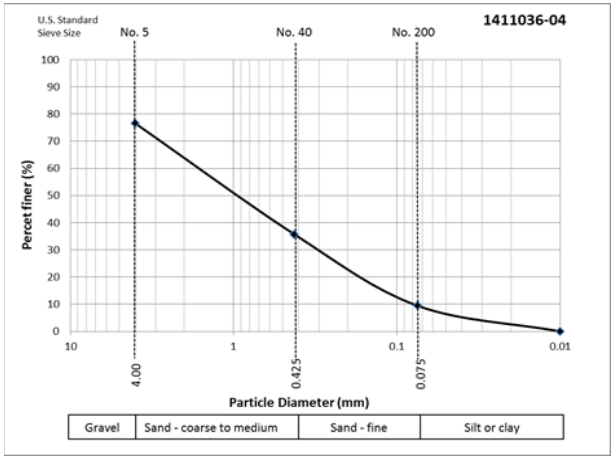

1410045-05
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

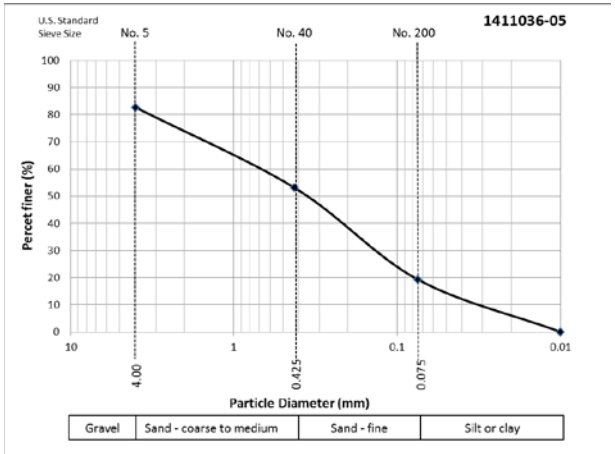
Study Specific ID: Gas2-W1 through –W5



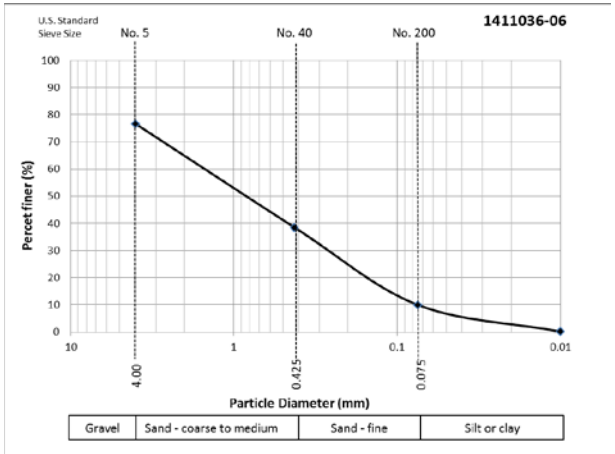


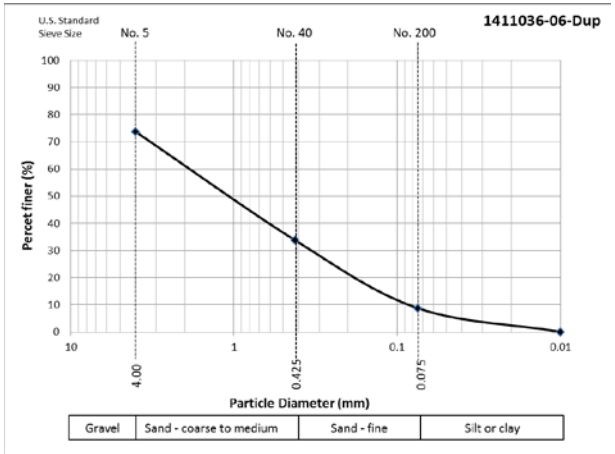


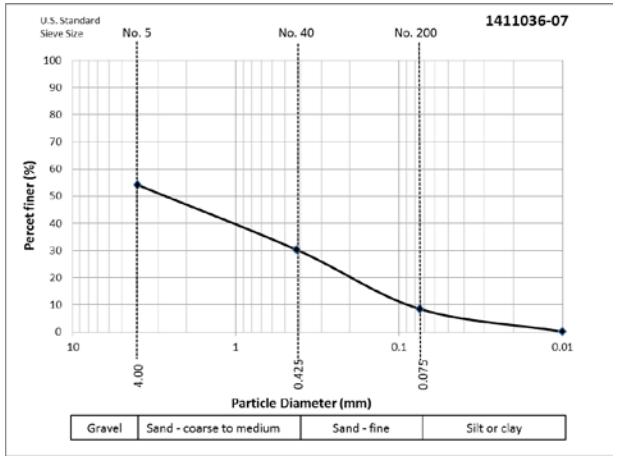


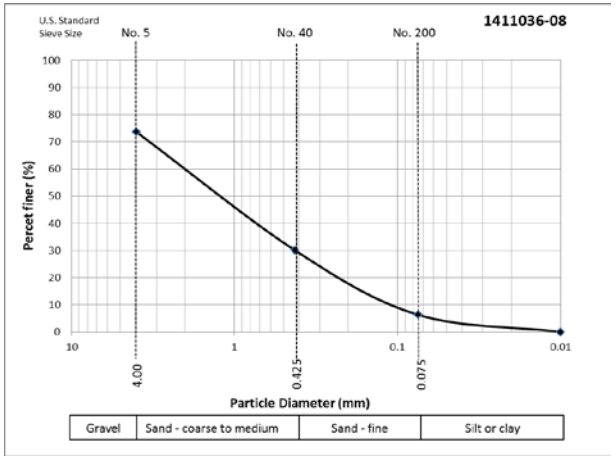


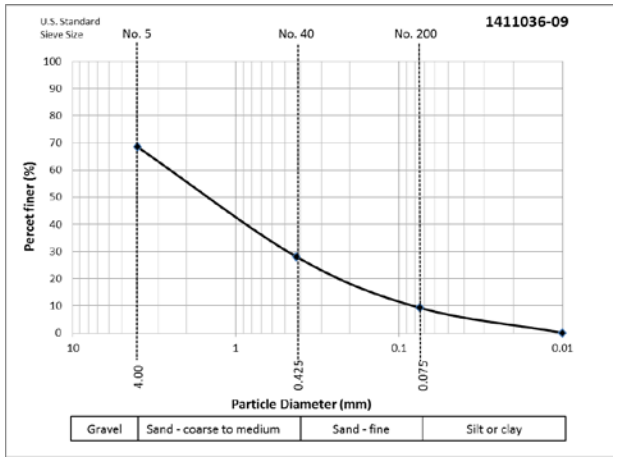
Study Specific ID: HOil1-W1 through –W5

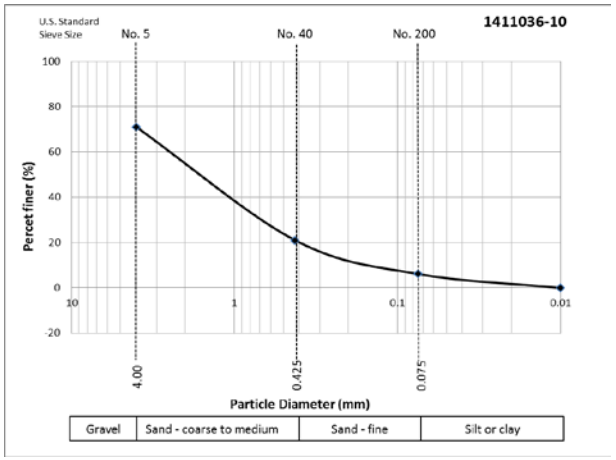




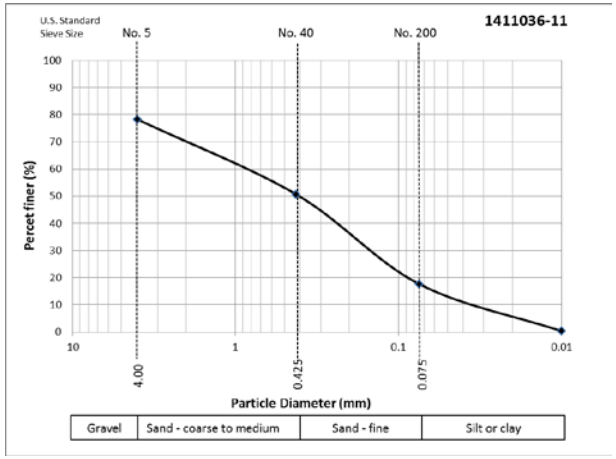

1411036-07
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
Particle Diameter (mm)
4.00
0.425
0.075
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

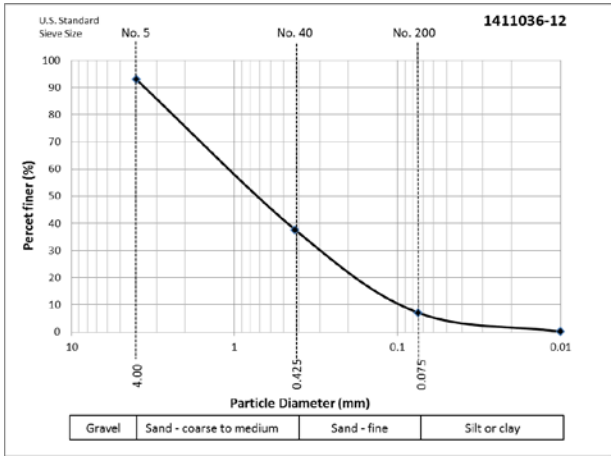

1411036-08
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
Particle Diameter (mm)
4.00
0.425
0.075
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

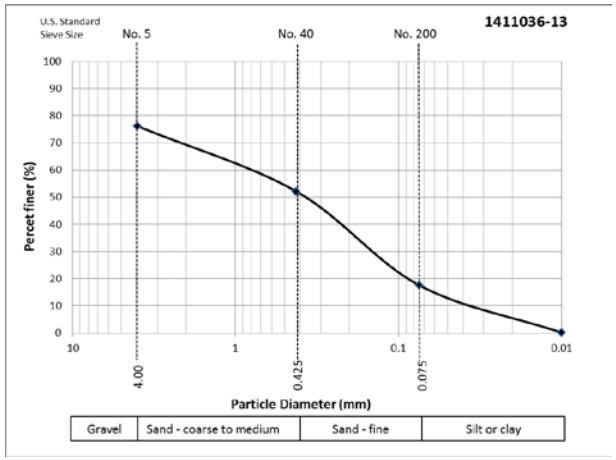

1411036-09
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
Particle Diameter (mm)
4.00
0.425
0.075
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

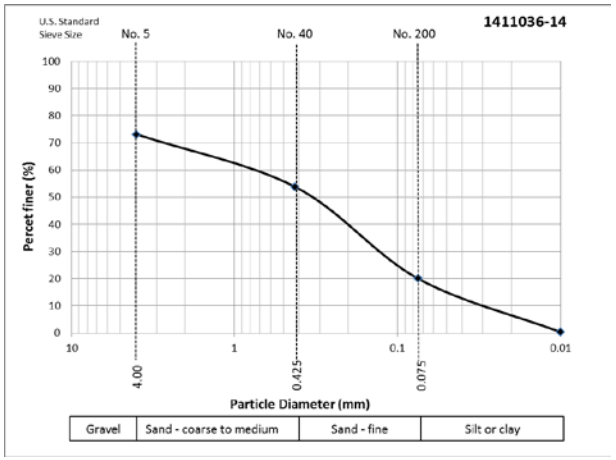

1411036-10
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
Particle Diameter (mm)
4.00
0.425
0.075
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

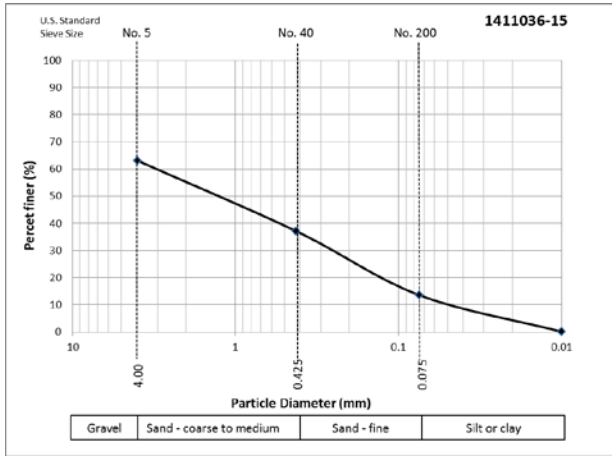
Study Specific ID: Gas3-W1 through –W5



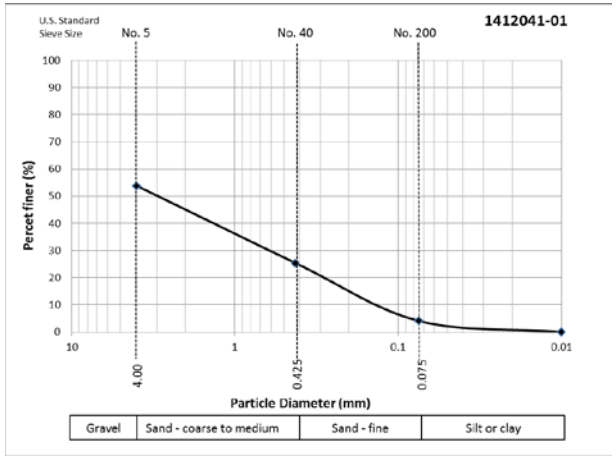


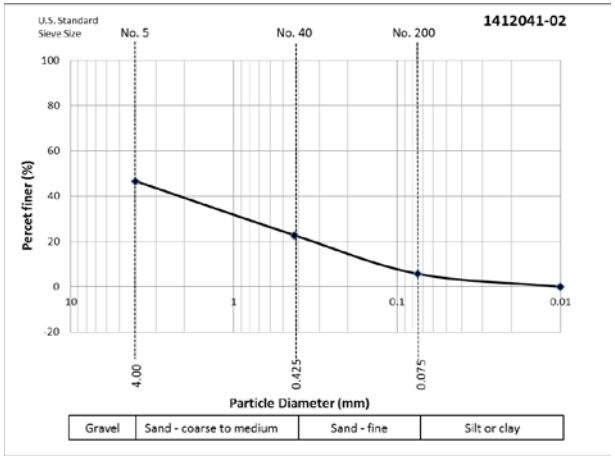


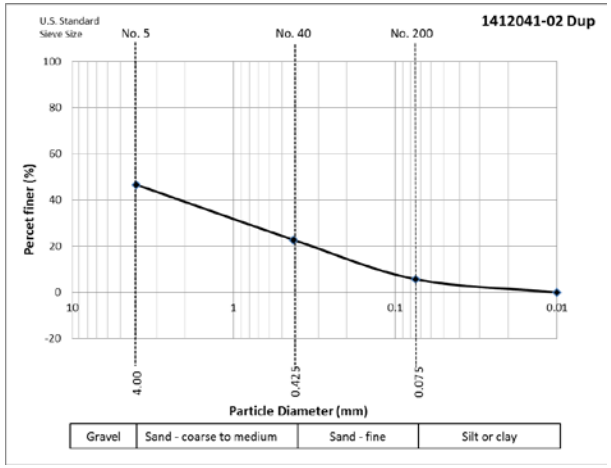


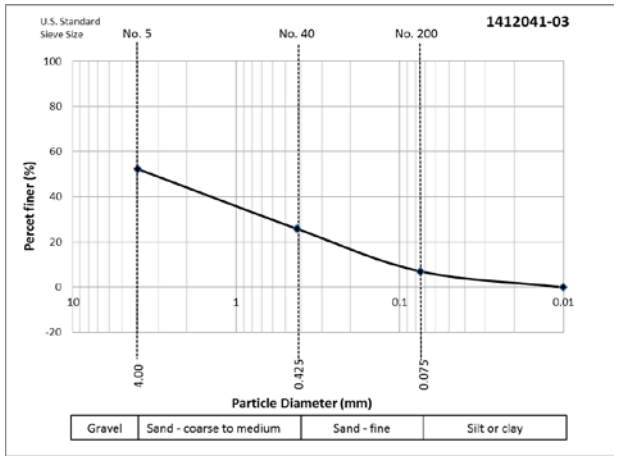


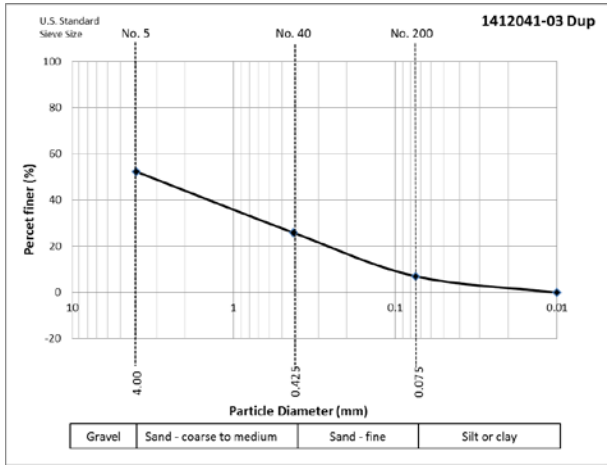
Study Specific ID: Gas4-W1 through –W5

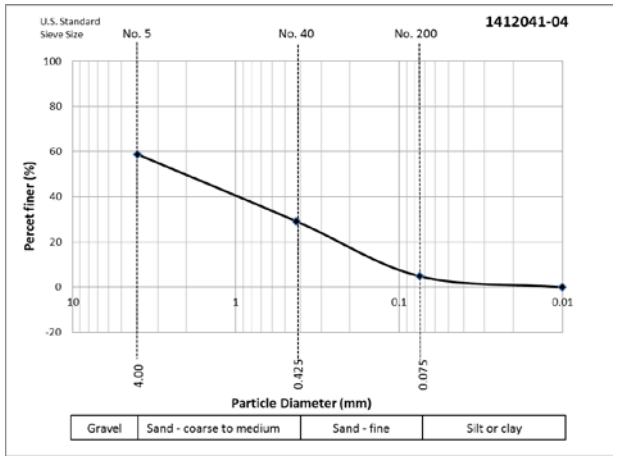


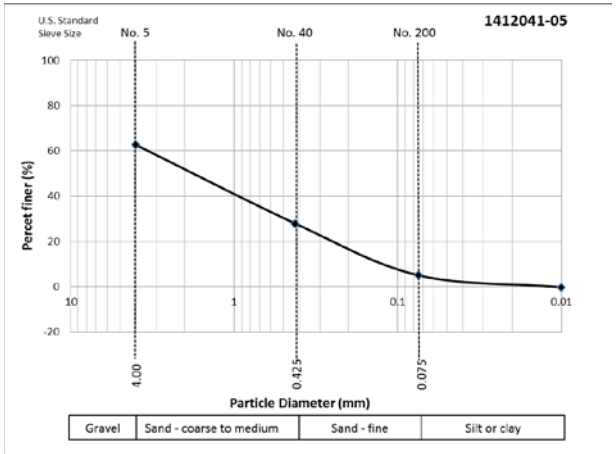



1412041-02 Dup
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
80
60
40
20
0
-20
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

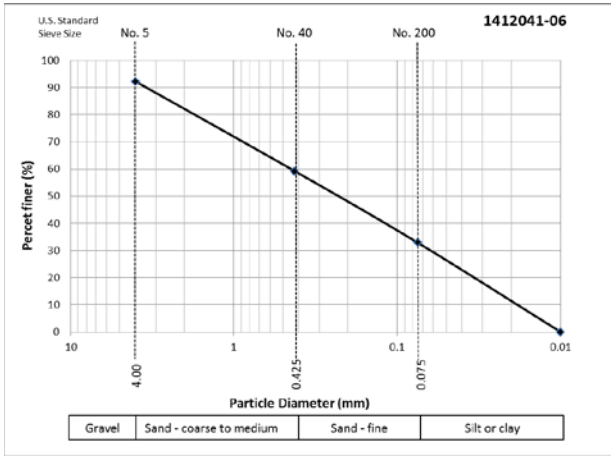

1412041-03
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
80
60
40
20
0
-20
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

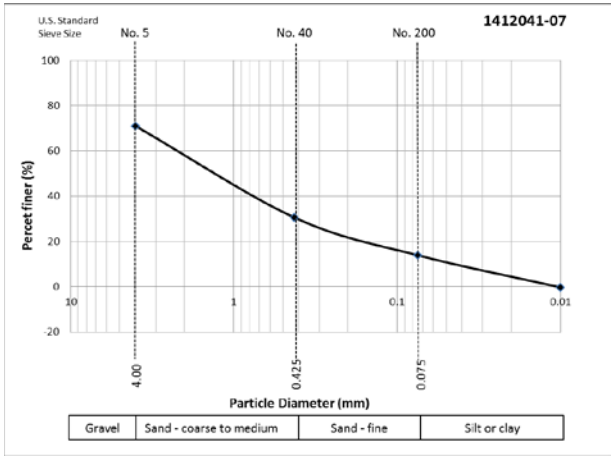

1412041-03 Dup
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
80
60
40
20
0
-20
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

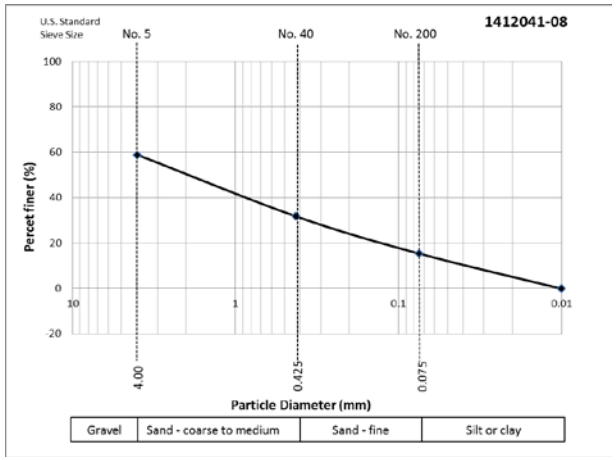

1412041-04
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
80
60
40
20
0
-20
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

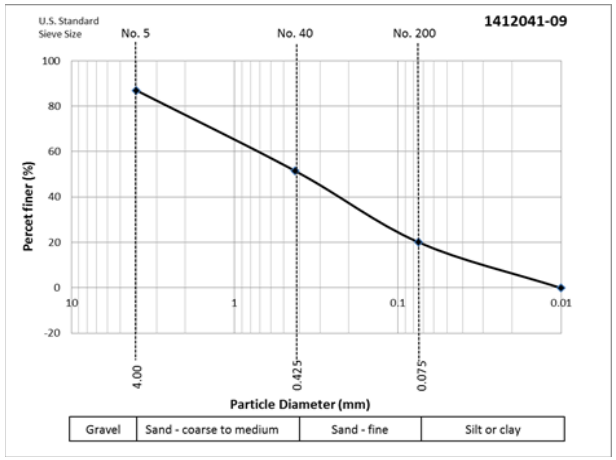


Site Specific ID: Diesel2-W1 through -W4

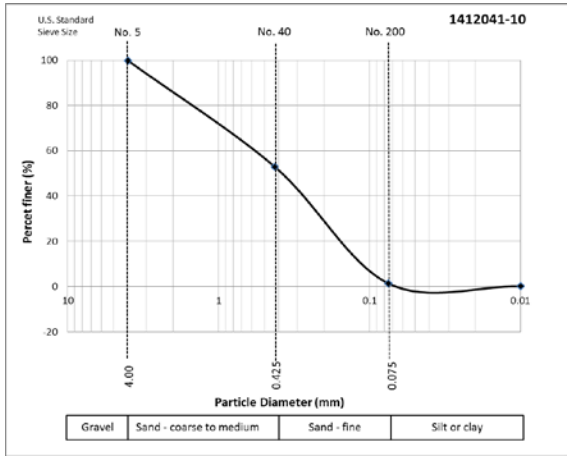


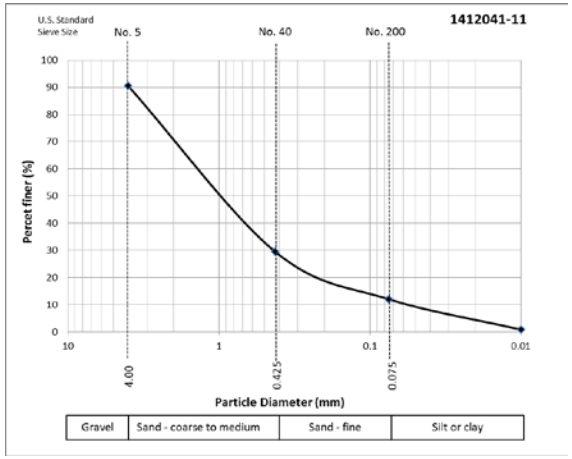


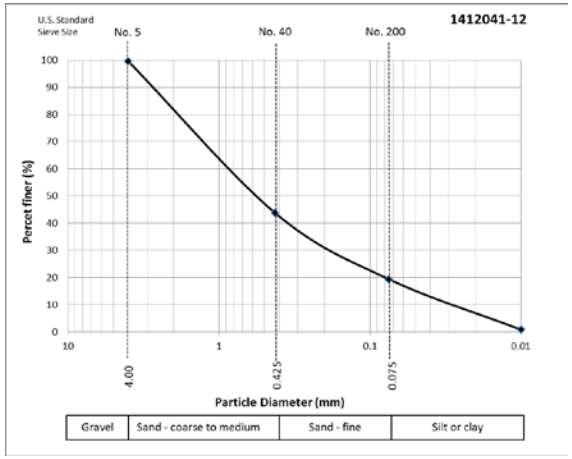


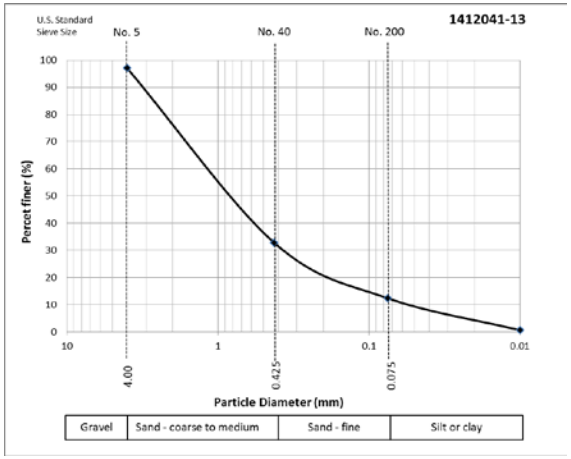


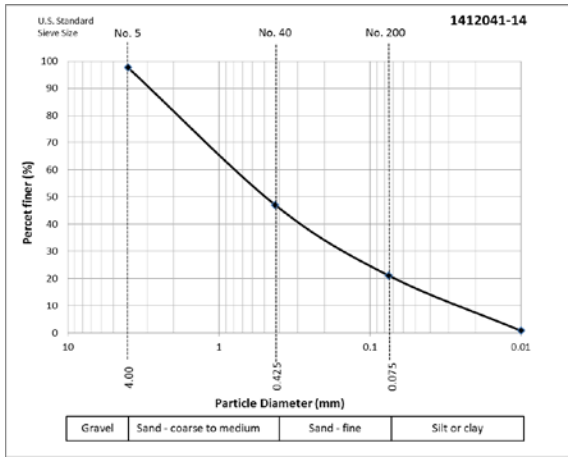
Study Specific ID: HOil2-W1 through -W5





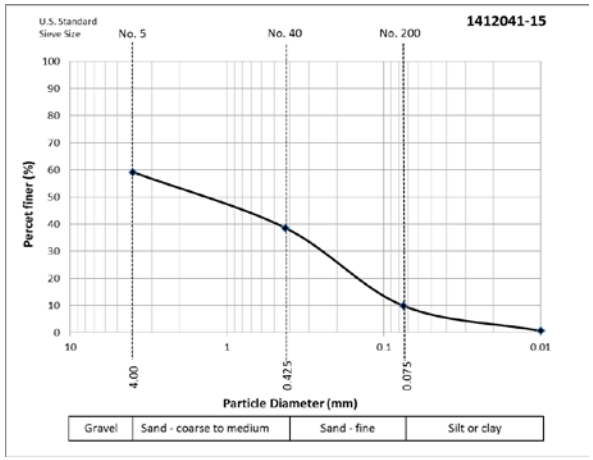

1412041-12
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

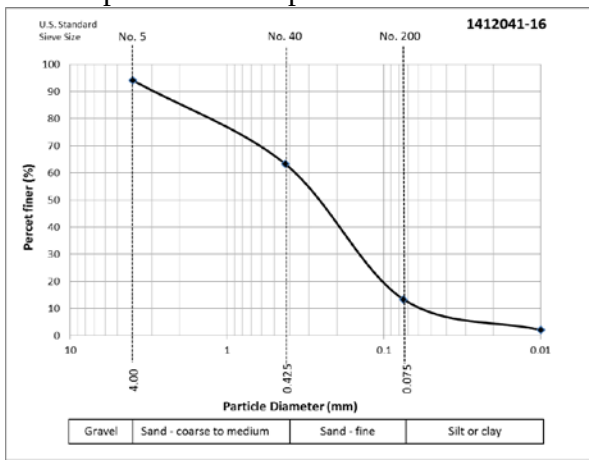

1412041-13
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

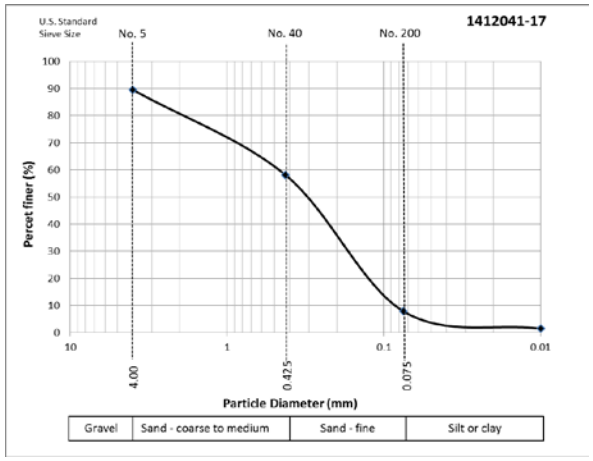

1412041-14
U.S. Standard Sieve Size
No. 5
No. 40
No. 200
Percet finer (%)
100
90
80
70
60
50
40
30
20
10
0
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

Study Specific ID: HOil3-W1 through -W5 (no data for -W3 through -W5 aka Sample ID 1412041-18 through -20)

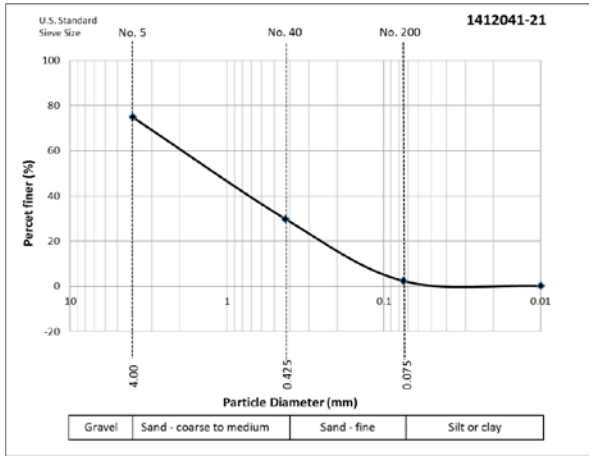
Field replicate of Sample 1412041-17

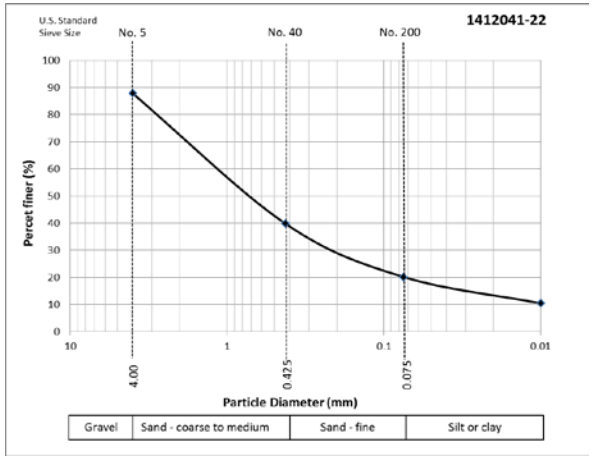


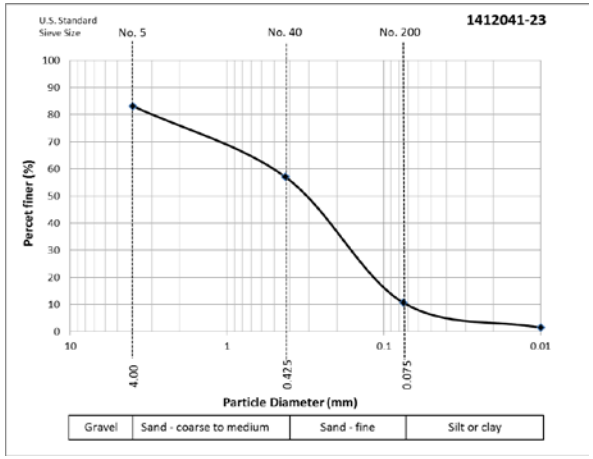


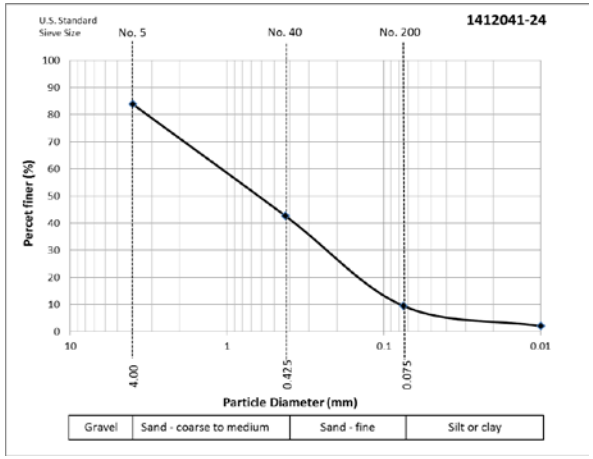


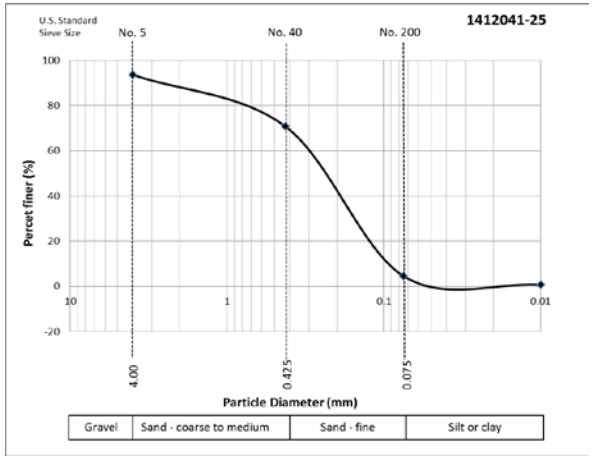
Study Specific ID: HOil4-W1 through -W5










U.S. Standard Sieve Size
1412041-25
No. 5
No. 40
No. 200
100
80
60
40
20
0
-20
Percet finer (%)
10
1
0.1
0.01
4.00
0.425
0.075
Particle Diameter (mm)
Gravel
Sand - coarse to medium
Sand - fine
Silt or clay

Appendix F. Chemical and Ancillary Results

Table F-1. Petroleum Hydrocarbon Results.

Sample ID	Gas (mg/Kg)		Gas RL (MRL)	#2 Diesel (mg/Kg)		#2 Diesel RL (MRL)	Heavy Oil (mg/Kg)		Heavy Oil RL (MRL)	Lube Oil (mg/Kg)		Lube Oil RL (MRL)
1409070-01	3.4	U	3.4	5.5	U	5.5	-		-	14	U	14
1409070-02	81		3.2	11	U	11	-		-	14	U	14
1409070-03	5.4		3.1	5.5	U	5.5	-		-	14	U	14
1409070-04	730	U	36	4,400		58	-		-	150	U	150
1409070-05	3.2	U	3.2	6.3	U	6.3	-		-	16	U	16
1409070-06	4.3	U	4.3	6.6	U	6.6	-		-	36	U	17
1409070-07	3.3	U	3.3	5.8	U	5.8	-		-	15	U	15
1409070-08	3.9	U	3.9	8.1	U	6.2	-		-	16	U	16
1409070-09	1,100	U	35	3,900		58	-		-	150	U	150
1410045-01	28		4.6	110	U	35	-		-	260		90
1410045-02	56		4.9	21	U	6	-		-	320		91
1410045-03	170		4.2	120	U	5.6	-		-	14	U	14
1410045-04	95		5	360	U	18	-		-	160		47
1410045-05	16		4.5	35	U	35	-		-	740		89
1411036-01	330		42	92	U	5.7	-		-	38		14
1411036-02	150		39	100	U	5	-		-	13	U	13
1411036-03	130		21	23	U	5.3	-		-	14	U	14
1411036-04	29		3.8	14	U	5.1	-		-	13	U	13
1411036-05	4.2	U	4.2	5.7	U	5.4	-		-	14	U	14
1411036-06	740	U	48	8,900		180	-		-	450	U	450
1411036-07	800	U	50	4,600		30	-		-	77	U	77
1411036-08	96	U	3.8	260		5.3	-		-	14	U	14

Sample ID	Gas (mg/Kg)		Gas RL (MRL)	#2 Diesel (mg/Kg)		#2 Diesel RL (MRL)	Heavy Oil (mg/Kg)		Heavy Oil RL (MRL)	Lube Oil (mg/Kg)		Lube Oil RL (MRL)
1411036-09	15	U	4	80		5.4	-		-	14	U	14
1411036-10	4.7	U	4.4	35		5.6	-		-	14	U	14
1411036-11	8.4	U	8.4	5.6	U	5.6	-		-	45		14
1411036-12	67		9.9	6.3	U	6.3	-		-	16	U	16
1411036-13	90		8.5	11	U	5.7	-		-	14	U	14
1411036-14	8.4	U	8.4	5.6	U	5.6	-		-	14	U	14
1411036-15	1,100		87	140	U	5.7	-		-	91		14
1412041-01	300		22	110	U	29	73	U	73	73	U	73
1412041-02	370		22	280	U	29	73	U	73	73	U	73
1412041-03	370		21	160	U	29	73	U	73	73	U	73
1412041-04	120		8.6	150	U	28	72	U	72	72	U	72
1412041-05	1,900		86	1,100	U	28	71	U	71	71	U	71
1412041-06	1500		94	270		31	77	U	77	77	U	77
1412041-07	200		10	1,400		62	160	U	160	160	U	160
1412041-08	750		48	500		31	78	U	78	78	U	78
1412041-09	54		4.8	60	U	60	150	U	150	150	U	150
1412041-10	2,100	U	86	17,000	U	3,400	45,000		8,600	8,600	U	8,600
1412041-11	45	U	5.6	1,400	U	65	3,800		170	170	U	170
1412041-12	5.5	U	5.5	6.6	U	6.6	17	U	17	17	U	17
1412041-13	120	U	5.6	33	U	33	740		83	83	U	83
1412041-14	23	U	5.6	65	U	65	500		160	160	U	160
1412041-15	6.3	U	6.3	71	U	71	3,100		180	180	U	180
1412041-16	77	U	7.2	1,600	U	1,500	38,000		3,900	12,000	U	3,900
1412041-17	44	U	7.5	1,000	U	790	22,000		2,000	7,400	U	2,000
1412041-18	150	U	15	8,200	U	5,500	160,000		14,000	51,000	U	14,000
1412041-19	450	U	21	34,000	U	28,000	500,000		70,000	150,000	U	70,000

Sample ID	Gas (mg/Kg)		Gas RL (MRL)	#2 Diesel (mg/Kg)		#2 Diesel RL (MRL)	Heavy Oil (mg/Kg)		Heavy Oil RL (MRL)	Lube Oil (mg/Kg)		Lube Oil RL (MRL)
1412041-20	25	U	14	1,300	U	1,300	150,000		3,200	83,000	U	3,200
1412041-21	5	U	5	62	U	62	1,600		160	1,100	U	160
1412041-22	24	U	24	200	U	200	32,000		500	12,000	U	500
1412041-23	500	U	59	8,800	U	5,400	120,000		14,000	23,000	U	14,000
1412041-24	210	U	61	20,000		340	38,000	U	860	1,600		860
1412041-25	8.6	U	6.7	15	U	15	120	U	37	37	U	37

MRL=Method Reporting Limit

RL=Reporting Limit

Table F-2. Ancillary Results.

Sample ID	Solids (%)		Solids RL (MRL)	TOC (%)		TOC RL (MRL)	TOC DL (MDL)
1409070-01	90.5		0.001	0.1	U	0.1	0.03
1409070-02	90		0.001	0.21		0.1	0.03
1409070-03	90.5		0.001	0.1	U	0.1	0.03
1409070-04	84.8		0.001	0.28		0.1	0.03
1409070-05	79		0.001	0.1	U	0.1	0.03
1409070-06	74.5		0.001	1.14		0.1	0.03
1409070-07	84.8		0.001	0.1	U	0.1	0.03
1409070-08	79.8		0.001	0.14		0.1	0.03
1409070-09	84.6		0.001	0.15		0.1	0.03
1410045-01	84.4		0.001	0.59		0.1	0.03
1410045-02	82.4		0.001	0.22		0.1	0.03
1410045-03	88.8		0.001	0.27		0.1	0.03
1410045-04	80.7		0.001	0.36		0.1	0.03
1410045-05	84.7		0.001	0.26		0.1	0.03
1411036-01	88		0.001	0.1	U	0.1	0.03
1411036-02	91.7		0.001	0.1	U	0.1	0.03
1411036-03	88.4		0.001	0.1	U	0.1	0.03
1411036-04	92.9		0.001	0.1	U	0.1	0.03
1411036-05	88.8		0.001	0.1	U	0.1	0.03
1411036-06	83.8		0.001	0.44		0.1	0.03
1411036-07	81.7		0.001	0.52		0.1	0.03
1411036-08	92.8		0.001	0.1	U	0.1	0.03
1411036-09	90.9		0.001	0.1	U	0.1	0.03
1411036-10	87.9		0.001	0.1	U	0.1	0.03
1411036-11	88.2		0.001	0.15		0.1	0.03

Sample ID	Solids (%)		Solids RL (MRL)	TOC (%)		TOC RL (MRL)	TOC DL (MDL)
1411036-12	78.4		0.001	0.1	U	0.1	0.03
1411036-13	87.5		0.001	0.1	U	0.1	0.03
1411036-14	88.3		0.001	0.1	U	0.1	0.03
1411036-15	86.3		0.001	0.1	U	0.1	0.03
1412041-01	86.7		0.001	0.24		0.1	0.03
1412041-02	86		0.001	0.25		0.1	0.03
1412041-03	86.2		0.001	0.28		0.1	0.03
1412041-04	87.3		0.001	0.2		0.1	0.03
1412041-05	87.9		0.001	0.23		0.1	0.03
1412041-06	81.9		0.001	0.79		0.1	0.03
1412041-07	80.8		0.001	0.34		0.1	0.03
1412041-08	80.7		0.001	0.83		0.1	0.03
1412041-09	80.7		0.001	1.27		0.1	0.03
1412041-10	87.1		0.001	2.95		0.1	0.03
1412041-11	75.7		0.001	0.65		0.1	0.03
1412041-12	75.6		0.001	0.33		0.1	0.03
1412041-13	76		0.001	0.67		0.1	0.03
1412041-14	76.6		0.001	1.08		0.1	0.03
1412041-15	70		0.001	2.8		0.1	0.03
1412041-16	64.6		0.001	4.65		0.1	0.03
1412041-17	62.8		0.001	6.45		0.1	0.03
1412041-18	36.3		0.001	26		0.1	0.03
1412041-19	28.5		0.001	62.5		0.1	0.03
1412041-20	39.3		0.001	55.1		0.1	0.03
1412041-21	80.1		0.001	0.94		0.1	0.03
1412041-22	24.9		0.001	26.7		0.1	0.03

Sample ID	Solids (%)		Solids RL (MRL)	TOC (%)		TOC RL (MRL)	TOC DL (MDL)
1412041-23	72.9		0.001	11.8		0.1	0.03
1412041-24	43.9		0.001	11.8		0.1	0.03
1412041-25	67.1		0.001	1.07		0.1	0.03

DL=Detection Limit
MDL=Method Detection Limit
MRL=Method Reporting Limit
RL=Reporting Limit
TOC=Total Organic Carbon

Table F-3. Extractable Petroleum Hydrocarbon, Aromatic Results (µg/kg dw).

Sample ID	EPH, C8-C10 Aromatics		LOQ | MDL EPH, C8-C10 Aromatics	EPH, >C10-C12 Aromatics		LOQ | MDL EPH, >C10-C12 Aromatics	EPH, >C12-C16 Aromatics		LOQ | MDL EPH, >C12-C16 Aromatics	EPH, >C16-C21 Aromatics		LOQ | MDL EPH, >C16-C21 Aromatics	EPH, >C21-C34 Aromatics		LOQ | MDL EPH, >C21-C34 Aromatics
1409070-01	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1409070-02	4,600	J	2,200	2,800	J	2,200	2,200	U	2,200	3,200		2,200	2,200	U	2,200
1409070-03	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1409070-04	12,000	U	12,000	12,000	U	12,000	86,000		12,000	140,000		12,000	12,000	U	12,000
1409070-05	2,500	U	2,500	2,500	U	2,500	2,500	U	2,500	2,500	U	2,500	2,500	U	2,500
1409070-06	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300
1409070-07	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400
1409070-08	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400
1409070-09	12,000	U	12,000	58,000		12,000	280,000		12,000	320,000		12,000	12,000	U	12,000
1410045-01	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	3,400		2,300
1410045-02	2,300	U	2,300	2,300	U	2,300	3,000		2,300	3,300		2,300	70,000		2,300

Sample ID	EPH, C8-C10 Aromatics		LOQ | MDL EPH, C8-C10 Aromatics	EPH, >C10-C12 Aromatics		LOQ | MDL EPH, >C10-C12 Aromatics	EPH, >C12-C16 Aromatics		LOQ | MDL EPH, >C12-C16 Aromatics	EPH, >C16-C21 Aromatics		LOQ | MDL EPH, >C16-C21 Aromatics	EPH, >C21-C34 Aromatics		LOQ | MDL EPH, >C21-C34 Aromatics
1410045-03	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300
1410045-04	2,600		2,400	8,700		2,400	6,500		2,400	2,400	U	2,400	10,000		2,400
1410045-05	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	16,000		2,300
1411036-01	6,600		2,300	11,000		2,300	5,800		2,300	2,300	U	2,300	2,300	U	2,300
1411036-02	2,000	U	2,000	2,100		2,000	2,000	U	2,000	2,000	U	2,000	2,000	U	2,000
1411036-03	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1411036-04	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100
1411036-05	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100
1411036-06	2,300	U	2,300	28,000		2,300	290,000		2,300	650,000		2,300	140,000		2,300
1411036-07	2,400	U	2,400	22,000		2,400	280,000		2,400	610,000		2,400	59,000		2,400
1411036-08	2,200	U	2,200	2,200	U	2,200	21,000		2,200	63,000		2,200	5,800		2,200
1411036-09	2,200	U	2,200	2,200	U	2,200	7,300		2,200	13,000		2,200	2,200	U	2,200

Sample ID	EPH, C8-C10 Aromatics		LOQ | MDL EPH, C8-C10 Aromatics	EPH, >C10-C12 Aromatics		LOQ | MDL EPH, >C10-C12 Aromatics	EPH, >C12-C16 Aromatics		LOQ | MDL EPH, >C12-C16 Aromatics	EPH, >C16-C21 Aromatics		LOQ | MDL EPH, >C16-C21 Aromatics	EPH, >C21-C34 Aromatics		LOQ | MDL EPH, >C21-C34 Aromatics
1411036-10	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,600		2,200	2,200	U	2,200
1411036-11	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1411036-12	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400
1411036-13	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300
1411036-14	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1411036-15	18,000		2,300	30,000		2,300	14,000		2,300	2,300	U	2,300	2,300	U	2,300
1412041-01	2,200	U	2,200	3,000		2,200	7,200		2,200	3,200		2,200	2,200	U	2,200
1412041-02	2,300	U	2,300	7,400		2,300	12,000		2,300	4,200		2,300	2,300	U	2,300
1412041-03	2,300	U	2,300	4,300		2,300	6,700		2,300	2,300	U	2,300	2,300	U	2,300
1412041-04	2,300	U	2,300	2,900		2,300	4,900		2,300	2,300	U	2,300	2,300	U	2,300
1412041-05	5,200		2,200	60,000		2,200	100,000		2,200	18,000		2,200	2,200	U	2,200
1412041-06	3,100		2,300	4,900		2,300	17,000		2,300	27,000		2,300	2,300	U	2,300

Sample ID	EPH, C8-C10 Aromatics		LOQ | MDL EPH, C8-C10 Aromatics	EPH, >C10-C12 Aromatics		LOQ | MDL EPH, >C10-C12 Aromatics	EPH, >C12-C16 Aromatics		LOQ | MDL EPH, >C12-C16 Aromatics	EPH, >C16-C21 Aromatics		LOQ | MDL EPH, >C16-C21 Aromatics	EPH, >C21-C34 Aromatics		LOQ | MDL EPH, >C21-C34 Aromatics
1412041-07	2,400	U	2,400	7,800		2,400	57,000		2,400	100,000		2,400	11,000		2,400
1412041-08	15,000		2,400	16,000		2,400	21,000		2,400	56,000		2,400	5,200		2,400
1412041-09	2,700	U	2,700	2,700	U	2,700	2,700	U	2,700	2,700	U	2,700	2,700	U	2,700
1412041-10	3,000		2,300	180,000		2,300	1,500,000		2,300	1,900,000		2,300	970,000		2,300
1412041-11	3,300		2,600	89,000		2,600	600,000		2,600	720,000		2,600	350,000		2,600
1412041-12	2,600	U	2,600	2,600	U	2,600	2,600	U	2,600	2,600	U	2,600	2,600	U	2,600
1412041-13	2,600	U	2,600	7,300		2,600	50,000		2,600	68,000		2,600	31,000		2,600
1412041-14	2,600	U	2,600	2,600	U	2,600	2,600	U	2,600	19,000		2,600	45,000		2,600
1412041-15	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000	79,000		14,000	310,000		14,000
1412041-16	16,000	U	16,000	16,000	U	16,000	250,000		16,000	2,500,000		16,000	6,300,000		16,000
1412041-17	15,000	U	15,000	15,000	U	15,000	280,000		15,000	2,400,000		15,000	6,400,000		15,000
1412041-18	110,000	U	110,000	150,000		110,000	2,800,000		110,000	16,000,000		110,000	37,000,000		110,000

Sample ID	EPH, C8-C10 Aromatics		LOQ | MDL EPH, C8-C10 Aromatics	EPH, >C10-C12 Aromatics		LOQ | MDL EPH, >C10-C12 Aromatics	EPH, >C12-C16 Aromatics		LOQ | MDL EPH, >C12-C16 Aromatics	EPH, >C16-C21 Aromatics		LOQ | MDL EPH, >C16-C21 Aromatics	EPH, >C21-C34 Aromatics		LOQ | MDL EPH, >C21-C34 Aromatics
1412041-19	250,000	U	250,000	610,000		250,000	9,700,000		250,000	42,000,000		250,000	85,000,000		250,000
1412041-20	120,000	U	120,000	120,000	U	120,000	120,000	U	120,000	1,100,000		120,000	8,000,000		120,000
1412041-21	11,000	U	11,000	11,000	U	11,000	11,000	U	11,000	45,000		11,000	230,000		11,000
1412041-22	33,000	U	33,000	33,000	U	33,000	140,000		33,000	980,000		33,000	4,200,000		33,000
1412041-23	59,000	U	59,000	120,000		59,000	1,600,000		59,000	6,900,000		59,000	15,000,000		59,000
1412041-24	18,000	U	18,000	18,000	U	18,000	310,000		18,000	1,100,000		18,000	510,000		18,000
1412041-25	3,000		2,700	2,700	U	2,700	2,700	U	2,700	2,700	U	2,700	2,700	U	2,700

EPH=Extractable Petroleum Hydrocarbons

LOQ=Limit of Quantitation

Table F-3 (continued). Extractable Petroleum Hydrocarbon, Aliphatic Results (µg/kg dw).

Sample ID	EPH, C8-C10 Aliphatics		LOQ | MDL EPH, C8-C10 Aliphatics	EPH, >C10-C12 Aliphatics		LOQ | MDL EPH, >C10-C12 Aliphatics	EPH, >C12-C16 Aliphatics		LOQ | MDL EPH, >C12-C16 Aliphatics	EPH, >C16-C21 Aliphatics		LOQ | MDL EPH, >C16-C21 Aliphatics	EPH, >C21-C34 Aliphatics		LOQ | MDL EPH, >C21-C34 Aliphatics
1409070-01	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1409070-02	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1409070-03	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1409070-04	12,000	U	12,000	150,000		12,000	840,000		12,000	280,000		12,000	12,000	U	12,000
1409070-05	4,500	J	2,500	2,500	U	2,500	2,500	U	2,500	2,500	U	2,500	2,500	U	2,500
1409070-06	3,700	J	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	3,200		2,300
1409070-07	3,300	J	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400
1409070-08	4,300	J	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400
1409070-09	38,000		12,000	620,000		12,000	1,600,000		12,000	480,000		12,000	12,000	U	12,000
1410045-01	11,000	J	2,300	9,100		2,300	2,300	U	2,300	2,300	U	2,300	21,000		2,300
1410045-02	10,000	J	2,300	35,000		2,300	17,000		2,300	2,400		2,300	88,000		2,300

Sample ID	EPH, C8-C10 Aliphatics		LOQ | MDL EPH, C8-C10 Aliphatics	EPH, >C10-C12 Aliphatics		LOQ | MDL EPH, >C10-C12 Aliphatics	EPH, >C12-C16 Aliphatics		LOQ | MDL EPH, >C12-C16 Aliphatics	EPH, >C16-C21 Aliphatics		LOQ | MDL EPH, >C16-C21 Aliphatics	EPH, >C21-C34 Aliphatics		LOQ | MDL EPH, >C21-C34 Aliphatics
1410045-03	12,000	J	2,300	11,000		2,300	3,000		2,300	2,300	U	2,300	2,300	U	2,300
1410045-04	54,000		2,400	56,000		2,400	12,000		2,400	2,400	U	2,400	15,000		2,400
1410045-05	8,800	J	2,300	5,300		2,300	2,300	U	2,300	2,300	U	2,300	30,000		2,300
1411036-01	53,000		2,300	62,000		2,300	13,000		2,300	2,300	U	2,300	2,300	U	2,300
1411036-02	15,000		2,000	16,000		2,000	3,600		2,000	2,000	U	2,000	2,000	U	2,000
1411036-03	18,000		2,200	22,000		2,200	4,900		2,200	2,200	U	2,200	2,200	U	2,200
1411036-04	2,200		2,100	3,000		2,100	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100
1411036-05	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100	2,100	U	2,100
1411036-06	14,000		2,300	140,000		2,300	600,000		2,300	630,000		2,300	280,000		2,300
1411036-07	9,000		2,400	130,000		2,400	580,000		2,400	510,000		2,400	64,000		2,400
1411036-08	2,200	U	2,200	3,300		2,200	61,000		2,200	75,000		2,200	8,200		2,200
1411036-09	2,200	U	2,200	3,300		2,200	21,000		2,200	15,000		2,200	2,200	U	2,200

Sample ID	EPH, C8-C10 Aliphatics		LOQ | MDL EPH, C8-C10 Aliphatics	EPH, >C10-C12 Aliphatics		LOQ | MDL EPH, >C10-C12 Aliphatics	EPH, >C12-C16 Aliphatics		LOQ | MDL EPH, >C12-C16 Aliphatics	EPH, >C16-C21 Aliphatics		LOQ | MDL EPH, >C16-C21 Aliphatics	EPH, >C21-C34 Aliphatics		LOQ | MDL EPH, >C21-C34 Aliphatics
1411036-10	2,200	U	2,200	2,200	U	2,200	5,200		2,200	5,200		2,200	2,200	U	2,200
1411036-11	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	9,000		2,200
1411036-12	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400	2,400	U	2,400
1411036-13	2,300	U	2,300	2,300		2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300
1411036-14	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200	2,200	U	2,200
1411036-15	19,000		2,300	24,000		2,300	10,000		2,300	2,300	U	2,300	10,000		2,300
1412041-01	2,200	U	2,200	3,700		2,200	12,000		2,200	8,200		2,200	7,800		2,200
1412041-02	2,300	U	2,300	7,700		2,300	12,000		2,300	4,800		2,300	6,600		2,300
1412041-03	2,300	U	2,300	5,400		2,300	8,500		2,300	3,900		2,300	3,100		2,300
1412041-04	2,300	U	2,300	2,800		2,300	4,400		2,300	2,300		2,300	2,300	U	2,300
1412041-05	3,300		2,200	82,000		2,200	98,000		2,200	20,000		2,200	7,500		2,200
1412041-06	2,300	U	2,300	9,900		2,300	61,000		2,300	66,000		2,300	7,700		2,300

Sample ID	EPH, C8-C10 Aliphatics		LOQ | MDL EPH, C8-C10 Aliphatics	EPH, >C10-C12 Aliphatics		LOQ | MDL EPH, >C10-C12 Aliphatics	EPH, >C12-C16 Aliphatics		LOQ | MDL EPH, >C12-C16 Aliphatics	EPH, >C16-C21 Aliphatics		LOQ | MDL EPH, >C16-C21 Aliphatics	EPH, >C21-C34 Aliphatics		LOQ | MDL EPH, >C21-C34 Aliphatics
1412041-07	4,700		2,400	41,000		2,400	230,000		2,400	230,000		2,400	41,000		2,400
1412041-08	7,100		2,400	18,000		2,400	110,000		2,400	140,000		2,400	15,000		2,400
1412041-09	3,700		2,700	5,300		2,700	6,400		2,700	3,800		2,700	9,200		2,700
1412041-10	21,000		2,300	400,000		2,300	1,700,000		2,300	1,300,000		2,300	1,000,000		2,300
1412041-11	12,000		2,600	120,000		2,600	470,000		2,600	380,000		2,600	330,000		2,600
1412041-12	2,600	U	2,600	2,600	U	2,600	2,600	U	2,600	2,600	U	2,600	2,600	U	2,600
1412041-13	2,600	U	2,600	8,300		2,600	35,000		2,600	32,000		2,600	32,000		2,600
1412041-14	2,600	U	2,600	2,600	U	2,600	22,000		2,600	29,000		2,600	27,000		2,600
1412041-15	14,000	U	14,000	14,000	U	14,000	28,000		14,000	88,000		14,000	160,000		14,000
1412041-16	16,000	U	16,000	39,000		16,000	460,000		16,000	650,000		16,000	1,300,000		16,000
1412041-17	15,000	U	15,000	61,000		15,000	550,000		15,000	740,000		15,000	1,400,000		15,000
1412041-18	110,000	U	110,000	460,000		110,000	3,100,000		110,000	3,800,000		110,000	7,000,000		110,000

Sample ID	EPH, C8-C10 Aliphatics		LOQ | MDL EPH, C8-C10 Aliphatics	EPH, >C10-C12 Aliphatics		LOQ | MDL EPH, >C10-C12 Aliphatics	EPH, >C12-C16 Aliphatics		LOQ | MDL EPH, >C12-C16 Aliphatics	EPH, >C16-C21 Aliphatics		LOQ | MDL EPH, >C16-C21 Aliphatics	EPH, >C21-C34 Aliphatics		LOQ | MDL EPH, >C21-C34 Aliphatics
1412041-19	250,000	U	250,000	1,600,000		250,000	11,000,000		250,000	14,000,000		250,000	27,000,000		250,000
1412041-20	120,000	U	120,000	120,000	U	120,000	870,000		120,000	2,300,000		120,000	6,000,000		120,000
1412041-21	11,000	U	11,000	11,000	U	11,000	11,000	U	11,000	55,000		11,000	150,000		11,000
1412041-22	33,000	U	33,000	130,000		33,000	1,000,000		33,000	2,100,000		33,000	3,400,000		33,000
1412041-23	59,000	U	59,000	500,000		59,000	2,800,000		59,000	3,400,000		59,000	5,500,000		59,000
1412041-24	45,000		18,000	570,000		18,000	2,600,000		18,000	2,200,000		18,000	730,000		18,000
1412041-25	2,700	U	2,700	2,700	U	2,700	2,700	U	2,700	2,700	U	2,700	3,700		2,700

EPH=Extractable Petroleum Hydrocarbons

LOQ=Limit of Quantitation

Table F-4. Volatile Petroleum Hydrocarbon, Aromatic Results (µg/kg dw).

Sample ID	VPH, >C8-C10 Aromatics		LOQ | MDL VPH, >C8-C10 Aromatics	VPH, >C10-C12 Aromatics		LOQ | MDL VPH, >C10-C12 Aromatics	VPH, >C12-C13 Aromatics		LOQ | MDL VPH, >C12-C13 Aromatics
1409070-01	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500
1409070-02	570,000	E	4,400	160,000	J	4,400	5,200	J	4,400
1409070-03	4,300	U	4,300	4,300	U	4,300	4,300	U	4,300
1409070-04	250,000	J	68,000	1,300,000	J	68,000	460,000	J	68,000
1409070-05	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1409070-06	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600
1409070-07	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1409070-08	13,000	U	13,000	13,000	U	13,000	13,000	U	13,000
1409070-09	110,000		17,000	520,000		17,000	54,000		17,000
1410045-01	24,000		12,000	24,000		12,000	12,000	U	12,000
1410045-02	32,000		11,000	72,000		11,000	22,000		11,000

Sample ID	VPH, >C8-C10 Aromatics		LOQ | MDL VPH, >C8-C10 Aromatics	VPH, >C10-C12 Aromatics		LOQ | MDL VPH, >C10-C12 Aromatics	VPH, >C12-C13 Aromatics		LOQ | MDL VPH, >C12-C13 Aromatics
1410045-03	67,000		11,000	54,000		11,000	12,000		11,000
1410045-04	260,000		15,000	210,000		15,000	38,000		15,000
1410045-05	13,000		12,000	13,000		12,000	12,000	U	12,000
1411036-01	450,000		43,000	220,000		43,000	43,000	U	43,000
1411036-02	270,000		39,000	210,000		39,000	39,000	U	39,000
1411036-03	64,000		30,000	55,000		30,000	30,000	U	30,000
1411036-04	55,000		7,200	49,000		7,200	7,900		7,200
1411036-05	15,000		7,400	12,000		7,400	7,400	U	7,400
1411036-06	96,000		8,400	320,000		8,400	57,000		8,400
1411036-07	52,000		8,400	200,000		8,400	80,000		8,400
1411036-08	8,200	U	8,200	48,000		8,200	56,000		8,200
1411036-09	7,200	U	7,200	17,000		7,200	30,000		7,200

Sample ID	VPH, >C8-C10 Aromatics		LOQ | MDL VPH, >C8-C10 Aromatics	VPH, >C10-C12 Aromatics		LOQ | MDL VPH, >C10-C12 Aromatics	VPH, >C12-C13 Aromatics		LOQ | MDL VPH, >C12-C13 Aromatics
1411036-10	6,800	U	6,800	6,800	U	6,800	6,800	U	6,800
1411036-11	8,500	U	8,500	8,500	U	8,500	8,500	U	8,500
1411036-12	13,000		12,000	12,000	U	12,000	12,000	U	12,000
1411036-13	17,000		7,900	37,000		7,900	18,000		7,900
1411036-14	7,800	U	7,800	7,800	U	7,800	7,800	U	7,800
1411036-15	370,000		7,700	300,000		7,700	36,000		7,700
1412041-01	100,000		39,000	190,000		39,000	55,000		39,000
1412041-02	60,000		45,000	140,000		45,000	49,000		45,000
1412041-03	110,000		45,000	190,000		45,000	54,000		45,000
1412041-04	160,000		55,000	230,000		55,000	66,000		55,000
1412041-05	370,000		48,000	620,000		48,000	190,000		48,000
1412041-06	670,000		44,000	560,000		44,000	260,000		44,000

Sample ID	VPH, >C8-C10 Aromatics		LOQ | MDL VPH, >C8-C10 Aromatics	VPH, >C10-C12 Aromatics		LOQ | MDL VPH, >C10-C12 Aromatics	VPH, >C12-C13 Aromatics		LOQ | MDL VPH, >C12-C13 Aromatics
1412041-07	56,000	U	56,000	140,000		56,000	190,000		56,000
1412041-08	160,000		50,000	94,000		50,000	50,000	U	50,000
1412041-09	79,000	U	79,000	79,000	U	79,000	79,000	U	79,000
1412041-10	25,000		9,600	220,000		9,600	98,000		9,600
1412041-11	12,000	U	12,000	48,000		12,000	86,000		12,000
1412041-12	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1412041-13	14,000	U	14,000	14,000	U	14,000	14,000		14,000
1412041-14	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1412041-15	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000
1412041-16	20,000	U	20,000	40,000	J	20,000	66,000	J	20,000
1412041-17	19,000	U	19,000	22,000	J	19,000	42,000	J	19,000
1412041-18	41,000	U	41,000	54,000	J	41,000	96,000	J	41,000

Sample ID	VPH, >C8-C10 Aromatics		LOQ | MDL VPH, >C8-C10 Aromatics	VPH, >C10-C12 Aromatics		LOQ | MDL VPH, >C10-C12 Aromatics	VPH, >C12-C13 Aromatics		LOQ | MDL VPH, >C12-C13 Aromatics
1412041-19	260,000	U	260,000	260,000	U	260,000	480,000	J	260,000
1412041-20	45,000	U	45,000	45,000	U	45,000	45,000	U	45,000
1412041-21	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600
1412041-22	75,000	U	75,000	75,000	U	75,000	75,000	U	75,000
1412041-23	28,000	J	12,000	100,000	J	12,000	65,000	J	12,000
1412041-24	61,000		23,000	95,000		23,000	63,000		23,000
1412041-25	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000

LOQ=Limit of Quantitation

VPH=Volatile Petroleum Hydrocarbons

Table F-4 (continued). Volatile Petroleum Hydrocarbon, Aliphatic Results (µg/kg dw).

Sample ID	VPH, C5-C6 Aliphatics		LOQ | MDL VPH, C5-C6 Aliphatics	VPH, >C6-C8 Aliphatics		LOQ | MDL VPH, >C6-C8 Aliphatics	VPH, >C8-C10 Aliphatics		LOQ | MDL VPH, >C8-C10 Aliphatics	VPH, >C10-C12 Aliphatics		LOQ | MDL VPH, >C10-C12 Aliphatics
1409070-01	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500
1409070-02	28,000	J	4,400	500,000	E	4,400	4,400	U	4,400	220,000	E	4,400
1409070-03	4,300	U	4,300	4,300	U	4,300	4,300	U	4,300	4,300	U	4,300
1409070-04	68,000	U	68,000	68,000	U	68,000	68,000	U	68,000	68,000	U	68,000
1409070-05	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1409070-06	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600
1409070-07	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1409070-08	13,000	U	13,000	13,000	U	13,000	13,000	U	13,000	13,000	U	13,000
1409070-09	17,000	U	17,000	17,000	U	17,000	17,000	U	17,000	17,000	U	17,000
1410045-01	12,000	U	12,000	14,000		12,000	17,000		12,000	16,000		12,000
1410045-02	11,000	U	11,000	11,000	U	11,000	11,000	U	11,000	11,000	U	11,000

Sample ID	VPH, C5-C6 Aliphatics		LOQ | MDL VPH, C5-C6 Aliphatics	VPH, >C6-C8 Aliphatics		LOQ | MDL VPH, >C6-C8 Aliphatics	VPH, >C8-C10 Aliphatics		LOQ | MDL VPH, >C8-C10 Aliphatics	VPH, >C10-C12 Aliphatics		LOQ | MDL VPH, >C10-C12 Aliphatics
1410045-03	11,000	U	11,000	54,000		11,000	55,000		11,000	29,000		11,000
1410045-04	15,000	U	15,000	220,000		15,000	160,000		15,000	100,000		15,000
1410045-05	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1411036-01	60,000		43,000	450,000		43,000	170,000		43,000	250,000		43,000
1411036-02	84,000		39,000	580,000		39,000	210,000		39,000	98,000		39,000
1411036-03	30,000	U	30,000	96,000		30,000	46,000		30,000	30,000	U	30,000
1411036-04	7,200	U	7,200	73,000		7,200	36,000		7,200	25,000		7,200
1411036-05	7,400	U	7,400	34,000		7,400	14,000		7,400	7,500		7,400
1411036-06	8,400	U	8,400	11,000		8,400	8,400	U	8,400	8,400	U	8,400
1411036-07	8,400	U	8,400	8,400	U	8,400	8,400	U	8,400	8,400	U	8,400
1411036-08	8,200	U	8,200	8,200	U	8,200	8,200	U	8,200	8,200	U	8,200
1411036-09	7,200	U	7,200	7,200	U	7,200	7,200	U	7,200	7,200	U	7,200

Sample ID	VPH, C5-C6 Aliphatics		LOQ | MDL VPH, C5-C6 Aliphatics	VPH, >C6-C8 Aliphatics		LOQ | MDL VPH, >C6-C8 Aliphatics	VPH, >C8-C10 Aliphatics		LOQ | MDL VPH, >C8-C10 Aliphatics	VPH, >C10-C12 Aliphatics		LOQ | MDL VPH, >C10-C12 Aliphatics
1411036-10	6,800	U	6,800	6,800	U	6,800	6,800	U	6,800	6,800	U	6,800
1411036-11	8,500	U	8,500	8,500	U	8,500	8,500	U	8,500	8,500	U	8,500
1411036-12	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1411036-13	7,900	U	7,900	15,000		7,900	7,900		7,900	7,900	U	7,900
1411036-14	7,800	U	7,800	7,800	U	7,800	7,800	U	7,800	7,800	U	7,800
1411036-15	15,000		7,700	190,000		7,700	7,700	U	7,700	96,000		7,700
1412041-01	39,000	U	39,000	39,000	U	39,000	39,000	U	39,000	61,000		39,000
1412041-02	45,000	U	45,000	45,000	U	45,000	45,000	U	45,000	45,000	U	45,000
1412041-03	45,000	U	45,000	45,000	U	45,000	45,000	U	45,000	61,000		45,000
1412041-04	55,000	U	55,000	55,000	U	55,000	55,000	U	55,000	100,000		55,000
1412041-05	48,000	U	48,000	86,000		48,000	48,000	U	48,000	130,000		48,000
1412041-06	44,000	U	44,000	68,000		44,000	44,000	U	44,000	290,000		44,000

Sample ID	VPH, C5-C6 Aliphatics		LOQ | MDL VPH, C5-C6 Aliphatics	VPH, >C6-C8 Aliphatics		LOQ | MDL VPH, >C6-C8 Aliphatics	VPH, >C8-C10 Aliphatics		LOQ | MDL VPH, >C8-C10 Aliphatics	VPH, >C10-C12 Aliphatics		LOQ | MDL VPH, >C10-C12 Aliphatics
1412041-07	56,000	U	56,000	56,000	U	56,000	56,000	U	56,000	56,000	U	56,000
1412041-08	50,000	U	50,000	50,000	U	50,000	50,000	U	50,000	110,000		50,000
1412041-09	79,000	U	79,000	79,000	U	79,000	79,000	U	79,000	79,000	U	79,000
1412041-10	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600
1412041-11	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1412041-12	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1412041-13	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000
1412041-14	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000
1412041-15	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000
1412041-16	20,000	U	20,000	20,000	U	20,000	20,000	U	20,000	20,000	U	20,000
1412041-17	19,000	U	19,000	19,000	U	19,000	19,000	U	19,000	19,000	U	19,000
1412041-18	41,000	U	41,000	41,000	U	41,000	41,000	U	41,000	41,000	U	41,000

Sample ID	VPH, C5-C6 Aliphatics		LOQ | MDL VPH, C5-C6 Aliphatics	VPH, >C6-C8 Aliphatics		LOQ | MDL VPH, >C6-C8 Aliphatics	VPH, >C8-C10 Aliphatics		LOQ | MDL VPH, >C8-C10 Aliphatics	VPH, >C10-C12 Aliphatics		LOQ | MDL VPH, >C10-C12 Aliphatics
1412041-19	260,000	U	260,000	260,000	U	260,000	260,000	U	260,000	260,000	U	260,000
1412041-20	45,000	U	45,000	45,000	U	45,000	45,000	U	45,000	45,000	U	45,000
1412041-21	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600	9,600	U	9,600
1412041-22	75,000	U	75,000	75,000	U	75,000	75,000	U	75,000	75,000	U	75,000
1412041-23	12,000	U	12,000	12,000	U	12,000	12,000	U	12,000	39,000	J	12,000
1412041-24	23,000	U	23,000	23,000	U	23,000	23,000	U	23,000	160,000		23,000
1412041-25	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000	14,000	U	14,000

LOQ=Limit of Quantitation

VPH=Volatile Petroleum Hydrocarbons

Table F-5. Volatile Organic Compounds (BTEX) Results (µg/kg dw).

Sample ID	Benzene		LOQ | MDL Benzene	Toluene		LOQ | MDL Toluene	Ethylbenzene		LOQ | MDL Ethylbenzene	m, p-Xylene		LOQ | MDL m, p-Xylene	o-Xylene		LOQ | MDL o-Xylene	Methyl t-butyl ether		LOQ | MDL Methyl t-butyl ether
1409070-01	450	U	450	450	U	450	450	U	450	890	U	890	450	U	450	450	U	450
1409070-02	860	J	440	1,900	J	440	25,000	E	440	140,000	E	880	40,000	E	440	940	J	440
1409070-03	430	U	430	430	U	430	430	U	430	850	U	850	430	U	430	430	U	430
1409070-04	6,800	U	6,800	6,800	U	6,800	6,800	U	6,800	14,000	U	14,000	6,800	U	6,800	6,800	U	6,800
1409070-05	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,400	U	2,400	1,200	U	1,200	1,200	U	1,200
1409070-06	960	U	960	960	U	960	960	U	960	1,900	U	1,900	960	U	960	960	U	960
1409070-07	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,400	U	2,400	1,200	U	1,200	1,200	U	1,200
1409070-08	1,300	U	1,300	1,300	U	1,300	1,300	U	1,300	2,500	U	2,500	1,300	U	1,300	1,300	U	1,300
1409070-09	1,700	U	1,700	1,700	U	1,700	1,700	U	1,700	3,300	U	3,300	1,700	U	1,700	1,700	U	1,700
1410045-01	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,300	U	2,300	1,200	U	1,200	1,200	U	1,200
1410045-02	1,100	U	1,100	1,100	U	1,100	1,100	U	1,100	2,200	U	2,200	1,100	U	1,100	1,100	U	1,100
1410045-03	1,100	U	1,100	1,100	U	1,100	1,600		1,100	2,100	U	2,100	1,100	U	1,100	1,100	U	1,100

Sample ID	Benzene		LOQ | MDL Benzene	Toluene		LOQ | MDL Toluene	Ethylbenzene		LOQ | MDL Ethylbenzene	m, p-Xylene		LOQ | MDL m, p-Xylene	o-Xylene		LOQ | MDL o-Xylene	Methyl t-butyl ether		LOQ | MDL Methyl t-butyl ether
1410045-04	1,500	U	1,500	1,500	U	1,500	8,300		1,500	3,100	U	3,100	1,900		1,500	1,500	U	1,500
1410045-05	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,400	U	2,400	1,200	U	1,200	1,200	U	1,200
1411036-01	4,300	U	4,300	4,300	U	4,300	18,000		4,300	53,000		8,700	5,200		4,300	4,300	U	4,300
1411036-02	3,900	U	3,900	3,900	U	3,900	7,100		3,900	7,800	U	7,800	3,900	U	3,900	3,900	U	3,900
1411036-03	3,000	U	3,000	3,000	U	3,000	3,000	U	3,000	6,000	U	6,000	3,000	U	3,000	3,000	U	3,000
1411036-04	720	U	720	720	U	720	1,600		720	1,400	U	1,400	720	U	720	720	U	720
1411036-05	740	U	740	740	U	740	740	U	740	1,500	U	1,500	740	U	740	740	U	740
1411036-06	840	U	840	840	U	840	2,200		840	1,700	U	1,700	950		840	840	U	840
1411036-07	840	U	840	840	U	840	940		840	1,700	U	1,700	840	U	840	840	U	840
1411036-08	820	U	820	820	U	820	820	U	820	1,600	U	1,600	820	U	820	820	U	820
1411036-09	720	U	720	720	U	720	720	U	720	1,400	U	1,400	720	U	720	720	U	720
1411036-10	680	U	680	680	U	680	680	U	680	1,400	U	1,400	680	U	680	680	U	680
1411036-11	850	U	850	850	U	850	850	U	850	1,700	U	1,700	850	U	850	850	U	850

Sample ID	Benzene		LOQ | MDL Benzene	Toluene		LOQ | MDL Toluene	Ethylbenzene		LOQ | MDL Ethylbenzene	m, p-Xylene		LOQ | MDL m, p-Xylene	o-Xylene		LOQ | MDL o-Xylene	Methyl t-butyl ether		LOQ | MDL Methyl t-butyl ether
1411036-12	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	3,200		2,400	1,200	U	1,200	1,200	U	1,200
1411036-13	790	U	790	790	U	790	790	U	790	1,600	U	1,600	790	U	790	790	U	790
1411036-14	780	U	780	780	U	780	780	U	780	1,600	U	1,600	780	U	780	780	U	780
1411036-15	770	U	770	2,500		770	27,000		770	50,000		1,500	5,900		770	770	U	770
1412041-01	3,900	U	3,900	3,900	U	3,900	3,900	U	3,900	7,900	U	7,900	3,900	U	3,900	3,900	U	3,900
1412041-02	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	9,100	U	9,100	4,500	U	4,500	4,500	U	4,500
1412041-03	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	9,100	U	9,100	4,500	U	4,500	4,500	U	4,500
1412041-04	5,500	U	5,500	5,500	U	5,500	5,500	U	5,500	14,000		11,000	5,500	U	5,500	5,500	U	5,500
1412041-05	4,800	U	4,800	4,800	U	4,800	6,500		4,800	32,000		9,600	4,800	U	4,800	4,800	U	4,800
1412041-06	4,400	U	4,400	4,400	U	4,400	21,000		4,400	120,000		8,800	4,400	U	4,400	4,400	U	4,400
1412041-07	5,600	U	5,600	5,600	U	5,600	5,600	U	5,600	11,000	U	11,000	5,600	U	5,600	5,600	U	5,600
1412041-08	5,000	U	5,000	5,000	U	5,000	6,100		5,000	29,000		10,000	7,500		5,000	5,000	U	5,000
1412041-09	7,900	U	7,900	7,900	U	7,900	7,900	U	7,900	16,000	U	16,000	7,900	U	7,900	7,900	U	7,900

Sample ID	Benzene		LOQ | MDL Benzene	Toluene		LOQ | MDL Toluene	Ethylbenzene		LOQ | MDL Ethylbenzene	m, p-Xylene		LOQ | MDL m, p-Xylene	o-Xylene		LOQ | MDL o-Xylene	Methyl t-butyl ether		LOQ | MDL Methyl t-butyl ether
1412041-10	960	U	960	960	U	960	960	U	960	1,900	U	1,900	960	U	960	960	U	960
1412041-11	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,400	U	2,400	1,200	U	1,200	1,200	U	1,200
1412041-12	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,500	U	2,500	1,200	U	1,200	1,200	U	1,200
1412041-13	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	2,800	U	2,800	1,400	U	1,400	1,400	U	1,400
1412041-14	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,500	U	2,500	1,200	U	1,200	1,200	U	1,200
1412041-15	1,400	U	1,400	1,400	U	1,400	2,800	U	2,800	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400
1412041-16	2,000	U	2,000	2,000	U	2,000	2,000	U	2,000	4,000	U	4,000	2,000	U	2,000	2,000	U	2,000
1412041-17	1,900	U	1,900	1,900	U	1,900	1,900	U	1,900	3,800	U	3,800	1,900	U	1,900	1,900	U	1,900
1412041-18	4,100	U	4,100	4,100	U	4,100	4,100	U	4,100	8,100	U	8,100	4,100	U	4,100	4,100	U	4,100
1412041-19	26,000	U	26,000	26,000	U	26,000	26,000	U	26,000	52,000	U	52,000	26,000	U	26,000	26,000	U	26,000
1412041-20	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	9,100	U	9,100	4,500	U	4,500	4,500	U	4,500
1412041-21	960	U	960	960	U	960	960	U	960	1,900	U	1,900	960	U	960	960	U	960
1412041-22	7,500	U	7,500	7,500	U	7,500	7,500	U	7,500	15,000	U	15,000	7,500	U	7,500	7,500	U	7,500

Sample ID	Benzene		LOQ | MDL Benzene	Toluene		LOQ | MDL Toluene	Ethylbenzene		LOQ | MDL Ethylbenzene	m, p-Xylene		LOQ | MDL m, p-Xylene	o-Xylene		LOQ | MDL o-Xylene	Methyl t-butyl ether		LOQ | MDL Methyl t-butyl ether
1412041-23	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,400	U	2,400	1,200	U	1,200	1,200	U	1,200
1412041-24	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	4,700	U	4,700	2,300	U	2,300	2,300	U	2,300
1412041-25	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	2,800	U	2,800	1,400	U	1,400	1,400	U	1,400

BTEX=Benzene, Toluene, Ethylbenzene, and Xylenes.

LOQ=Limit of Quantitation

Table F-5 (continued). Volatile Organic Compounds (BTEX) Results (µg/kg dw).

Sample ID	Pentane		LOQ | MDL Pentane	Hexane		LOQ | MDL Hexane	Octane		LOQ | MDL Octane	Decane		LOQ | MDL Decane	Dodecane		LOQ | MDL Dodecane
1409070-01	450	U	450	450	U	450	450	U	450	450	U	450	450	U	450
1409070-02	1,500	J	440	6,900	J	440	16,000	J	440	4,400	J	440	10,000	J	440
1409070-03	430	U	430	430	U	430	430	U	430	430	U	430	430	U	430
1409070-04	6,800	U	6,800	6,800	U	6,800	6,800	U	6,800	6,800	U	6,800	51,000		6,800
1409070-05	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200
1409070-06	960	U	960	960	U	960	960	U	960	960	U	960	960	U	960
1409070-07	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200
1409070-08	1,300	U	1,300	1,300	U	1,300	1,300	U	1,300	1,300	U	1,300	1,300	U	1,300
1409070-09	1,700	U	1,700	1,700	U	1,700	1,700	U	1,700	1,700	U	1,700	26,000		1,700
1410045-01	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,500		1,200
1410045-02	1,100	U	1,100	1,100	U	1,100	1,100	U	1,100	1,100	U	1,100	3,600		1,100
1410045-03	1,100	U	1,100	1,100	U	1,100	4,200		1,100	2,500		1,100	2,500		1,100
1410045-04	1,500	U	1,500	2,900		1,500	18,000		1,500	8,300		1,500	9,800		1,500
1410045-05	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200

Sample ID	Pentane		LOQ | MDL Pentane	Hexane		LOQ | MDL Hexane	Octane		LOQ | MDL Octane	Decane		LOQ | MDL Decane	Dodecane		LOQ | MDL Dodecane
1411036-01	14,000		4,300	18,000		4,300	36,000		4,300	34,000		4,300	16,000		4,300
1411036-02	15,000		3,900	26,000		3,900	19,000		3,900	6,000		3,900	11,000		3,900
1411036-03	3,000	U	3,000	3,000	U	3,000	9,400		3,000	3,000	U	3,000	3,200		3,000
1411036-04	1,200		720	2,300		720	5,800		720	6,000		720	3,400		720
1411036-05	1,000		740	870		740	1,900		740	1,600		740	1,200		740
1411036-06	840	U	840	840	U	840	2,800		840	1,200		840	11,000		840
1411036-07	840	U	840	840	U	840	1,200		840	900		840	7,500		840
1411036-08	820	U	820	820	U	820	820	U	820	820	U	820	1,800		820
1411036-09	720	U	720	720	U	720	720	U	720	720	U	720	720	U	720
1411036-10	680	U	680	680	U	680	680	U	680	680	U	680	680	U	680
1411036-11	850	U	850	850	U	850	850	U	850	850	U	850	850	U	850
1411036-12	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200
1411036-13	790	U	790	790	U	790	790	U	790	1,300		790	1,400		790
1411036-14	780	U	780	780	U	780	780	U	780	780	U	780	780	U	780
1411036-15	2,000		770	3,000		770	9,700		770	11,000		770	6,600		770

Sample ID	Pentane		LOQ | MDL Pentane	Hexane		LOQ | MDL Hexane	Octane		LOQ | MDL Octane	Decane		LOQ | MDL Decane	Dodecane		LOQ | MDL Dodecane
1412041-01	3,900	U	3,900	3,900	U	3,900	3,900	U	3,900	3,900	U	3,900	4,000		3,900
1412041-02	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500
1412041-03	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500
1412041-04	5,500	U	5,500	5,500	U	5,500	5,500	U	5,500	5,500	U	5,500	5,500	U	5,500
1412041-05	4,800	U	4,800	4,800	U	4,800	4,800	U	4,800	8,500		4,800	9,200		4,800
1412041-06	4,400	U	4,400	4,400	U	4,400	7,000		4,400	14,000		4,400	12,000		4,400
1412041-07	5,600	U	5,600	5,600	U	5,600	5,600	U	5,600	5,600	U	5,600	5,600	U	5,600
1412041-08	5,000	U	5,000	5,000	U	5,000	5,000	U	5,000	5,000	U	5,000	5,000	U	5,000
1412041-09	7,900	U	7,900	7,900	U	7,900	7,900	U	7,900	7,900	U	7,900	7,900	U	7,900
1412041-10	960	U	960	960	U	960	960	U	960	960	U	960	2,900		960
1412041-11	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	2,000		1,200
1412041-12	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200
1412041-13	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400
1412041-14	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200
1412041-15	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400

Sample ID	Pentane		LOQ | MDL Pentane	Hexane		LOQ | MDL Hexane	Octane		LOQ | MDL Octane	Decane		LOQ | MDL Decane	Dodecane		LOQ | MDL Dodecane
1412041-16	2,000	U	2,000	2,000	U	2,000	2,000	U	2,000	2,000	U	2,000	2,000	U	2,000
1412041-17	1,900	U	1,900	1,900	U	1,900	1,900	U	1,900	1,900	U	1,900	1,900	U	1,900
1412041-18	4,100	U	4,100	4,100	U	4,100	4,100	U	4,100	4,100	U	4,100	4,100	U	4,100
1412041-19	26,000	U	26,000	26,000	U	26,000	26,000	U	26,000	26,000	U	26,000	26,000	U	26,000
1412041-20	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500	4,500	U	4,500
1412041-21	960	U	960	960	U	960	960	U	960	960	U	960	960	U	960
1412041-22	7,500	U	7,500	7,500	U	7,500	7,500	U	7,500	7,500	U	7,500	7,500	U	7,500
1412041-23	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	1,200	U	1,200	5,000	J	1,200
1412041-24	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,300	U	2,300	2,600		2,300
1412041-25	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400	1,400	U	1,400

BTEX=Benzene, Toluene, Ethylbenzene, and Xylenes.

LOQ=Limit of Quantitation

Appendix G. Bioassay Data

Table G-1. *Eisenia foetida* 14-day survival and normal morphology.

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
Laboratory Control	1	10	100	96.7	5.8			10	100	100	0.0		
	2	10	100					10	100				
	3	9	90					9	100				
1409070-01	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1409070-02	1	10	100	93.3	5.8	96.6	10.6%	10	100	100	0.0	100	2.87%
	2	9	90					9	100				
	3	9	90					9	100				
1409070-03	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1409070-04	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1409070-04 pH	1	0	0	6.7	5.8	6.9	10.6%	0	NA	NA	NA	NA	NA
	2	1	10					1	100				
	3	1	10					1	100				
1409070-05	1	10	100	96.7	5.8	100	10.6%	10	100	100	0.0	100	2.87%
	2	9	90					9	100				
	3	10	100					10	100				
1409070-05 pH	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
	2	10	100					10	100				
	3	10	100					10	100				
1409070-06	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1409070-06 pH	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1409070-07	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1409070-08	1	7	70	90.0	17.3	93.1	23.3%	7	100	100	0.0	100	3.38%
	2	10	100					10	100				
	3	10	100					10	100				
1409070-09	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1410045-01	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1410045-02	1	10	100	96.7	5.8	100	10.6%	10	100	100	0.0	100	2.87%
	2	9	90					9	100				
	3	10	100					10	100				
1410045-02 pH	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
1410045-03	1	10	100	96.7	5.8	100	10.6%	10	100	100	0.0	100	2.87%
	2	10	100					10	100				
	3	9	90					9	100				
1410045-04	1	10	100	96.7	5.8	100	10.6%	10	100	100	0.0	100	2.87%
	2	9	90					9	100				
	3	10	100					10	100				
1410045-04 pH	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1410045-05	1	10	100	96.7	5.8	100	7.35%	10	100	100	0.0	100	2.87%
	2	9	90					9	100				
	3	10	100					10	100				
1411036-01	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-02	1	7	70	90.0	17.3	93.1	7.35%	7	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-03	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-04	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-05	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
	3	10	100					10	100				
1411036-06	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1411036-07	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1411036-08	1	0	0	23.3	20.8	24.1	27.1%	0	NA	NA	NA	NA	NA
	2	4	40					4	100				
	3	3	30					3	100				
1411036-09	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-10	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-11	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-12	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1411036-13	1	10	100	96.7	5.8	100	10.6%	10	100	100	0.0	100	2.87%
	2	10	100					10	100				
	3	9	90					9	100				
1411036-14	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
	2	10	100					10	100				
	3	10	100					10	100				
1411036-15	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1412041-01	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-02	1	5	50	76.7	25.2	79.3	31.1%	5	100	100	0.0	100	4.12%
	2	10	100					10	100				
	3	8	80					8	100				
1412041-03	1	9	90	96.7	5.8	100	10.6%	9	100	100	0.0	100	2.87%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-04	1	9	90	66.7	25.2	69.0	27.6%	9	100	100	0.0	100	4.61%
	2	7	70					7	100				
	3	4	40					4	100				
1412041-05	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1412041-06	1	8	80	83.3	5.8	86.2	9.85%	8	100	100	0.0	100	2.90%
	2	8	80					8	100				
	3	9	90					9	100				
1412041-07	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
1412041-08	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-09	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-10	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1412041-11	1	9	90	80.0	10.0	82.8	13.0%	9	100	100	0.0	100	3.10%
	2	8	80					8	100				
	3	7	70					7	100				
1412041-12	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-13	1	9	90	96.7	5.8	100	10.6%	9	100	100	0.0	100	2.87%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-14	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-15	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-16	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
	3	0	0					0	NA				
1412041-17	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1412041-18	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1412041-19	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1412041-20	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-21	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-22	1	10	100	100	0.0	103	7.35%	10	100	100	0.0	100	2.79%
	2	10	100					10	100				
	3	10	100					10	100				
1412041-23	1	0	0	0.0	0.0	0.0	7.35%	0	NA	NA	NA	NA	NA
	2	0	0					0	NA				
	3	0	0					0	NA				
1412041-24	1	7	70	70.0	0.0	72.4	10.2%	7	100	100	0.0	100	2.79%
	2	7	70					7	100				
	3	7	70					7	100				
1412041-25	1	8	80	90.0	10.0	93.1	14.8%	8	100	100	0.0	100	3.03%

Test Initiated January 21, 2015		Survival						Normal Morphology					
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	# Normal	% Normal	Mean % Normal	St. Dev.	% of Control	PMSD
	2	10	100					10	100				
	3	9	90					9	100				

NA: Not available; no survivors so endpoint could not be measured
PMSD: Percent Minimum Significant Difference
Gray: Significantly different from control

Table G-2. *Lactuca sativa* 14-day survival, wet weight, and dry weight.

Test Initiated January 21, 2015		**Survival**						**Wet Weight**					**Dry Weight**				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
Laboratory Control I	1	5	100	100.0	0.0			0.08784	92.7	5.73			0.00664	7.24	0.63		
	2	5	100					0.10025					0.00804				
	3	5	100					0.08909					0.00702				
	4	5	100					0.08730					0.00656				
	5	5	100					0.09913					0.00792				
Laboratory Control 2[a]	1	5	100	96.0	8.9			0.09495	102.7	8.86			0.00840	8.48	0.75		
	2	5	100					0.09509					0.00743				
	3	4	80					0.11884					0.00963				
	4	5	100					0.09963					0.00805				
	5	5	100					0.10479					0.00890				
1409070-01	1	5	100	96	8.9	96	9.54%	0.02263	19.7	2.65	21.2	6.33%	0.00258	2.18	0.36	30.1	9.26%
	2	5	100					0.01833					0.00203				
	3	5	100					0.02303					0.00232				
	4	5	100					0.01794					0.00240				
	5	4	80					0.01647					0.00156				
1409070-02	1	5	100	32	46	32	46.7%	0.01038	7.02	9.73	6.84	16.34%	0.00134	0.77	1.02	9.1	16.7%
	2	3	60					0.02473					0.00254				
	3	0	0					0.00000					0.00000				
	4	0	0					0.00000					0.00000				
	5	0	0					0.00000					0.00000				
1409070-03	1	5	100	100	0.0	100	0.00%	0.01740	19.3	2.70	20.8	6.35%	0.00169	1.86	0.30	25.6	8.95%
	2	5	100					0.02304					0.00222				
	3	5	100					0.02066					0.00182				
	4	5	100					0.01526					0.00139				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	5	100					0.02019					0.00215				
1409070-04	1	4	80	84	17	84	14.2%	0.01678	14.0	2.23	15.1	6.16%	0.00195	1.52	0.31	21.0	8.97%
	2	5	100					0.01510					0.00141				
	3	5	100					0.01009					0.00116				
	4	3	60					0.01358					0.00126				
	5	4	80					0.01465					0.00180				
1409070-04 pH	1	5	100	88	18	88	15.0%	0.01085	13.8	2.32	14.9	6.20%	0.00094	1.41	0.36	19.5	9.27%
	2	4	80					0.01301					0.00203				
	3	5	100					0.01635					0.00139				
	4	3	60					0.01202					0.00123				
	5	5	100					0.01662					0.00148				
1409070-05	1	5	100	96	8.9	96	9.5%	0.02247	22.9	1.99	24.7	6.08%	0.00205	2.24	0.22	31.0	8.55%
	2	5	100					0.02277					0.00220				
	3	5	100					0.02190					0.00211				
	4	5	100					0.02669					0.00267				
	5	4	80					0.02085					0.00218				
1409070-05 pH	1	4	80	88	11	88	10.7%	0.03155	36.4	6.20	39.3	8.46%	0.00193	2.64	0.52	36.5	10.4%
	2	5	100					0.04159					0.00327				
	3	4	80					0.04088					0.00294				
	4	4	80					0.02666					0.00214				
	5	5	100					0.04156					0.00293				
1409070-06	1	2	40	72	23	72	17.7%	0.01666	15.8	1.03	17.1	6.69%	0.00134	1.30	0.07	18.0	9.29%
	2	5	100					0.01722					0.00132				
	3	3	60					0.01481					0.00117				
	4	4	80					0.01600					0.00132				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	4	80					0.01456					0.00135				
1409070-06 pH	1	5	100	96	8.9	96	9.54%	0.07015	64.7	6.42	69.8	8.63%	0.00522	4.54	0.59	62.7	11.09%
	2	4	80					0.06709					0.00444				
	3	5	100					0.07215					0.00523				
	4	5	100					0.05763					0.00398				
	5	5	100					0.05662					0.00383				
1409070-07	1	5	100	88	11	88	10.7%	0.02130	18.0	2.62	19.4	6.32%	0.00216	1.98	0.36	27.4	9.3%
	2	4	80					0.01830					0.00197				
	3	4	80					0.01659					0.00174				
	4	5	100					0.01378					0.00150				
	5	4	80					0.01987					0.00254				
1409070-08	1	5	100	88	11	88	10.7%	0.02169	22.1	1.34	23.8	5.90%	0.00239	2.07	0.32	28.6	9.07%
	2	4	80					0.02289					0.00164				
	3	4	80					0.02215					0.00206				
	4	4	80					0.02392					0.00246				
	5	5	100					0.01990					0.00178				
1409070-09	1	5	100	88	11	88	10.7%	0.00779	9.56	2.69	10.3	6.35%	0.00086	0.84	0.15	11.7	8.28%
	2	5	100					0.00596					0.00059				
	3	4	80					0.00941					0.00105				
	4	4	80					0.01071					0.00085				
	5	4	80					0.01391					0.00088				
1410045-01	1	3	60	76	8.9	76	9.17%	0.03311	30.3	2.55	32.6	6.29%	0.00246	2.53	0.21	35.0	8.51%
	2	4	80					0.02705					0.00222				
	3	4	80					0.02775					0.00244				
	4	4	80					0.03302					0.00281				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	4	80					0.03044					0.00273				
1410045-02	1	5	100	100	0.0	100	0.00%	0.02529	28.5	2.59	30.8	6.31%	0.00217	2.31	0.25	31.9	8.68%
	2	5	100					0.02892					0.00201				
	3	5	100					0.02677					0.00213				
	4	5	100					0.02877					0.00256				
	5	5	100					0.03298					0.00265				
1410045-02 pH	1	5	100	100	0.0	100	5.33%	0.07667	76.3	8.06	82.3	9.92%	0.00472	4.61	0.86	63.8	13.6%
	2	6	100					0.08454					0.00557				
	3	5	100					0.07703					0.00329				
	4	5	100					0.08189					0.00544				
	5	5	100					0.06130					0.00406				
1410045-03	1	5	100	92	11	92	10.7%	0.01456	16.5	1.58	17.8	5.96%	0.00119	1.33	0.17	18.3	8.35%
	2	5	100					0.01613					0.00128				
	3	4	80					0.01795					0.00162				
	4	4	80					0.01866					0.00140				
	5	5	100					0.01515					0.00114				
1410045-04	1	3	60	92	18	92	16.8%	0.00797	10.7	1.58	10.4	9.34%	0.00079	1.01	0.13	11.9	9.54%
	2	5	100					0.01053					0.00097				
	3	5	100					0.01137					0.00105				
	4	5	100					0.01091					0.00105				
	5	5	100					0.01281					0.00119				
1410045-04 pH	1	5	100	92	18	92	14.9%	0.02793	24.1	3.75	26.0	6.87%	0.00235	1.90	0.41	26.3	9.59%
	2	5	100					0.01877					0.00131				
	3	3	60					0.02183					0.00164				
	4	5	100					0.02312					0.00186				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	5	100					0.02869					0.00235				
1410045-05	1	5	100	100	0.0	100	0.00%	0.01716	17.4	1.40	18.8	5.91%	0.00186	1.85	0.12	25.5	9.39%
	2	5	100					0.01680					0.00194				
	3	5	100					0.01536					0.00162				
	4	5	100					0.01832					0.00191				
	5	5	100					0.01949					0.00189				
1411036-01	1	5	100	88	11	88	10.7%	0.01562	12.1	2.43	13.1	6.24%	0.00135	2.26	1.19	31.2	17.2%
	2	4	80					0.01244					0.00456				
	3	4	80					0.00925					0.00215				
	4	4	80					0.00964					0.00182				
	5	5	100					0.01379					0.00142				
1411036-02	1	5	100	92	11	92	10.7%	0.02108	18.2	2.62	19.7	6.32%	0.00204	1.69	0.20	23.3	8.47%
	2	4	80					0.01759					0.00148				
	3	4	80					0.01347					0.00150				
	4	5	100					0.01944					0.00173				
	5	5	100					0.01953					0.00170				
1411036-03	1	4	80	92	11	92	10.75%	0.01363	21.0	8.03	22.6	9.89%	0.00169	1.70	0.24	23.6	8.63%
	2	4	80					0.01636					0.00167				
	3	5	100					0.01544					0.00166				
	4	5	100					0.03536					0.00138				
	5	5	100					0.02401					0.00213				
1411036-04	1	5	100	96	8.9	96	9.67%	0.01515	15.7	1.59	16.9	5.96%	0.00146	1.62	0.18	22.4	8.38%
	2	5	100					0.01331					0.00140				
	3	5	100					0.01645					0.00186				
	4	6	100					0.01816					0.00179				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	4	80					0.01551					0.00160				
1411036-05	1	5	100	96	8.9	96	9.67%	0.01798	18.6	1.32	20.1	5.90%	0.00172	1.83	0.19	25.3	8.41%
	2	5	100					0.01664					0.00219				
	3	5	100					0.01834					0.00185				
	4	6	100					0.02026					0.00170				
	5	4	80					0.01989					0.00170				
1411036-06	1	4	80	92	11	92	10.7%	0.01250	13.9	1.58	15.0	5.96%	0.00116	1.32	0.22	18.3	8.55%
	2	5	100					0.01671					0.00138				
	3	5	100					0.01230					0.00105				
	4	4	80					0.01407					0.00170				
	5	5	100					0.01408					0.00131				
1411036-07	1	3	60	60	14	60	11.7%	0.01604	11.1	5.74	12.0	8.13%	0.00115	1.07	0.24	14.8	8.61%
	2	4	80					0.01544					0.00138				
	3	2	40					0.00161					0.00090				
	4	3	60					0.01514					0.00121				
	5	3	60					0.00722					0.00071				
1411036-08	1	5	100	96	8.9	96	9.54%	0.01689	16.8	1.59	18.1	5.96%	0.00158	1.59	0.32	22.0	9.07%
	2	5	100					0.01662					0.00138				
	3	5	100					0.01866					0.00222				
	4	5	100					0.01789					0.00133				
	5	4	80					0.01399					0.00144				
1411036-09	1	5	100	92	11	92	10.7%	0.00745	8.6	4.52	9.3	7.32%	0.00135	1.60	0.19	22.1	8.43%
	2	5	100					0.01739					0.00166				
	3	5	100					0.00746					0.00146				
	4	4	80					0.00627					0.00193				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	4	80					0.00447					0.00161				
1411036-10	1	4	80	92	11	92	10.7%	0.00866	11.3	4.74	12.1	7.46%	0.00110	1.44	0.20	19.9	8.47%
	2	5	100					0.01470					0.00158				
	3	4	80					0.00326					0.00139				
	4	5	100					0.01633					0.00142				
	5	5	100					0.01331					0.00170				
1411036-11	1	5	100	100	0.0	100	0.00%	0.02775	27.8	6.74	30.0	8.87%	0.00241	2.19	0.19	30.3	8.42%
	2	5	100					0.04042					0.00188				
	3	5	100					0.02310					0.00234				
	4	5	100					0.02112					0.00207				
	5	5	100					0.02674					0.00224				
1411036-12	1	4	80	92	11	92	10.7%	0.02107	18.2	3.10	19.6	6.53%	0.00161	1.61	0.26	22.2	8.74%
	2	4	80					0.02011					0.00181				
	3	5	100					0.02038					0.00193				
	4	5	100					0.01659					0.00153				
	5	5	100					0.01282					0.00116				
1411036-13	1	5	100	92	11	92	10.7%	0.01638	19.2	2.36	20.7	6.21%	0.00151	1.96	0.61	27.1	11.2%
	2	5	100					0.01756					0.00159				
	3	5	100					0.02214					0.00187				
	4	4	80					0.02187					0.00315				
	5	4	80					0.01799					0.00168				
1411036-14	1	5	100	96	8.9	96	9.54%	0.02165	15.9	3.85	17.2	6.92%	0.00179	1.45	0.29	20.0	8.89%
	2	5	100					0.01431					0.00146				
	3	5	100					0.01006					0.00090				
	4	4	80					0.01800					0.00154				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	5	100					0.01562					0.00154				
1411036-15	1	3	60	56	22	56	16.6%	0.01077	14.0	3.97	15.1	6.99%	0.00279	2.13	0.44	29.5	9.86%
	2	4	80					0.01276					0.00147				
	3	3	60					0.01229					0.00213				
	4	1	20					0.02183					0.00237				
	5	3	60					0.01233					0.00191				
1412041-01	1	5	100	92	11	92	10.7%	0.01845	16.4	3.66	17.7	6.82%	0.00158	1.42	0.22	19.6	8.53%
	2	5	100					0.01275					0.00115				
	3	4	80					0.01553					0.00140				
	4	4	80					0.02235					0.00173				
	5	5	100					0.01276					0.00122				
1412041-02	1	5	100	96	8.9	96	9.54%	0.01816	16.5	1.88	17.8	6.05%	0.00153	1.51	0.17	20.9	8.34%
	2	5	100					0.01372					0.00183				
	3	5	100					0.01472					0.00144				
	4	5	100					0.01821					0.00135				
	5	4	80					0.01755					0.00141				
1412041-03	1	5	100	96	8.9	96	9.54%	0.01432	15.6	2.92	16.8	6.45%	0.00128	1.36	0.27	18.8	8.76%
	2	5	100					0.01046					0.00091				
	3	4	80					0.01715					0.00145				
	4	5	100					0.01829					0.00143				
	5	5	100					0.01781					0.00173				
1412041-04	1	4	80	92	11	92	10.7%	0.01548	15.3	1.36	16.5	5.90%	0.00156	1.33	0.16	18.4	8.32%
	2	5	100					0.01667					0.00141				
	3	5	100					0.01385					0.00118				
	4	5	100					0.01363					0.00111				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	4	80					0.01687					0.00139				
1412041-05	1	4	80	84	17	84	16.08%	0.01724	16.5	2.54	16.1	8.34%	0.00192	1.74	0.74	20.6	11.5%
	2	3	60					0.01983					0.00064				
	3	4	80					0.01816					0.00294				
	4	5	100					0.01270					0.00165				
	5	5	100					0.01467					0.00157				
1412041-06	1	3	60	76	17	76	14.1%	0.01825	13.2	4.04	14.2	7.03%	0.00246	1.85	0.35	25.6	9.20%
	2	4	80					0.01793					0.00196				
	3	4	80					0.00985					0.00159				
	4	3	60					0.00908					0.00148				
	5	5	100					0.01088					0.00175				
1412041-07	1	6	100	100	0.0	100	5.33%	0.01195	16.4	2.65	17.7	6.33%	0.00143	1.63	0.18	22.5	8.37%
	2	5	100					0.01828					0.00164				
	3	5	100					0.01584					0.00148				
	4	5	100					0.01608					0.00193				
	5	5	100					0.01976					0.00167				
1412041-08	1	5	100	96	8.9	96	9.54%	0.01926	14.9	3.73	16.1	6.85%	0.00140	1.39	0.24	19.2	8.64%
	2	5	100					0.01271					0.00168				
	3	5	100					0.01310					0.00110				
	4	5	100					0.01933					0.00165				
	5	4	80					0.01012					0.00114				
1412041-09	1	5	100	96	8.9	96	9.54%	0.02189	23.3	2.94	25.2	6.46%	0.00152	1.68	0.29	23.2	8.88%
	2	5	100					0.02532					0.00184				
	3	4	80					0.02523					0.00198				
	4	5	100					0.02599					0.00187				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	5	100					0.01818					0.00118				
1412041-10	1	2	40	32	11	32	12.2%	0.01566	13.2	3.08	12.9	8.49%	0.00150	1.33	0.20	15.7	8.47%
	2	2	40					0.00770					0.00102				
	3	2	40					0.01386					0.00141				
	4	1	20					0.01253					0.00119				
	5	1	20					0.01643					0.00153				
1412041-11	1	5	100	100	0.0	100	0.00%	0.01999	26.8	5.94	28.9	8.28%	0.00205	2.25	0.28	31.0	8.80%
	2	5	100					0.02116					0.00181				
	3	5	100					0.02801					0.00240				
	4	5	100					0.03650					0.00258				
	5	5	100					0.02851					0.00238				
1412041-12	1	4	80	96	8.9	96	9.54%	0.01914	18.2	3.10	19.7	6.53%	0.00178	1.66	0.23	22.9	8.58%
	2	5	100					0.01261					0.00128				
	3	5	100					0.01763					0.00152				
	4	5	100					0.02172					0.00186				
	5	5	100					0.02003					0.00186				
1412041-13	1	5	100	100	0.0	100	0.00%	0.03531	38.9	5.23	42.0	7.78%	0.00375	4.22	1.16	58.3	17.0%
	2	5	100					0.03735					0.00383				
	3	5	100					0.04330					0.00380				
	4	5	100					0.03220					0.00322				
	5	5	100					0.04646					0.00651				
1412041-14	1	5	100	96	8.9	96	9.54%	0.01707	17.5	2.18	18.9	6.15%	0.00477	2.31	1.23	31.9	17.8%
	2	4	80					0.01386					0.00148				
	3	5	100					0.02064					0.00178				
	4	5	100					0.01825					0.00172				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	5	100					0.01762					0.00181				
1412041-15	1	5	100	92	11	92	10.7%	0.03575	34.1	2.49	36.8	6.26%	0.00314	2.76	0.20	38.1	8.45%
	2	4	80					0.03733					0.00272				
	3	5	100					0.03496					0.00273				
	4	5	100					0.03223					0.00255				
	5	4	80					0.03042					0.00266				
1412041-16	1	4	80	76	22	76	16.9%	0.01813	22.3	2.99	24.1	6.48%	0.00153	1.88	0.21	25.9	8.51%
	2	2	40					0.02614					0.00194				
	3	5	100					0.01958					0.00184				
	4	4	80					0.02415					0.00219				
	5	4	80					0.02368					0.00187				
1412041-17	1	5	100	68	23	68	17.8%	0.02154	23.4	2.19	25.3	6.15%	0.00141	2.03	0.41	28.1	9.61%
	2	3	60					0.02207					0.00194				
	3	3	60					0.02244					0.00203				
	4	2	40					0.02763					0.00268				
	5	4	80					0.02349					0.00211				
1412041-18	1	4	80	72	11	72	12.2%	0.01351	16.6	2.00	16.1	8.22%	0.00194	2.01	0.29	23.7	8.77%
	2	4	80					0.01837					0.00243				
	3	3	60					0.01530					0.00154				
	4	3	60					0.01897					0.00209				
	5	4	80					0.01674					0.00205				
1412041-19	1	3	60	64	17	64	15.2%	0.00310	3.8	1.41	3.7	9.31%	0.00043	0.59	0.19	6.99	8.45%
	2	4	80					0.00511					0.00080				
	3	4	80					0.00155					0.00034				
	4	3	60					0.00381					0.00060				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	2	40					0.00542					0.00080				
1412041-20	1	5	100	72	30	72	26.7%	0.01332	17.9	4.53	19.3	7.32%	0.00126	1.65	0.32	22.8	9.05%
	2	2	40					0.01269					0.00169				
	3	2	40					0.02431					0.00164				
	4	5	100					0.02154					0.00146				
	5	4	80					0.01748					0.00222				
1412041-21	1	3	60	68	11	68	10.3%	0.02959	22.6	9.78	24.4	11.36%	0.00183	2.06	0.22	28.5	8.55%
	2	3	60					0.02715					0.00234				
	3	4	80					0.00357					0.00222				
	4	3	60					0.02937					0.00178				
	5	4	80					0.02321					0.00216				
1412041-22	1	4	80	76	17	76	16.0%	0.01693	25.3	4.28	24.7	8.91%	0.00173	2.44	0.39	28.8	9.24%
	2	3	60					0.02612					0.00232				
	3	4	80					0.02778					0.00270				
	4	3	60					0.02723					0.00268				
	5	5	100					0.02862					0.00279				
1412041-23	1	0	0	36	33	36	27.5%	0.00000	9.4	4.93	9.1	9.40%	0.00000	0.92	0.49	10.9	9.70%
	2	1	20					0.01258					0.00112				
	3	1	20					0.01168					0.00113				
	4	4	80					0.00903					0.00093				
	5	3	60					0.01364					0.00145				
1412041-24	1	4	80	88	18	88	15.0%	0.01409	12.0	1.27	13.0	5.88%	0.00159	1.40	0.14	19.3	8.24%
	2	5	100					0.01166					0.00127				
	3	5	100					0.01077					0.00143				
	4	5	100					0.01282					0.00122				

Test Initiated January 21, 2015		Survival						Wet Weight					Dry Weight				
Sample ID	Rep	# Alive	% Survival	Mean % Survival	St. Dev.	% of Control	PMSD	Wet Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD	Dry Weight / Org (mg)	Mean Mass / Org (mg)	St. Dev.	% of Control	PMSD
	5	3	60					0.01081					0.00148				
1412041-25	1	5	100	96	8.9	96	9.5%	0.02768	24.4	2.68	26.3	6.34%	0.00233	1.93	0.25	26.7	8.69%
	2	5	100					0.02618					0.00196				
	3	4	80					0.02029					0.00164				
	4	5	100					0.02539					0.00204				
	5	5	100					0.02239					0.00168				

a. Samples compared to control 2: 1409070-02, 1410045-04, 1412041-05, 1412041-10, 141204-18, 141204-19, 141204-22, 141204-23

Note: There were six seeds initiated in one replicate for samples 1410045-02 pH, 1411036-04, 1411036-05, 1412041-07

NA: Not available; no survivors so endpoint could not be measured

PMSD: Percent Minimum Significant Difference

Gray: Significantly different from control

Appendix H. Glossary, Acronyms, and Abbreviations

Glossary

Bioaccumulation: General term describing a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical.

LC_{25}: LC_{25} is the median lethal concentration or the concentration of a substance at which 25% of the test population are killed.

LC_{50}: LC_{50} is the median lethal concentration or the concentration of a substance at which 25% of the test population are killed.

NWTPH-Dx: The qualitative and quantitative method (extended) for semi-volatile ("diesel") petroleum products in soil and water.

NWTPH-Gx: The qualitative and quantitative method (extended) for volatile ("gasoline") petroleum products in soil and water.

NWTPH-HCID: A qualitative and semi-quantitative screen to determine the presence and type of petroleum products that may exist in water or soil.

Model Toxic Control Act (MTCA): A comprehensive regulatory scheme to identify, investigate, and clean up contaminated properties that are, or may be, a threat to human health or the environment.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Percent Minimum Significant Difference (PMSD): The smallest difference which would be statistically significant expressed as the percent difference from control response. For example, a PMSD of 15% means that a 15% reduction in survival, etc. from the control would be significant but a 14% reduction would not.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Photoionization Detector (PID): A portable instrument that measures volatile organic compounds and other gases in concentrations from sub parts per billion to 10 000 parts per million (ppm).

Phytotoxicity: A toxic effect by a compound on plant growth.

XRF: Instrument that measures metal concentrations using X-rays.

Acronyms and Abbreviations

BTEX	Benzene, toluene, ethylbenzene, and xylenes
DRO	Diesel range organics
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
EPH	Extractable Petroleum Hydrocarbons
GRO	Gasoline range organics
i.e.	That is
LC_{XX}	Lethal concentration at percent (xx) of population died
LOAEL	Lowest Observed Adverse Effect Level
MEL	Manchester Environmental Laboratory
MTCA	Model Toxic Control Act
NWTPH-Dx	Northwest TPH hydrocarbon-Dx (extended)
NWTPH-Gx	Northwest TPH hydrocarbon-Gx (extended)
NWTPH-HCID	Northwest TPH hydrocarbon Identification
PID	Photoionization Detector
PMSD	Percent Minimum Significant Difference
QAPP	Quality Assurance Project Plan
QC	Quality control
TEE	Terrestrial Ecological Evaluations
TOC	Total organic carbon
TPH	Total petroleum hydrocarbon
VPH	Volatile Petroleum Hydrocarbons
VOC	Volatile Organic Compounds
WAC	Washington Administrative Code
XRF	X-ray fluorescence instrument

Units of Measurement

dw	dry weight
ft	feet
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
mg	milligram
mg/kg	milligrams per kilogram (parts per million)
µg/kg	micrograms per kilogram (parts per billion)
ww	wet weight