REMEDIAL INVESTIGATION WORK PLAN

Texaco Strickland Cleanup Site
6808 196th Street Southwest
Lynnwood, Washington 98036

Prepared for: Strickland Real Estate Holdings, LLC and
Chevron Environmental Management Company

Project No. 180357 • March 6, 2019 • Final

earth + water

Aspect
CONSULTING

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1 Introduction

Aspect Consulting, LLC (Aspect) prepared this Remedial Investigation Work Plan (RI Work Plan) for the Texaco Strickland Cleanup Site (the Site), located at 6808 196th Street Southwest in Lynnwood, Washington (the Property; Figure 1). The Property is recorded by the Snohomish County Tax Assessor as tax parcel #27042000200600. Preparation of this RI Work Plan was conducted in compliance with Washington State Department of Ecology (Ecology) Agreed Order 14315 (Appendix A), issued to potentially liable parties (PLPs) Strickland Real Estate Holdings, LLC (SREH) and Chevron Environmental Management Company (CEMC).

The Property was historically occupied by a Texaco-branded service station from about 1959 until 1974. From 1977 until 2006, the Property was operated as an automotive lube oil facility. The Property is currently occupied by the Aloha Café.

Releases of petroleum products have occurred at the Property. Petroleum releases have impacted soil, groundwater, and soil vapor on the Property and have potentially migrated onto adjacent properties. On-Property activities to characterize the nature and extent of petroleum impacts to date have been completed by Conestoga-Rovers & Associates (CRA), on behalf of Shell, as a former operator of the lube oil facility on the Property. CRA completed an initial RI of the Site in 2011 (CRA, 2011), which is included as Appendix B and provides the framework for identification of additional RI investigation activities necessary to complete the Site RI and subsequent Feasibility Study (FS).

Data gaps were identified through review of CRA's 2011 RI, review of additional historical Site files, and review of environmental assessment work completed at the adjacent Chri-Mar Apartments property located south of the Property. The identified Site characterization data gaps are related to both petroleum releases from operation of the former Texaco service station and from operation of the subsequent lube facility. Additionally, releases of chlorinated solvents from a historical dry cleaner (Slater's 1-Hour Cleaner) on the contiguous property to the west have impacted soil and groundwater. These chlorinated solvents may be commingled with petroleum compounds in groundwater in the southwestern area of the Site.

This RI Work Plan addresses resolution of all presently identified Site characterization data gaps. The Work Plan summarizes the Site investigation and remedial action history, identifies existing data gaps for all affected media, and presents a scope of work to address the identified Site data gaps.

2 Site Setting

2.1 Property Description

The Property is zoned as commercial and is currently occupied by the Aloha Café. Surrounding parcels are zoned as both commercial and residential.

The contiguous parcel to the west of the Property is occupied by a strip mall, which includes a historical dry cleaner (Slater's 1-Hour Cleaners). Chlorinated solvents have been confirmed in soil and groundwater at that property.

A strip mall is also located to the north across 196th Street SW. This property was historically occupied by a Shell service station, which had confirmed releases of petroleum hydrocarbons to soil and groundwater.

The parcel to the east of the Property, across 68th Ave W, is currently used as parking for Edmonds Community College. This parcel was previously occupied by an Exxon-branded service station, which had confirmed releases of petroleum hydrocarbons to soil and groundwater. A remedial excavation was conducted on the parcel in 2005, and a No Further Action (NFA) determination was issued by Ecology in 2007.

The contiguous parcel to the south is occupied by the Chri-Mar Apartments.

2.2 Site Geology and Hydrogeology

Based on review of drilling logs in CRA's 2011 RI, Site soil is interpreted to consist of imported fill to depths of approximately 7.5 feet below ground surface (bgs). This fill soil is underlain by unconsolidated silt, sand, gravel, and clay characteristic of a weathered glacial lacustrine deposit. The lacustrine deposit increases in density from 18 feet bgs to 32.5 feet bgs, the maximum depth explored at the Site.

Shallow groundwater is present in the weathered glacial soil at depths varying seasonally from approximately 6 to 15 feet bgs. Groundwater flow at the Site is generally to the southwest, with some documented seasonal variation.

3 Summary of Prior Site RI and Cleanup Activities

3.1 1977 Underground Storage Tank Closure

The Property was occupied by a Texaco-branded service station from 1959 until 1974. CRA (2011) reported that three gasoline underground storage tanks (USTs) were likely present on the Property, and that these USTs were decommissioned in 1977 when the Property was converted to a lube oil facility. The pre-1977 USTs were reportedly located in the northeastern corner of the Property, and the dispenser islands were located in the north-central portion of the Property (Figure 2). Details on the means and methods of decommissioning of the service station infrastructure and USTs are unknown.

3.2 1995 Underground Storage Tank Closure and Soil Characterization.

Petroleum-impacted soil related to the former lube oil facility was discovered in 1995 during removal of a 3,000-gallon lube oil UST and closure-in-place of a 500-gallon waste oil UST (Figure 3). Nowicki & Associates (Nowicki) oversaw the removal of approximately 65 tons of soil impacted with total petroleum hydrocarbons as oil (TPHo) above Washington Model Toxics Control Act (MTCA) Method A cleanup level from the area of the former 3,000-gallon UST (Nowicki, 1995). Post-excavation sidewall and bottom samples collected by Nowicki confirmed successful removal of soils impacted by TPHo.

The 500-gallon waste oil UST located beneath the building was decommissioned by cleaning and slurry filling. A soil boring was advanced approximately 4 feet south of the tank fill, and samples were collected and analyzed for both TPHo and total petroleum hydrocarbons as gasoline (TPHg). Both TPHo and TPHg were detected at concentrations exceeding MTCA Method A cleanup levels. No remediation of the impacted soil in this area has been completed to date.

The releases were reported to Ecology in 1995. The Site was subsequently listed with Ecology’s leaking underground storage tank (LUST) program, as Site ID #6802.

3.3 Historical Environmental Investigations

The following summaries present the results of completed historical Site investigations. These summaries are in part excerpted directly from Appendix B of CRA (2011), included as Appendix B to this RI Work Plan.

3.3.1 1995 Soil Characterization Report:

In November 1995, Nowicki conducted an investigation to characterize subsurface impacts to soil and groundwater on the Property (Nowicki, 1995). Two soil borings, SB1 and SB2, were advanced to the north of the former waste oil UST. Laboratory analytical results indicated concentrations of TPH as gasoline (TPHg) and benzene, toluene, ethylbenzene, and xylenes (BTEX) above the MTCA Method A screening levels. More information is available in Nowicki’s *Waste Oil UST – Characterization Soil Boring*, dated November 20, 1995.

3.3.2 2003 Phase I Environmental Site Assessment:

In January 2003, FINEnvironmental, Inc. (FINE) conducted a Phase I Site Environmental Site Assessment (ESA) of the Property (FINE, 2003). Results of the Phase I ESA indicated that the Property was occupied by a Texaco-branded gasoline service station prior to 1977. Results also identified Leaking UST (LUST) sites at adjacent properties to the north and east. More information is available in FINE’s *Phase I Environmental Site Assessment Limited Compliance Audit*, dated January 28, 2003 (FINE, 2003).

3.3.3 2004 Phase I Environmental Assessment:

GeoEngineers, Inc. (GeoEngineers) completed a limited Phase I ESA in December 2003, prior to Shell's purchase of the Jiffy Lube facility on the Property (GeoEngineers, 2004). Results of the ESA indicated similar findings of the Phase I ESA conducted by FINE in 2003. Complete information is available in GeoEngineers' *Limited Phase I Environmental Site Assessment*, dated February 11, 2004 (GeoEngineers, 2004).

3.3.4 November 2006 Site Investigation:

In November 2006, Cambria Environmental Technology (Cambria) installed five monitoring wells (MW-1 through MW-5) and advanced one soil boring (SB-1) at the Property. Soil samples were collected from each boring and submitted for laboratory analysis. Analytical results indicated benzene concentrations above the MTCA Method A cleanup level in soil samples collected from each of the soil borings. TPHg, toluene, ethylbenzene, and total xylenes were also detected above MTCA Method A cleanup levels in soil samples from borings MW-3, MW-4, and MW-5. Complete information is available in Conestoga-Rovers & Associates' (CRA) *Site Investigation Report*, dated May 31, 2007.

3.3.5 July 2007 Site Investigation:

In July 2007, CRA conducted an additional Site investigation, including the installation of five monitoring wells (MW-6 through MW-10). Laboratory analytical results from soil samples collected from four out of five well borings indicated concentrations of benzene above the MTCA Method A cleanup level. TPHg and total xylenes concentrations were additionally detected above the MTCA Method A cleanup levels in soil samples collected from boring MW-8 at 15 and 20 feet bgs. Complete information is available in CRA's *Site Investigation Report*, dated October 23, 2007.

3.3.6 August 2011 Remedial Investigation Report

CRA completed an RI for the Site in August 2011. The RI compiled and tabulated all historical Site soil and groundwater data collected through July 2010. The CRA RI presented a summary of soil and groundwater conditions for most on-Property areas and provided a detailed evaluation of Site geology and hydrogeology. CRA concluded that releases from former service station operations were the primary cause of the documented soil and groundwater impacts, and that releases related to operation of the former lube oil facility were limited to soil impacts beneath the existing Aloha Café building. This Work Plan will evaluate all potential sources to the Site, including documented upgradient sources.

Information from the CRA RI formed the primary basis for evaluation of Site data gaps, and preparation of this RI Work Plan.

3.3.7 Groundwater Quality Monitoring 2006-2012

Groundwater monitoring has occurred periodically at up to ten monitoring wells (MW-1 through MW-10) since Cambria's initial subsurface investigation in 2006. The most recent reported groundwater monitoring occurred in October 2012. The existing monitoring well locations are shown on Figure 4. Groundwater samples have been analyzed routinely for TPHg, TPHd, TPHo, BTEX, and periodically for fuel additives and lead. A comprehensive tabulated summary of historical groundwater analytical results is presented in CRA's *2012 Annual Groundwater Monitoring Report* (CRA, 2013).

3.3.8 Light Non-Aqueous Phase Liquid Monitoring 2006-2012

Light non-aqueous phase liquid has been measured periodically in monitoring wells MW-3, MW-4, and MW-5. Measured LNAPL thickness has ranged from 0.01 feet to 0.49 feet, with the thickest accumulation measured in MW-5 in November 2012 (Appendix B). Trace amounts of LNAPL have also periodically been documented in monitoring well MW-8. The top of well screen in MW-8 is generally located below the static water table, so the presence and thickness of LNAPL in this well cannot be properly evaluated.

Groundwater samples were collected from wells MW-3 through MW-5 in 2006 and 2007. These wells, which contain measurable LNAPL, have not been sampled since 2007.

3.4 Off-Property Environmental Investigations

The following summaries present the results of completed historical Site investigations at adjacent properties.

3.4.1 February 2016 Investigation – Chri-Mar Apartments

In February 2016, Environmental Associates, Inc. (EAI) conducted a limited subsurface investigation on behalf of Milestone Properties at the Chri-Mar Apartments (EAI, 2016a), located south-adjacent to the Property (Figure 2). EAI oversaw the advancement of five soil borings (B-1 through B-5) and the collection of grab soil and groundwater samples. No TPHg, TPHd, TPHo, or BTEX compounds were detected in soil or groundwater at any of the sampling locations. EAI (2016a) is included as Appendix C.

EAI's investigation reported the presence of tetrachloroethene (PCE) in soil and groundwater, with concentrations exceeding the MTCA Method A cleanup level in soil at borings B-2 and B-3. Additionally, concentrations of trichloroethene (TCE) were reported in groundwater at boring B-3 at concentrations exceeding the MTCA Method A cleanup level. Grab soil vapor samples were also collected from borings B-1 and B-3. Concentrations of benzene exceeding the MTCA sub-slab soil screening levels were reported at both locations. PCE and TCE were also reported in soil vapor at B-3, with concentrations of TCE exceeding the MTCA sub-slab soil screening level.

The source of the PCE and TCE reported by EAI appears to be a former dry cleaner that was present in the strip mall located immediately west of the Property (Slater's 1-Hour Cleaners). The location of this former dry cleaner is now occupied by the Yeah Tasty Szechuan & BBQ.

3.4.2 March 2016 Investigation – Chri-Mar Apartments

In March 2016, EAI returned to the Chri-Mar Apartments property to conduct indoor and outdoor air sampling on behalf of Milestone Properties (EAI, 2016b). Two indoor air samples were collected from the interior of the Chri-Mar complex, and one outdoor air sample was collected. Samples were collected over a 24-hour period.

PCE was reported in both indoor and outdoor samples at concentrations below the MTCA Method B indoor air cleanup levels. Benzene was reported in both indoor and outdoor air at concentrations exceeding the MTCA Method B indoor air cleanup levels. The benzene concentration reported in indoor air was only nominally higher than that reported for the outdoor air samples. EAI (2016b) is included as Appendix D.

4 Summary of Current Environmental Conditions

The following sections provide synopses of current environmental conditions for all media at the Site.

4.1.1 Soil

Figure 3 depicts the currently inferred lateral extent of soil at the Site with concentrations of TPHs and/or BTEX compounds exceeding MTCA Method A cleanup levels. The inferred extent of soil impacts shown on Figure 3 includes several samples that exhibited only benzene exceedances. These exceedances were accompanied by very low or non-detectable concentrations of TPHg. Benzene exceedances in soil, when unaccompanied by exceedances of TPHg or other BTEX compounds, are considered sourced from dissolved-phase benzene in the soil pore water.

The deepest vertical detections of co-located benzene and TPHg are considered representative of the deepest impacts to soil. These occur at approximately 17.5 feet bgs at MW-3, MW-4, and MW-5. Impacts to soil have been vertically delineated at explorations MW-6, MW-7, MW-8, and MW-9 (CRA, 2011 – Table 1, Figures 6A and 6B).

4.1.2 Groundwater

Figure 4 depicts the currently inferred lateral extent of groundwater at the Site with concentrations of TPHs and/or BTEX compounds exceeding MTCA Method A cleanup levels. Based on depth to water measurements, groundwater elevation varies approximately 5 feet seasonally in the unconfined aquifer present at the Site. Given that Site contaminants of concern are petroleum hydrocarbons, and the Site has a shallow, unconfined aquifer with limited seasonal variation in depth to water, a shallow groundwater plume can be expected. Appreciable vertical migration of contaminants in the aquifer is therefore not a concern.

4.1.3 LNAPL

Figure 4 depicts the currently inferred extent of LNAPL at the Site. The LNAPL has been documented extending in a hydraulically downgradient direction to beneath the existing Aloha Café structure.

5 Summary of Identified Site Data Gaps

Review of historical reports and related data have resulted in the identification of the following nine key Site characterization data gaps:

1. **Potential presence of pre-1977 underground service station infrastructure**, including both piping and USTs.
2. **Lateral extent of Site soil impacts.** Further evaluation is needed in specific areas to complete the Site characterization and evaluate remedial options.
3. **Potential comingling of separate petroleum releases to the Subject Property.** Further evaluation is needed in specific areas to assess potential comingling of the documented TPHo and TPHg releases.
4. **Vertical extent of Site soil impacts.** While the majority of locations have been vertically delineated with regards to petroleum impacts to soil, some locations in the north-central portion of the Site lack vertical delineation where soil samples were only collected to a maximum depth of 17.5 feet bgs.
5. **Lateral extent of Site groundwater impacts.** Further evaluation of cross-gradient and downgradient water quality is needed to complete the Site characterization and evaluate remedial options.
6. **Potential upgradient sources.** Further evaluation of upgradient soil and water quality is needed to complete the Site characterization.
7. **Potential comingling with off-Property chlorinated solvent releases**. Further evaluation is needed to assess whether release(s) of chlorinated solvents or other petroleum-based cleaners from the adjacent Slater's One Hours Cleaners are comingled with releases of petroleum hydrocarbons form the Site.
8. **LNAPL assessment/recoverability**. The delineation of the LNAPL accumulation is incomplete, and LNAPL recovery options have not been evaluated. LNAPL recoverability testing is needed and practical LNAPL recovery efforts implemented.
9. **Soil vapor migration/intrusion.** The potential for migration of petroleum-related soil vapor into on- and off-property structures requires further evaluation.

6 Proposed Work Elements to Address Data Gaps

The following sections detail the nature and scope of supplemental RI activities that are considered necessary to sufficiently characterize the Site, complete an FS, and identify a preferred remedy. The proposed work will be completed in accordance with the project-specific Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan, included as Appendices E and F, respectively.

6.1 Task 1 – Permitting, Access Agreements, Locating, and Health and Safety Planning

Coordination with the City of Lynnwood will be required to obtain a Right of Way Permit for certain proposed subsurface borings and monitoring wells, and to prepare a Traffic Control Plan. Access agreements will also be required for planned explorations on the property to the south (Chri-Mar Apartments) and the property to the west (strip mall/Yeah Tasty Szechuan & BBQ). SREH will take the lead on securing access agreements.

One-Call locating will be contacted to identify and mark all public underground utilities. A private utility locate company will also be contracted to ensure that all proposed exploration locations are clear of utility obstructions. Additionally, a project-specific health and safety plan will be developed after completion of the Traffic Control Plan, and finalization of the access agreements (Appendix H).

6.2 Task 2 – Geophysical Survey

Aspect will subcontract with a geophysics consultant to conduct electromagnetic and ground penetrating radar (GPR) geophysical surveys of the northeastern portion of the Property. The purpose of these surveys will be to evaluate the potential presence of any remaining subsurface service station infrastructure, including potential USTs and product/vent lines.

The results of the geophysical survey will be evaluated prior to moving ahead with the other planned Site investigation work. Recommendations and modifications to this Work Plan may be warranted based on the results of the geophysical survey. Any substantive modifications this Work Plan will require prior approval of the SREH, CEMC, and Ecology.

6.3 Task 3 – Subsurface Borings and Monitoring Well Installation

Figure 5 shows the location of proposed supplemental soil borings and monitoring wells, respectively. Table 1 provides a summary of these locations and rationale for each planned supplemental exploration.

A total of 13 soil and monitoring well borings will be completed using direct push methods. Borings B-5, B-6, B-7, and B-8 are intended to further delineate the lateral extent of petroleum hydrocarbon-impacted soil. The remaining eight borings will be completed as monitoring wells (MW-11 to MW-19) and will serve to gather supplemental soil and groundwater quality data.

Monitoring well placement was evaluated using the historical and most recent November 2012 groundwater analytical and LNAPL accumulation data. The planned monitoring wells are intended to both further characterize the lateral extent of impacted groundwater (wells MW-14, and MW-16 through MW-19), and also better delineate the area of LNAPL accumulation (wells MW-11, MW-12, MW-13, and MW-15).

All soil borings will be drilled using direct-push equipment, with a targeted depth of approximately 25 feet bgs, to the bottom of field-screened impacts, or to refusal. There is reasonable confidence that soil conditions will permit boring and well installation using direct-push methods. Hollow-stem auger drilling techniques will be used in the event that soil conditions prove unsuitable for direct-push equipment.

During drilling, soil samples will be collected continuously if using direct-push drilling or at 2.5-foot intervals if hollow-stem auger is used, per the SAP. If indicators of hydrocarbon impacts are observed, up to three soil samples for laboratory analysis will be collected from each boring, using U.S. Environmental Protection Agency (EPA) Method 5035A protocols for TPH-Gx and VOC samples. If no field indicators of hydrocarbon impacts are observed in a boring, then one soil sample will be collected from the soil-groundwater interface.

All monitoring wells will be constructed in accordance with Washington Administrative Code (WAC) 173-160 by licensed drillers. Wells will consist of 2-inch diameter Schedule 40 PVC blank casing and 0.010-inch slot (10-slot) pre-packed well screen. Well screens will be 15 feet in length to accommodate seasonal groundwater fluctuations. With documented depths to water of 7 to 15 feet below grade, the pre-packed well screens are planned to be set from 5 to 20 feet below grade, contingent on field observations. All wells will be completed with an appropriate protective seal and secured with locking well caps. A licensed surveyor will survey top-of-casing and ground surface elevations to the nearest one-hundredth of a foot NAVD88 vertical datum, as well as the horizontal location of each well.

Detailed procedures for the soil boring installation, field screening and soil sampling, and the monitoring well construction, development, and groundwater sampling, are provided in the SAP (Appendix E). The SAP also includes well installation methods for hollow-stem auger drilling, in the event that this drilling method proves to be necessary.

Waste generated during the soil boring advancement and monitoring well installation/sampling will be stored onsite in U.S. Department of Transportation (DOT)-approved 55-gallon containers. At the conclusion of sampling activities, the waste will be profiled and transported for disposal at an appropriate facility.

6.4 Task 4 – Soil Vapor Sampling

Collection of five soil vapor samples is planned to further evaluate and characterize the concentrations of petroleum hydrocarbons in shallow Site soils. The proposed locations of the soil vapor monitoring are shown on Figure 6. The soil vapor results will be used to evaluate the vapor intrusion risk into the on- and off-Property buildings, in accordance with the following Ecology guidance:

- Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action. Revised February 2016. Ecology Publication No. 09-09-047

- Updated Process for Initially Assessing the Potential for Petroleum Vapor Intrusion: Implementation Memorandum No. 14. March 2016. Ecology Publication No. 16-09-046
- Petroleum Vapor Intrusion (PVI); Updated Screening levels, Cleanup Levels, and Assessing PVI Threats to Future Buildings: Implementation Memorandum No. 18. January 2018. Ecology Publication No. 17-09-043

The planned soil vapor sampling includes:

- Locations SVS-1 and SVS-2 will be interior sub-slab samples, intended to evaluate the potential for vapor intrusion risk within the Aloha Café building.
- Locations GP-1, GP-2, and GP-3 will be installed as soil gas probes at depths of approximately 5 feet bgs. These probes are located at the southern Property boundary and are intended to evaluate the potential vapor intrusion risk south of the Property.
- Vapor sampling will be accomplished using soil vapor pins installed through the concrete floor slab within the Aloha Café building and using soil gas probes installed to approximately 5 feet bgs in the parking lot. The vapor pins and gas probes will be installed, sealed, seal tested, and sampled in accordance with Aspect's Field Procedures as outlined in the SAP (Appendix E).
- One initial round of soil vapor sample collection is planned. Samples will be collected in accordance with Aspect's Field Procedures as outlined in the SAP (Appendix E) and submitted to a state-certified laboratory for analysis of select VOCs by EPA Method TO-15 and aliphatic and aromatic hydrocarbons by Massachusetts Department of Environmental Protection Air-Phase Petroleum Hydrocarbons (MA APH). Vapor samples will also be analyzed for methane, oxygen, and carbon dioxide.
- Interior sub-slab pins will be retained for potential additional future sampling.

6.5 Task 5 – Soil and Groundwater Analyses

Based on the confirmed presence of TPHg, TPHd, and TPHo at the Site, all soil samples retained for analysis will be submitted to a state-certified laboratory for analysis of petroleum hydrocarbons by Northwest Methods NWTPH-Gx and NWTPH-Dx. The samples will also be analyzed for volatile compounds (BTEX, MTBE, EDB, EDC, and naphthalene) by EPA Method 8260C. Selected soil samples with elevated TPHg will also be analyzed for lead by EPA Method 6010C. Samples from borings on the western portion of the Subject Property (B-06, MW-14, MW-16, MW-18, and MW-19) will also be analyzed for halogenated VOCs by EPA Method 8260C.

Two quarterly rounds of groundwater sampling are planned from all Site monitoring wells (except those with measurable LNAPL). Sampling will be performed using low-flow sampling methods as outlined in the SAP (Appendix E). Groundwater samples will be submitted to a state-certified laboratory for analysis of petroleum hydrocarbons by Northwest Methods NWTPH-Gx and NWTPH-Dx, volatile petroleum compounds by EPA Method 8260C, and total lead by EPA Method 6010C. Samples collected from wells MW-14, MW-16, MW-18, and MW-19 will also be analyzed for halogenated VOCs by EPA Method 8260C.

6.6 Task 6 – Data Validation

All newly collected soil, soil vapor, and groundwater analytical data will be validated by a qualified third party in accordance with EPA 2A (Stage 2A) data validation criteria. Validation will include completeness and compliance checks of sample receipt conditions and sample-related Quality Control (QC) results. Data will be flagged with appropriate validation qualifiers, as necessary, in all data tabulations. Additional details on data validation are provided in the Quality Assurance Project Plan (Appendix E).

6.7 Task 7 – LNAPL Recovery Testing

Transmissivity testing will be performed at two selected wells to assess the recoverability of LNAPL. The wells will be chosen based on an observed LNAPL thickness greater than 0.20 feet. The tests will be conducted during a dry period when no precipitation infiltration is occurring, to the extent practical.

The tests will be performed using a peristaltic pump and results analyzed in accordance with the American Petroleum Institute (API) LNAPL Transmissivity Workbook (API, 2016). Both the testing and analysis will be conducted in accordance with the ASTM International (ASTM) E2856-13, *Guide for Estimation of LNAPL Transmissivity* and API's LNAPL Transmissivity Workbook (2016). A copy of API's LNAPL Transmissivity Workbook guide is included as Appendix F.

After testing, LNAPL thicknesses will be monitored weekly for a minimum period of 1 month to evaluate long-term LNAPL recovery. Water and LNAPL generated during the tests will be collected and stored properly in a sealed and labeled 55-gallon drum, pending profiling and disposal.

6.8 Task 8 – Data Evaluation and Reporting

The supplemental and historical RI data will be evaluated for sufficiency, and any residual RI data gaps identified. Identified residual RI data gaps will be communicated to the PLPs and Ecology, along with a supplemental proposed exploration plan, to address those data gaps.

Once the RI data collected is considered sufficient, a draft supplemental RI report will be prepared documenting the sampling efforts, summarizing the Property soil and hydrogeologic conditions, and presenting a synopsis of historical and current soil, soil vapor, and groundwater quality data. Geologic cross sections incorporating hydrogeologic and chemical data from new borings and monitoring wells will be prepared to illustrate the inferred lateral and vertical extent of impacts in soil and groundwater. Data tabulations will include comparisons to appropriate MTCA cleanup levels for soil and groundwater, and screening levels for soil vapor.

The draft supplemental RI report will be prepared in compliance with Ecology's RI report template and Ecology's *Remedial Investigation Checklist* (Ecology, 2016).

Electronic submittal of site, location, and sample data to Ecology's Environmental Information Management System will be completed in conjunction with report submittal, as required by Agreed Order 14315.

7 References

American Petroleum Institute (API), 2016, API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis User Guide, Publication 4762, April 2016.

Conestoga-Rovers & Associates (CRA), 2011, Remedial Investigation Report, Former Jiffy Lube Facility, 6808 196th Street Southwest, Lynnwood, Washington. August 17, 2011.

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Washington State Department of Ecology (Ecology), 2016, Remedial Investigation Checklist, Publication No. 16-09-006, available at https://fortress.wa.gov/ecy/publications/SummaryPages/1609006.html.

8 Limitations

Work for this project was performed for the Strickland Real Estate Holdings and Chevron Environmental Management Company (Client), and this report was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made. The Work Plan scope and format follows the general requirements stipulated in Ecology Agreed Order 14315 and relevant Ecology guidance documents.

All reports prepared by Aspect Consulting for the Client apply only to the services described in the Agreement(s) with the Client. Any use or reuse by any party other than the Client is at the sole risk of that party, and without liability to Aspect Consulting. Aspect Consulting's original files/reports shall govern in the event of any dispute regarding the content of electronic documents furnished to others.

Please refer to Appendix H titled "Report Limitations and Guidelines for Use" for additional information governing the use of this report.

TABLES

Table 1. Subsurface Exploration Locations and Rationale

Project No. 180357, Texaco Strickland Cleanup Site, 6808 196th Street SW, Lynnwood, WA

Exploration Location	Rationale
Soil	
B-5	Lateral delineation of hydrocarbon impacts in soil north of observed LNAPL plume at MW-5.
B-6	Lateral delineation of hydrocarbon impacts in soil to the west of MW-9.
B-7	Lateral delineation of hydrocarbon impacts in soil to the south of the Aloha Café building.
B-8	Lateral delineation of hydrocarbon impacts in soil hydraulically downgradient of MW-6.
Groundwater	
MW-11	Lateral delineation of hydrocarbon impacts in soil, and LNAPL plume/groundwater quality to the north of the Property.
MW-12	Lateral delineation of hydrocarbon impacts in soil, the LNAPL plume/groundwater quality to the north of the Property.
MW-13	Lateral delineation of hydrocarbon impacts in soil, the LNAPL plume/groundwater quality between the former UST and pump island locations.
MW-14	Lateral delineation of hydrocarbon impacts in soil, groundwater quality on the contiguous parcel to the west of the Property.
MW-15	Lateral delineation of hydrocarbon impacts in soil, LNAPL plume/groundwater quality downgradient of the Aloha Café building.
MW-16	Lateral delineation of downgradient, on-Property groundwater quality.
MW-17	Lateral delineation of downgradient, on-Property groundwater quality.
MW-18	Lateral delineation of downgradient groundwater quality, on Chri-Mar parcel.
MW-19	Lateral delineation of downgradient, on-Property groundwater quality.
Soil Gas	
SVS-1	Subslab sample beneath Aloha Café building, to provide sub-slab vapor concentrations for comparison to MTCA screening levels.
SVS-2	Subslab sample beneath Aloha Café building, to provide sub-slab vapor concentrations for comparison to MTCA screening levels.
GP-1	Subasphalt soil gas probe to be installed to an approximate depth of 5 feet bgs, hydraulically upgradient side of Chri-Mar apartment building, to provide soil vapor concentrations for comparison to MTCA screening levels near the Subject Property boundary.
GP-2	Subasphalt soil gas probe to be installed to an approximate depth of 5 feet bgs, hydraulically upgradient side of Chri-Mar apartment building, to provide soil vapor concentrations for comparison to MTCA screening levels near the Subject Property boundary.
GP-3	Subasphalt soil gas probe to be installed to an approximate depth of 5 feet bgs, hydraulically upgradient side of Chri-Mar apartment building, to provide soil vapor concentrations for comparison to MTCA screening levels near the Subject Property boundary.

Notes

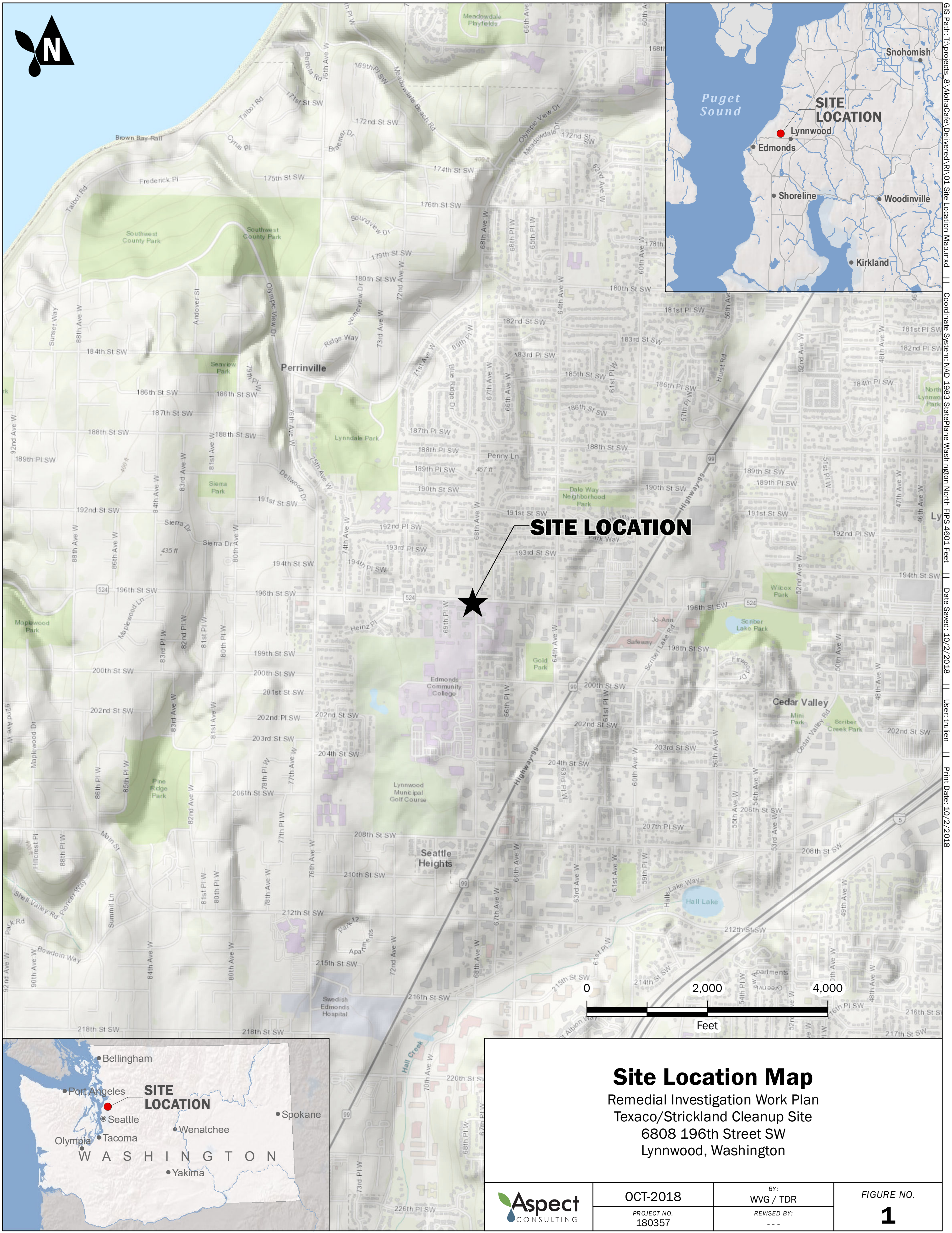
LNAPL = light nonaqueous phase liquid

UST = underground storage tank

MTCA = Model Toxics Control Act

bgs = below ground surface

FIGURES



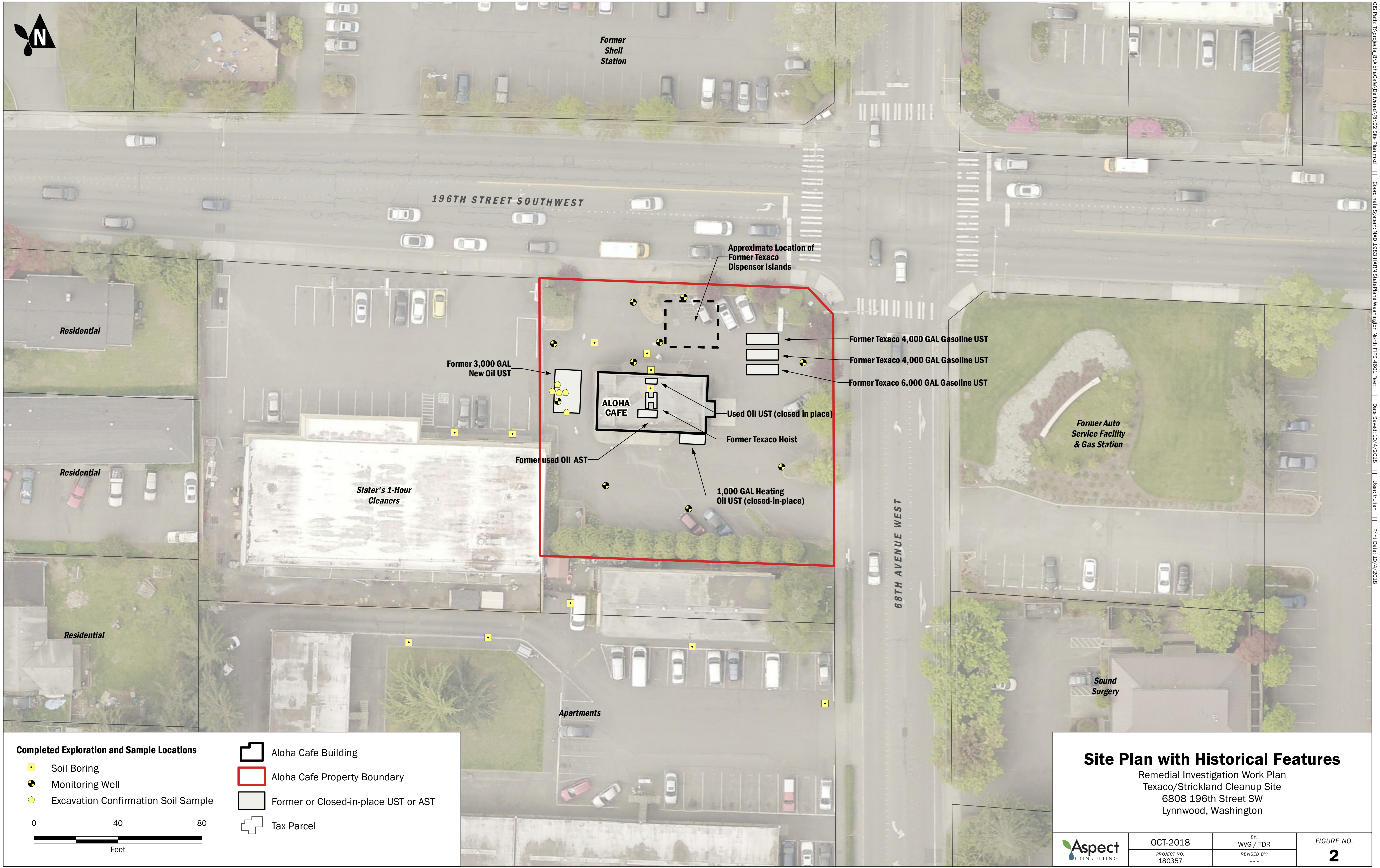
GIS Path: T:\projects_8\AlohaCafe\Delivered\RI\01 Site Location Map.mxd || Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet || Date Saved: 10/2/2018 || User: trulien || Print Date: 10/2/2018

Site Location Map

Remedial Investigation Work Plan
Texaco/Strickland Cleanup Site
6808 196th Street SW
Lynnwood, Washington

Aspect CONSULTING	OCT-2018	BY: WVG / TDR	FIGURE NO.
	PROJECT NO. 180357	REVISED BY: - - -	1

Basemap Layer Credits || Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community



Completed Exploration and Sample Locations

- ▣ Soil Boring
- ◕ Monitoring Well
- ⬠ Excavation Confirmation Soil Sample

0 40 80
Feet

- Aloha Cafe Building
- 🟥 Aloha Cafe Property Boundary
- ▭ Former or Closed-in-place UST or AST
- Tax Parcel

Basemap Layer Credits || Pictometry, King County

Site Plan with Historical Features

Remedial Investigation Work Plan
Texaco/Strickland Cleanup Site
6808 196th Street SW
Lynnwood, Washington

Aspect CONSULTING

OCT-2018	BY: WVG / TDR	FIGURE NO.
PROJECT NO. 180357	REVISED BY: - - -	2

GIS Path: T:\projects_8\AlohaCafe\Delivered\RI\02 Site Plan.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 10/4/2018 || User: trulien || Print Date: 10/4/2018

● TPH-O Detected at Concentrations > MTCA Method A Cleanup Level

● Hydrocarbons Not Detected, or Detected Below MTCA Method A Cleanup Level

● TPH-G and/or BTEX Compounds Detected at Concentrations > MTCA Method A Cleanup Level

⬢ PCE Detected at Concentration > MTCA Method A Cleanup Level

⊡ Soil Boring

◉ Monitoring Well

⬠ Excavation Confirmation Soil Sample

Inferred Extent of Soil with Hydrocarbons > MTCA Method A Cleanup Level

Inferred Extent of Soil with PCE > MTCA Method A Cleanup Level

Aloha Cafe Building

Aloha Cafe Property Boundary

Former or Closed-in-place UST or AST

Tax Parcel

* Only benzene detected at concentrations > MTCA Method A cleanup level in these samples.

Each circle on the rose diagram represents one sampleing event. The blue slivers represent groundwater flow direction in degrees and each quarter of the rose diagram is broken into 10 sections representing 9 degrees of flow direction per section. *(Rose diagram from CRA's 2011 'Remedial Investigation Report')*

Historical Soil Investigation Results

Remedial Investigation Work Plan
Texaco/Strickland Cleanup Site
6808 196th Street SW
Lynnwood, Washington

Aspect CONSULTING

FEB-2019

PROJECT NO.
180357

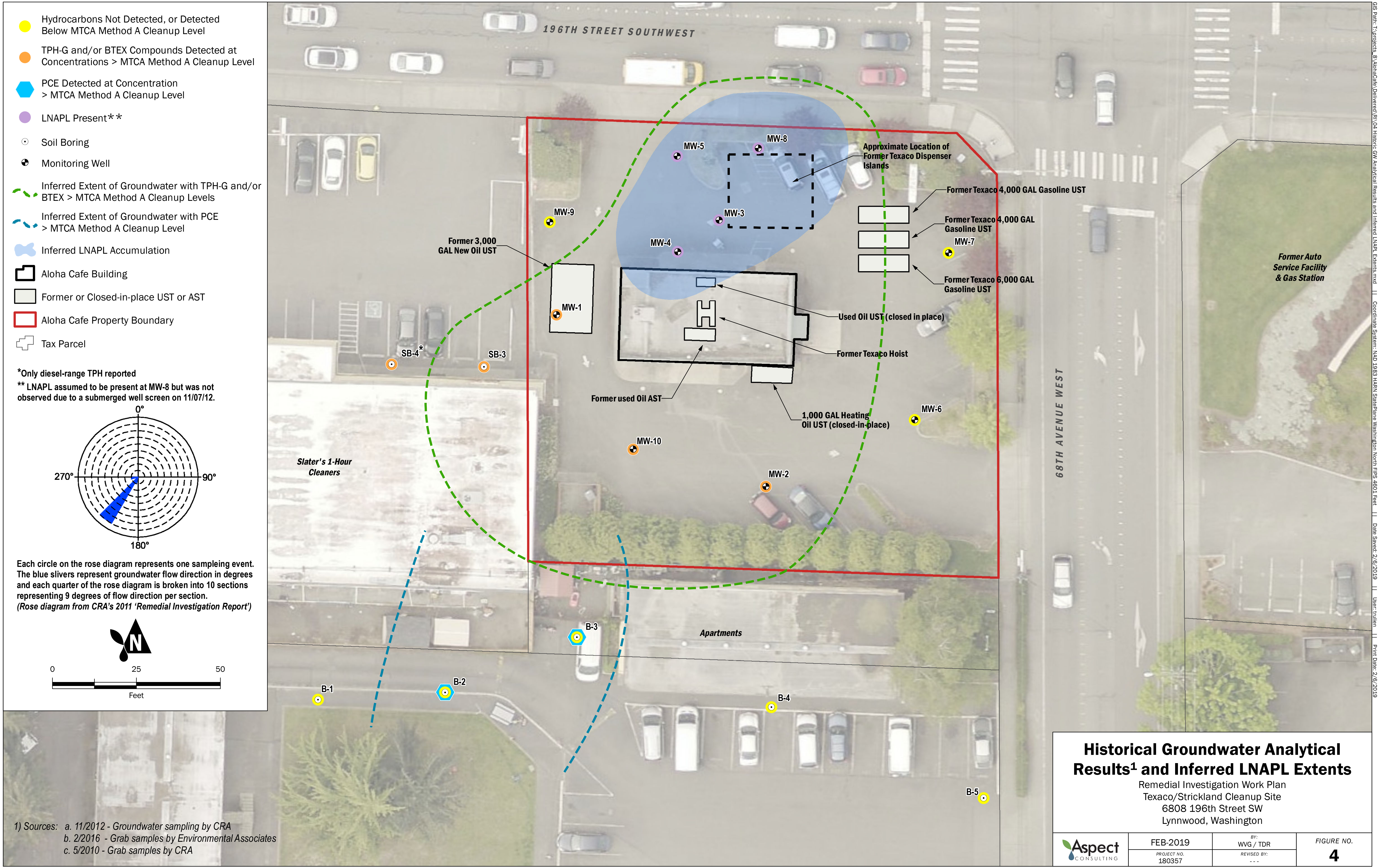
BY:
WVG / TDR

REVISED BY:
- - -

FIGURE NO.
3

Basemap Layer Credits || Pictometry, King County

GIS Path: T:\projects_8\AlohaCafe\Delivered\RI\03 Historical Soil Investigation Results.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2/6/2019 || User: trulien || Print Date: 2/6/2019



● Hydrocarbons Not Detected, or Detected Below MTCA Method A Cleanup Level

● TPH-G and/or BTEX Compounds Detected at Concentrations > MTCA Method A Cleanup Level

⬢ PCE Detected at Concentration > MTCA Method A Cleanup Level

● LNAPL Present**

⊙ Soil Boring

◐ Monitoring Well

Inferred Extent of Groundwater with TPH-G and/or BTEX > MTCA Method A Cleanup Levels

Inferred Extent of Groundwater with PCE > MTCA Method A Cleanup Level

Inferred LNAPL Accumulation

Aloha Cafe Building

Former or Closed-in-place UST or AST

Aloha Cafe Property Boundary

Tax Parcel

*Only diesel-range TPH reported

** LNAPL assumed to be present at MW-8 but was not observed due to a submerged well screen on 11/07/12.

Each circle on the rose diagram represents one sampling event. The blue slivers represent groundwater flow direction in degrees and each quarter of the rose diagram is broken into 10 sections representing 9 degrees of flow direction per section.
(Rose diagram from CRA's 2011 'Remedial Investigation Report')

1) Sources: a. 11/2012 - Groundwater sampling by CRA
b. 2/2016 - Grab samples by Environmental Associates
c. 5/2010 - Grab samples by CRA

Basemap Layer Credits || Pictometry, King County

Historical Groundwater Analytical Results^1 and Inferred LNAPL Extents

Remedial Investigation Work Plan
Texaco/Strickland Cleanup Site
6808 196th Street SW
Lynnwood, Washington

Aspect CONSULTING	FEB-2019	BY: WVG / TDR	FIGURE NO.
	PROJECT NO. 180357	REVISED BY: - - -	4

GIS Path: T:\projects_8\AlohaCafe\Delivered\RI\04 Historic GW Analytical Results and Inferred LNAPL Extents.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2/6/2019 || User: trulien || Print Date: 2/6/2019

Each circle on the rose diagram represents one sampleing event. The blue slivers represent groundwater flow direction in degrees and each quarter of the rose diagram is broken into 10 sections representing 9 degrees of flow direction per section. *(Rose diagram from CRA's 2011 'Remedial Investigation Report')*

Proposed Supplemental Soil Borings & Monitoring Wells

Remedial Investigation Work Plan
Texaco/Strickland Cleanup Site
6808 196th Street SW
Lynnwood, Washington

OCT-2018	BY: WVG / TDR	FIGURE NO. 5
PROJECT NO. 180357	REVISED BY: - - -	

Basemap Layer Credits || Pictometry, King County

GIS Path: T:\projects_8\AlohaCafe\Delivered\RI\05 Proposed Supplemental Soil Borings and Monitoring Wells.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2/11/2019 || User: trollen || Print Date: 2/12/2019

Proposed Supplemental Soil Vapor Monitoring Locations

Remedial Investigation Work Plan
Texaco/Strickland Cleanup Site
6808 196th Street SW
Lynnwood, Washington

Aspect Consulting	OCT-2018	BY: WVG / TDR	FIGURE NO. 6
	PROJECT NO. 180357	REVISED BY: - - -	

Each circle on the rose diagram represents one sampleing event. The blue slivers represent groundwater flow direction in degrees and each quarter of the rose diagram is broken into 10 sections representing 9 degrees of flow direction per section.
(Rose diagram from CRA's 2011 'Remedial Investigation Report')

Basemap Layer Credits || Pictometry, King County

GIS Path: T:\projects_8\AlohaCafe\Delivered\RI\06 Proposed Supplemental Soil Vapor Monitoring Locations.mxd || Coordinate System: NAD 1983 HARN StatePlane Washington North FIPS 4601 Feet || Date Saved: 2/6/2019 || User: trulien || Print Date: 2/6/2019

APPENDIX A

Exhibit B – Scope of Work: Agreed Order #14315

EXHIBIT B – SCOPE OF WORK (SOW)
Texaco Strickland Cleanup Site
6808 196th Street SW, Lynnwood, WA

PURPOSE

The work under this Agreed Order (AO) involves conducting a Remedial Investigation and Feasibility Study (RI/FS), including interim action(s) if necessary, and preparing a preliminary draft Cleanup Action Plan (dCAP) for the property located at 6808 196th Street Southwest in Lynnwood, Washington (the Site). The purpose of the RI/FS and preliminary dCAP is to provide sufficient data, analysis, and evaluations to enable the Washington State Department of Ecology (Ecology) to select a final cleanup alternative for the Site.

The Potentially Liable Persons (PLPs) will coordinate with Ecology throughout the work under this AO, and will keep Ecology informed of any changes, issues, or problems as they develop.

The SOW is divided into eight major tasks as follows:

Task 1. RI Work Plan
Task 2. Interim Action(s)
Task 3. Remedial Investigation
Task 4. Feasibility Study
Task 5. SEPA Compliance
Task 6. Public Participation
Task 7. Preliminary dCAP
Task 8. Progress Reports

To assist with preparation of these documents, Ecology's Toxics Cleanup Program (TCP) has developed checklists, which the PLPs shall use for the following remedial action reports and plans.

- Remedial Investigation Report Checklist
- Feasibility Study Report Checklist
- Cleanup Action Plan Checklist

The PLPs can download the checklist directly from the following website: http://www.ecy.wa.gov/programs/tcp/policies/checklists.html

Policy 840 Environmental Information Management System (EIM)

Ecology has updated Policy 840 related to data submittal requirements for TCP sites. Policy 840 requires environmental monitoring data collected at TCP sites as part of site investigations and cleanups to be submitted into EIM at the time of submittal for Ecology review of any report containing this data.

Environmental Data Validation

Environmental data validation must be performed using Ecology's TCP Data Validation and Sampling Analysis Plan (SAP)/Quality Assurance Project Plan (QAAP) for data validation for all Formal Cleanup Sites (Ecology September 23, 2016). Data validation shall be performed at Quality Assurance Level 2 (EAP2) with Third Party Data Validation.

Following Ecology's Lean Process, there are five mandatory Key project Meetings:

1. Kickoff Meeting held prior to commencement of AO negotiations with the principal contacts for PLPs and Ecology.
2. RI Planning and Scoping Meeting with Ecology Cleanup Project manager and PLP consultants.
3. RI Pre-Report Meeting occurs after the completion of RI field activities and prior to writing the RI Report; this will ensure the report can be reviewed and approved by Ecology after one review cycle.
4. FS Planning Meeting to discuss overall approach and contents of the FS to ensure the report can be reviewed and approved by Ecology after one review cycle. If appropriate, this meeting may be combined with the RI pre-report check-in.
5. dCAP Planning Meeting held prior to writing the Preliminary dCAP to discuss the contents of the dCAP and to identify the preferred Remedial Alternative.

The first Key Project Meeting was held November 15, 2017. During that meeting Ecology established communication protocols, expectations related to Key Project Documents and the timing and purpose of Key Project Meetings.

TASK 1. RI WORK PLAN

The PLPs shall prepare a Remedial Investigation Work Plan (Work Plan). The Work Plan shall include an overall description and schedule of all RI activities. The Work Plan shall clearly describe the project management strategy for implementing and reporting on RI activities. The responsibility and authority of all organizations and key personnel involved in conducting the RI will be outlined.

The second Key Project Meeting will be held prior to submittal of the RI Work Plan. The purpose of the Remedial Investigation Planning Meeting is to review requirements for the Work Plan and plan Remedial Investigation field work, discuss the preliminary Conceptual Site Model, and identify project data needs and preliminary plans for on-property interim action. The RI Work Plan shall be completed for the Site and approved by Ecology prior to the submission of Interim Action Work Plans.

The RI Work Plan shall describe general facility information; site history and conditions; including previous operations; past field investigations, including any data collection and analysis of soils, air, groundwater, surface water, and sediments; a conceptual site model showing contaminants, migration pathways in all environmental media, potential receptors, and screening levels based on the conceptual site model; geology and groundwater system characteristics; past, current, and future land use; identification of natural resources and ecological receptors; hazardous substances and their sources, etc., in compliance with Washington Administrative Code (WAC)173-340-350 and WAC 173-204-560.

As part of the project background, existing environmental data on site soil, groundwater, surface water, and sediments will be compiled and evaluated for data gaps. The data gaps will be used as the basis for conducting additional site investigations, if necessary. The Work Plan will also identify specific data collection procedures in a SAP and QAPP as part of the Work Plan in compliance with WAC 173-340-820 and WAC 173-204-600 for defining the nature and extent of contamination. The PLPs will also submit a copy of the Health and Safety Plan (HASP) for the project.

The SAP identifies the proposed number and location of all environmental samples and methods, including soil borings, groundwater monitoring wells, soil, groundwater, stormwater, seep, catch basin, approximate depths, and includes a quality assurance project plan. The SAP will describe the sampling objectives, the rationale for the sampling approach (based upon the identified data gaps), and plans for data use, and shall provide a detailed description of sampling tasks. The SAP shall describe specifications for sample identifiers; sampling equipment; the type, number, and location of samples to be collected; the analyses to be performed; descriptions of sampling equipment and methods to be used; sample documentation; sample containers, collection and handling; data and records management; and schedule.

The QAPP will be prepared in accordance with the Guidance for Preparation of Quality Assurance Project Plans, EPA Region 10, Quality Data Management Program, QA/R-5 and requirements of the EPA Contract Laboratory Program. The QAPP will also follow Ecology's Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (July 2004)[1]. Laboratories must meet the accreditation standards established in WAC 173-50.

The SAP, including the QAPP, will be submitted to Ecology for review and approval. As with all environmental work at the Site, work may not begin without written approval from Ecology. The plan shall provide seven (7) days' notice to Ecology prior to beginning sampling. Ecology may obtain split samples.

The PLPs or their contractors shall submit all new sampling data generated under this SAP and any other recently collected data to Ecology for entry into the Environmental Information Management System (EIM) in accordance with WAC 173-340-840(5) and

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[1] Found at http://www.ecy.wa.gov/biblio/0403030.html

Ecology's Toxics Cleanup Program Policy 840: Data Submittal Requirements. Only validated data will be entered into the EIM database within 60 days of submittal.

RI tasks and subtasks will include, but is not limited to soil, ground water, vapor, seep, surface water, sediment, and catch basin sampling and stormwater analysis, as necessary to address data gaps identified in the Work Plan. In addition, the following must be included in the Work Plan:

- Develop a preliminary conceptual site model for the Site including evaluation of all potential pathways and potential receptors that may exist for contaminants of concern at the Site.
- Define the nature and extent of contamination based on screening levels protective of all receptors at and downgradient of the Site.

The PLPs will provide Ecology with an Agency Review Draft Work Plan. Once Ecology reviews and approves the Work Plan, it will be considered the Final Work Plan. The Work Plan shall not be implemented until approved by Ecology. Once approved by Ecology, the PLPs will implement the Final Work Plan according to the schedule contained in Exhibit C. Ecology expects one iteration between preliminary draft and final draft of RI Work Plan, Remedial Investigation, Feasibility Study, and draft Cleanup Action Plan.

The PLPs shall prepare two (2) copies of the Agency Review Draft RI Work Plan and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology for review and comment. After incorporating Ecology's comments on the Agency Review Draft Work Plan and after Ecology approval, the PLPs shall prepare three (3) copies of the Final Work Plan and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology.

TASK 2. INTERIM ACTION(S)

Interim actions are remedial actions implemented prior to completion of the RI/FS:

- that are technically necessary to reduce a threat to human health or the environment by eliminating or substantially reducing one or more pathways for exposure to a hazardous substance;
- that correct a problem that may become substantially worse or cost substantially more to address if the remedial action is delayed; or
- that are needed to provide for completion of the remedial investigation/feasibility study or design of the cleanup action,

will be considered interim actions, will be implemented in accordance with WAC 173-340-430 and the AO, and will be designed in a manner that will not foreclose reasonable alternatives for any final cleanup action that may be required.

Based upon available information, interim action(s) pursuant to WAC 173-340-430 may be needed to expedite removal of free-phase light non-aqueous phase liquids (LNAPL) floating on the ground water surface at the Site. Additional interim actions deemed necessary by the PLPs or Ecology shall be conducted commensurate with this task description.

The scope of the interim actions may include, but not be limited to, typical source control or containment elements such as:

- Soil or sediment removal
- Groundwater remediation
- Expedited LNAPL removal
- Vapor mitigation
- Repair, slip lining, replacement, or closure of stormwater conveyances or other structures such as conduit, vaults, catch basins, etc.
- Removal of underground storage tanks and pipes
- Removal of old drain fields or former surface impoundments
- Proper abandonment of old wells
- Removal of contaminated building or other structural material
- Construction of a treatment facility
- Shoreline stabilization such as bulkhead repair, erosion or seepage control, and grading or clearing.

During the second Key Project Meeting (RI planning and scoping meeting) the results of pre-AO investigations and preliminary plans may be discussed for on-property interim action. Once the RI Work Plan has been approved by Ecology the PLPs will prepare and submit for Ecology approval an Agency Review Draft Interim Action Work Plan (dIAWP) with detail commensurate with the work to be performed. The Agency Review dIAWP shall include, as appropriate:

- Description of the interim action including its purpose, general requirements, and relationship to the (final) cleanup action (to the extent known);
- Summary of relevant RI/FS information, including at a minimum existing site conditions and alternative interim actions considered;
- Information regarding design and construction requirements, including a proposed schedule and personnel roles and responsibilities;
- Compliance Monitoring Plan;
- SAP/QAPP;
- Permits required.

The PLPs will also submit a copy of the Health and Safety Plan for the project. The PLPs will be responsible for complying with the State Environmental Policy Act (SEPA) Rules including preparing and submitting an environmental checklist for the interim action, and will assist Ecology with presentations at any additional meetings or hearings that might be necessary for SEPA compliance or as part of the Public Participation Plan.

The PLPs will incorporate Ecology's required changes into the dIAWP and provide Ecology with a Public Review dIAWP. After a public notice and comment period for the Public Review dIAWP (and SEPA determination), Ecology will approve the dIAWP (if appropriate) and the document will be considered Final. Once approved by Ecology, the PLPs will implement the interim action according to the schedule contained in the Final IAWP.

The PLPs shall prepare two (2) copies of the Agency Review dIAWP and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology for review. The PLPs shall incorporate Ecology's comments and then prepare two (2) copies of the Public Review dIAWP and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology. After the public notice and comment period, incorporating Ecology's and the public's comments on the Public Review dIAWP, and after Ecology approval, the PLPs shall prepare three (3) copies of the Final IAWP submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats.

Upon successful completion of the work, an Agency Review Draft Interim Action Report will be prepared as a separate deliverable. The PLPs shall prepare two (2) copies of the Agency Review Draft Interim Action Report and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology for review and approval. After incorporating Ecology's comments on the Agency Review Draft Interim Action Report and after Ecology approval, the PLPs shall prepare three (3) copies of the Final Interim Action Report (IAR) and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology.

TASK 3. REMEDIAL INVESTIGATION

The PLPs will conduct an RI that meets the requirements of WAC 173-340-350(7) and WAC 173-204-560 according to the Work Plan approved by Ecology (Task 2). The RI will determine the nature and extent of contamination exceeding preliminary Model Toxics Control Act (MTCA) cleanup levels, and any other regulatory requirements. The RI will provide sufficient data and information to define the nature and extent of contamination. The Final IAR (Task 2) will be included as an appendix to the RI Report.

Field sampling and analysis will be completed in general accordance with the SAP and QAPP. Deviation(s) from the approved SAP and QAPP must be communicated to Ecology immediately and documented as required by Ecology.

The PLPs shall provide interim data reports and updates to Ecology as new site data and information become available. Laboratory analysis data shall also be provided in electronic format when it has been validated. Raw laboratory data will be provided to Ecology upon request.

Prior to submittal of the Agency Review Draft RI Report, a third Key Project Meeting will be held. During the Remedial Investigation Pre-Report Check-In, Ecology and the PLPs will review available data and an updated conceptual site model and discuss the content and organization of the Draft RI Report. Ecology expects one iteration between preliminary drafts and final drafts of the Remedial Investigation, Feasibility Study, and draft Cleanup Action Plan.

The PLPs shall compile the results of the Site investigation into an Agency Review Draft RI Report. The PLPs shall prepare two (2) copies of the Agency Review Draft RI Report and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology for review and comment.

After incorporating Ecology's comments on the Agency Review Draft RI Report, the PLPs shall prepare three (3) copies of a Public Review Draft RI Report and submit them, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology for distribution and public comment. Electronic survey data for monitoring locations, electronic lab data, and GIS maps of contaminant distribution shall also be provided for both the Agency Review Draft RI Report and Public Review Draft RI Reports. The RI Report will not be considered Final until after a public review and comment period. The Agency Review Draft RI Report and/or Public Review Draft RI Reports may be submitted in conjunction with the Agency Review Draft FS Report and/or Public Review Draft FS Reports, discussed in Task 4 below.

If the data collected during this investigation is insufficient to define the full nature and extent of contamination, and to select a cleanup action plan an additional phase of investigation shall be conducted to define the extent of contamination.

TASK 4. FEASIBILITY STUDY

The PLPs will use the information obtained in the RI to complete the Feasibility Study consistent with WAC 173-340-350(8) according to the approved Work Plan Schedule (Exhibit C).

Prior to beginning the FS, a fourth Key Project Meeting will be held to review applicable or relevant and appropriate requirements (ARARs), potential remedial alternatives, and points of compliance. If appropriate this Key Project Meeting may be held in conjunction with the RI Pre-Report Planning Key Project Meeting.

The Agency Review Draft FS Report will provide a detailed analysis of each remedial alternative according to the applicable requirements of WAC 173-340-350. The remedial alternatives will take into account the completed on-property interim action, and will be evaluated for compliance with the applicable requirements of WAC 173-340-360 and WAC 173-204-560(4), including a detailed evaluation of remedial alternatives relative to the following criteria:

- Compliance with Cleanup Standards and Applicable Laws;
- Protection of Human Health and the Environment;
- Provision for a Reasonable Restoration Time Frame;

- Use of Permanent Solutions to the Maximum Extent Practicable;
- The Degree to which Recycling, Reuse, and Waste Minimization are Employed;
- Short-Term Effectiveness;
- Long-Term Effectiveness;
- Net Environmental Benefit;
- Implementability;
- Provision for Compliance Monitoring;
- Cost-Effectiveness; and
- Prospective Community Acceptance.

The remedial alternative that is judged to best satisfy the evaluation criteria will be identified. Justification for the selection will be provided, and the recommended remedial alternative further developed, in the FS Report.

The PLPs shall prepare two (2) copies of an Agency Review Draft FS Report and submit them, including one electronic copy in Word (.doc) and Adobe (.pdf) formats, to Ecology for review and comment.

After incorporating Ecology's comments on the Agency Review Draft FS Report, the PLPs will prepare three (3) copies of a Public Review Draft FS Report and submit them, along with one electronic copy in Word (.doc) and Adobe (.pdf) formats, to Ecology for distribution and public comment.

The FS Report will not be considered final until after the public review and comment period. After that period, the PLPs will incorporate Ecology's and the public's comments on the Public Review Draft FS Report and, after Ecology approval, will prepare three (3) copies of the Final FS Report and submit them along with one electronic copy in Word (.doc) and Adobe (.pdf) formats.

TASK 5. SEPA COMPLIANCE

The PLPs shall be responsible for complying with the State Environmental Policy Act (SEPA) Rules including preparing and submitting an environmental checklist. If the result of the threshold determination is a determination of significance (DS), the PLPs shall be responsible for the preparation of Draft and Final Environmental Impact Statements. The PLPs shall assist Ecology with coordinating SEPA public involvement requirements with MTCA public involvement requirements whenever possible, such that public comment periods and meetings or hearings, as applicable, can be held concurrently.

TASK 6. PUBLIC PARTICIPATION

The PLPs shall assist Ecology to prepare a draft Public Participation Plan that complies with the provisions of WAC 173-340-600(9).

The PLPs shall support Ecology in presenting the Public Review Draft RI/FS and SEPA evaluations at public meetings or hearings. The PLPs will assist Ecology with presentations at any additional meetings or hearings that might be necessary for SEPA compliance or as part of the Public Participation Plan.

After the public comment periods are completed, at Ecology's request, the PLPs shall prepare a Draft Responsiveness Summary that addresses public comments and if necessary, prepare a second Public Review Draft RI/FS Report that addresses public comments. The PLPs shall prepare two (2) copies of the Draft Responsiveness Summary and if necessary, second Public Review Draft RI/FS Report and submit them to Ecology for review and approval, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats, to Ecology.

After incorporating Ecology's comments and after Ecology approval, the PLPs shall prepare three (3) copies of the Final Responsiveness Summary after public comments are incorporated and submit them to Ecology for distribution, including one electronic copy each in Word (.doc) and Adobe (.pdf) formats.

TASK 7. PRELIMINARY DRAFT CLEANUP ACTION PLAN

Upon Ecology approval of the Public Review Draft RI/FS Report, the fifth Key Project Meeting will be held to discuss the contents of the dCAP and to identify the preferred remedial alternative. The dCAP will address all remedial actions required to be completed subsequent to the on-property interim action(s). The PLPs will prepare an Agency Review preliminary dCAP in accordance with WAC 173-340-380. The Agency Review preliminary dCAP will include a general description of the proposed remedial actions, cleanup standards developed from the RI/FS and rationale regarding their selection, a schedule for implementation, description of any institutional controls proposed, and a summary of applicable local, state, and federal laws pertinent to the proposed cleanup actions.

The PLPs will prepare two (2) copies of the Agency Review preliminary dCAP and submit them, along with one electronic copy in Word (.doc) and Adobe (.pdf) formats, for Ecology review.

TASK 8. PROGRESS REPORTS

The PLPs will submit Progress Reports at a quarterly frequency to Ecology until satisfaction of the AO, in accordance with Section VII.(D) of the AO. In addition, during implementation of the RI field investigations and on-Property interim action(s), the PLPs will provide email status updates to Ecology on the 1st and 15th of each month. If this day is a weekend or holiday, the email status updates will be submitted to Ecology on the next business day. In a month that a quarterly Progress Report is due, the email status update due on the 15th is not required.

Progress Reports will be submitted to the Ecology project coordinator by the 15th of the month following the reporting period. If this day is a weekend or holiday, Progress Reports will be submitted to Ecology on the next business day. At a minimum, Progress Reports will contain the following information regarding the preceding reporting period:

- A description of the actions which have been taken to comply with the AO;
- Summaries of sampling and testing reports and other data reports received by the PLPs;
- Summaries of deviations from approved Work Plans;
- Summaries of contacts with representatives of the local community, public interest groups, press, and federal, state, or tribal governments;
- Summaries of problems or anticipated problems in meeting the schedule or objectives set forth in the SOW and Work Plan;
- Summaries of solutions developed and implemented or planned to address any actual or anticipated problems or delays;
- Changes in key personnel; and
- A description of work planned for the next reporting period.

APPENDIX B

Remedial Investigation Report (CRA, 2011)

CONESTOGA-ROVERS
& ASSOCIATES

20818 44th Avenue West, Suite 190, Lynnwood, Washington 98036
Telephone: 425·563·6500 Facsimile: 425·563·6599
www.CRAworld.com

August 17, 2011

Reference No. 241739

Libby Goldstein
Dept of Ecology, NW Region
3190 160th Ave SE
Bellevue, WA 98008-5452

Re: Remedial Investigation Report
Former Jiffy Lube Facility
6808 196th Street Southwest
Lynnwood, WA
Sap Code 171152
Ecology F/S No. 27496218
VCP No. NW2070

Dear Ms. Goldstein:

Please find the enclosed Remedial Investigation Report for the former Jiffy Lube facility located at 6808 196th Street Southwest, Lynnwood, WA. We are requesting Ecology's review and opinion on this report. If you have any questions regarding the contents of the enclosed document, please call Christina McClelland at (425) 563-6514.

Yours truly,

CONESTOGA-ROVERS & ASSOCIATES

Christina McClelland

CM/cd/1
Encl.

Remedial Investigation Report

cc: Perry Pineda; Shell Oil Products US
Strickland Holdings

REMEDIAL INVESTIGATION REPORT

FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
LYNNWOOD, WASHINGTON

SAP CODE	171152
INCIDENT NO.	97605410
AGENCY NO.	27496218
VCP NO.	NW2070

Prepared For:
Shell Oil Products US
20945 S. Wilmington Ave
Carson, CA 90810

Prepared by:
Conestoga-Rovers
& Associates

20818 44th Avenue W, Suite 190
Lynnwood, Washington
U.S.A. 98036

Office: 425-563-6500
Fax: 425-563-6599

web: http:\\www.CRAworld.com

AUGUST 17, 2011
REF. NO. 241739 (7)
This report is printed on recycled paper.

REMEDIAL INVESTIGATION REPORT

FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
LYNNWOOD, WASHINGTON

SAP CODE	171152
INCIDENT NO.	97605410
AGENCY NO.	27496218
VCP NO.	NW2070

Prepared For:

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1.0 INTRODUCTION

1.1 SITE INFORMATION

Site Name: Former Jiffy Lube Facility

Site Address: 6808 196th Street Southwest, Lynnwood, Washington

Voluntary Cleanup Program Number: NW2070

Project Consultant: Conestoga-Rovers & Associates

Project Consultant Contact Information: Christina McClelland
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Lynnwood, Washington 98036
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Current Owner/Operator: Strickland Real Estate Holdings LLC

1.2 PURPOSE

Conestoga-Rovers & Associates (CRA) prepared this Remedial Investigation (RI) report on behalf of Equilon Enterprises LLC dba Shell Oil Products US (SOPUS) for the former Jiffy Lube Facility located at 6808 196th Street Southwest, Lynnwood, Snohomish County, Washington (Property; Figure 1).

This RI report was prepared to satisfy the items required by Washington Administrative Code (WAC) 173-340-350 and summaries remedial investigation findings for the Site. The Site background and summary of previous investigations and remediation activities presented in this report are a summary of historical Site investigations, the 2010 Site investigation completed by CRA, and documents prepared by CRA and previous consultants. A list of all documents reviewed in preparation of this report is included in Appendix A.

2.0 SITE IDENTIFICATION AND DESCRIPTION

2.1 SITE DISCOVERY AND REGULATORY STATUS

In August 1995, Nowicki and Associates (Nowicki) conducted soil compliance sampling in association with the removal of one 3,000-gallon new oil underground storage tank (UST) and the closure-in-place of one 500-gallon waste oil UST. Concentrations of total petroleum hydrocarbons (TPH) as diesel (TPHd) and TPH as heavy oil (TPHo) were detected above the Washington State Department of Ecology (Ecology) Model Toxics Control Act (MTCA) Method A cleanup levels in soil samples collected from west sidewall. Nowicki over-excavated the locations containing petroleum hydrocarbon impacted soil. Approximately 65 tons of petroleum-hydrocarbon impacted soil was removed from the new oil UST excavation. Soil samples collected from the sidewalls and bottom of the new oil UST excavation following over-excavation were below laboratory reporting limits for TPHd and TPHo.

A petroleum release was reported to Ecology on November 20, 1995, and the Site was listed with Ecology's leaking underground storage tank (LUST) program (ID #6802). The Site was entered into Ecology's Voluntary Cleanup Program (VCP) in 2009 and issued site number NW2070. In February 2007, the listing was amended to include petroleum hydrocarbon impacted groundwater as a "media affected." The current status of the Site with Ecology is "Cleanup Started" for soil and groundwater as of February 2007. It should be noted that in February 2007, Cambria Environmental Technologies reported a secondary release at the Site relating to gasoline range hydrocarbons found during a 2006 site investigation. The release of gasoline range hydrocarbons were erroneously added to the existing release of oil range hydrocarbons associated with the lube facility operation. The two releases occurred at different times and by different responsible parties. The distinction between these two releases will be discussed as part of this report.

MTCA Method A cleanup levels for soil will be used as screening levels for purposes of discussion of investigation results. Cleanup standards are more fully developed and discussed in Section 8.

2.2 SITE AND PROPERTY LOCATION/DEFINITION

The Property is a former Jiffy Lube Facility located on the southwest corner of 196th Street Southwest and 68th Avenue West in Lynnwood, Snohomish County, Washington (Property; Figure 1). The Property operated as a service station prior to converting to a lube facility in approximately 1977. All known business operators at the Property leased the Property from the Lorena Strickland Family. A legal description of the Property, including past and present owners and operators, is included in Appendix B. Currently the Aloha Café (a coffee shop) operates at the Property.

The MTCA site (Site) is defined as all affected areas from the petroleum release associated with the lube facility operation at the Property and any potentially impacted adjacent parcels. The Site boundary is presented on Figure 2. The affected areas associated with the gasoline range hydrocarbon release are not considered part of the Site described in this report.

2.3 NEIGHBORHOOD SETTING

The Property is zoned as commercial. The surrounding area is a combination of commercial and residential properties. The nearest residential area is located on the adjacent property to the south. A dry cleaners and carpet store occupies the adjacent property to the west. A strip mall occupies the property to the north across 196th Street Southwest, and a parking lot occupies the property to the east across 68th Avenue West (Figure 3).

2.4 PHYSIOGRAPHIC SETTING/TOPOGRAPHY

The Property is located at approximately 450 feet above mean sea level (msl) in a relatively flat area located approximately ¾ mile west of Scriber Lake.

Surface cover at the Property is primarily asphalt and concrete pavement. One catch basin is located in the southeastern corner of the Property. The area topography slopes gently from the site to the south and west, and is locally relatively level to the north and east.

3.0 PROPERTY DEVELOPMENT AND HISTORY

3.1 PAST PROPERTY USES AND FACILITIES

Based on the station building construction date, the Property was developed in approximately 1959. Historical documents suggest that a Texaco service station operated on the Property from 1959 to 1977, and was replaced by a lube oil facility under various ownership from 1977 to 2006. The layout of the original Texaco service station facilities are uncertain; however, the former dispenser islands are believed to have been located in the north-central portion of the Property and the former gasoline USTs were believed to be located in the northeastern corner of the Property. Three gasoline USTs were likely present at the Property. Equilon acquired the Jiffy Lube facility in 2004 and operated until the facility was taken out of service on April 30, 2006. According to Ecology's UST data summary, the lube facilities included one 3,000-gallon new oil UST, one 500-gallon waste oil UST (both installed in 1982), and one 500-gallon heating oil UST (of unknown installation date). In 1995, the new and waste USTs were replaced with above ground storage tanks (ASTs). A summary all historical USTs associated with the Property are listed below.

Tank Type & Volume	*Content*	*Date Installed*	*Date Decommissioned*	*Tank Operator*
Unknown	Gasoline	1959	1977	Texaco
Unknown	Gasoline	1959	1977	Texaco
Unknown	Gasoline	1959	1977	Texaco
3,000-gallon UST	New Oil	1982	1995	Jiffy Lube/Equilon
500-gallon UST	Waste Oil	1982	1995	Jiffy Lube/Equilon
500-gallon UST	Heating Oil	Unknown	1989	Jiffy Lube/Equilon

3.2 CURRENT PROPERTY USE AND FACILITIES

The Property currently operates as the Aloha Café. Facilities on the Property currently include the former station building (Figure 2). The Jiffy Lube facilities were decommissioned on April 30, 2006; however, no report documenting the decommissioning could be located.

3.3 PROPOSED OR POTENTIAL FUTURE PROPERTY USES

Planned use for the Property is uncertain; however, due to its location and zoning, it will likely continue as commercial use.

3.4 ZONING

The Property is zoned as commercial by the City of Lynnwood Zoning Map (2010), and surrounding properties are a mix of commercial and residential zoning.

3.5 TRANSPORTATION/ROADS

The Property is located on the southwestern corner of 196th Street Southwest and 68th Avenue West (Figure 2). 196th Street Southwest (also known as State Route 524) is a major east-west arterial which connects the City of Edmonds to the west to the City of Lynnwood. 68th Avenue West is a minor arterial connecting commercial areas to the south with residential areas to the north.

3.6 UTILITIES AND WATER SUPPLY

Utilities are present in the subsurface throughout the Property and overhead electrical lines run along the southern Property boundary. Subsurface electrical lines run from the station building to the station sign in the northeastern planter, water and natural gas lines run between the station building and the eastern Property boundary, and electrical and telecommunications lines run from the station building to the southeastern corner of the Property (Figure 2). Immediately off-property to the west, another natural gas line and overhead electric lines are present. Drinking water for the City of Lynnwood is provided by the Alderwood Water and Wastewater District, which acquires water from the City of Everett. The City of Everett sources water from Lake Spada Reservoir, Chaplain Reservoir, and the Sultan River.

3.7 POTENTIAL SOURCES OF CONTAMINATION FROM NEIGHBORING PROPERTIES

Two separate Phase I Environmental Site Assessments (ESA) in 2003 and 2004 indicate that former service stations had historically occupied the northwest and southeast corners of the intersection of 196th Street Southwest and 68th Avenue West, both of which are identified in Ecology's LUST list. An Environmental Data Resources, Inc. (EDR) report attached to the 2003 Phase I ESA indicated that twelve additional LUST sites were listed within ½ mile of the Property. There is also a dry cleaners on the adjacent property to the west, and a laundromat to the northeast, however neither property has a record of spills or violations. The twelve additional properties identified in the EDR report are all cross-gradient or downgradient of the Property. Based on the cross-gradient position of the former service station to the east, it is not considered to be a source of the release at the Property. The LUST facility immediately to the north is a potential source of the contamination at the Property based on its close proximity and upgradient location.

4.0 ENVIRONMENTAL INVESTIGATION SUMMARY

A total of 13 soil borings (including one hand auger boring) have been advanced on-Property, and two soil borings have been advanced off-Property. Ten of the on-Property soil borings were completed as monitoring wells. Additionally, six compliance soil samples have been collected at the Site.

A complete chronological summary of work completed at the Site during the investigations listed above is included as Appendix C. Reports summarized in Appendix C represent all available investigation reports obtained by or provided to

CRA. Figures 4A and 4B present the locations of all soil samples collected during the investigation activities at the Site. A summary of all soil sample locations submitted for analyses, including the date of the sample, depth, consultant performing sampling, and analytical methods and results are presented in Table 1. A summary of historical groundwater monitoring results are summarized in Table 2. All available historical boring logs for the previous investigations are included in Appendix D. Two soil borings were advanced via a hollow stem auger drill rig in May 2010 to a depth of 20 feet bgs on the adjacent property to the west (Figure 4A and 4B). Grab groundwater samples were collected from these borings from temporary monitoring wells. The borings were backfilled with bentonite chips upon completion. Soil boring logs from CRA's 2010 investigation are included in Appendix E. Laboratory analytical reports for soil samples collected in association with CRA's 2010 investigation are included as Appendix F.

5.0 NATURAL CONDITIONS

5.1 GEOLOGY

The Property is located in the Puget Lowland Physiographic province, which consists of mainly glacially-deposited sediments. The Puget Sound Lowland is a basin lying between the Cascade Mountain Range to the east and the Olympic Mountain Range to the west.

The Property is underlain by imported fill and native material. Fill comprises the subsurface to approximately 7.5 feet bgs, and is underlain by unconsolidated sediments (silts and sands with gravels and clay) characteristic of weathered till to approximately 18 feet bgs. The unconsolidated sediments are underlain by consolidated, dense silts and sands with gravel and clay, characteristic of unweathered till. The till extends to the maximum depth explored of 32.5 feet bgs

Cross sections describing subsurface soil conditions are included as Figures 5A, 5B, 6A and 6B.

5.2 GROUNDWATER

Shallow groundwater beneath the Site is present at average depths varying between approximately 6.1 to 14.9 feet bgs in Site monitoring wells. Groundwater encountered in the Site wells is likely perched water present on top of native material consisting of relatively lower permeable silts and interbedded sands, with trace amounts of gravel and clay. Groundwater flows to the southwest. Table 2 presents historical groundwater elevations and groundwater monitoring results for all Site wells. The EDR provided in a 2003 Phase I ESA for the Property indicated that no drinking water wells are present within ½ mile of the Property. A search of the Ecology Well Log database returned 3 potential wells within a 1-mile radius of the Site. The 3 wells are located 1 mile east-southeast, 0.75 miles southeast, and 0.5 miles northwest. Based on the age of the well installation (1953-1991), these wells likely no longer exist or are not used. The regional groundwater aquifer is estimated at greater than 300 feet bgs based on data provided in the well logs.

5.3 SURFACE WATER

Surface waters near the Site include Scriber Lake located approximately ¾ mile to the east.

5.4 TERRESTRIAL ECOLOGICAL RECEPTORS

The Site qualifies for a TEE exclusion because there is less than 1.5 acres of undeveloped land within a 500-foot radius of the Site. The TEE exclusion form is included in Appendix G.

6.0 CONTAMINANT OCCURRENCE AND MOVEMENT

6.1 SOIL

Table 1 summarizes soil analytical data for the Site. The locations of all soil samples are presented in Figures 4A and 4B. Figures 4A and 4B present the horizontal extent of petroleum hydrocarbons in soil, whereas Figures 5A, 5B, 6A, and 6B present the vertical extent of petroleum hydrocarbons in soil. Based on previous investigations, the extent of petroleum hydrocarbon-impacted soil related to Jiffy Lube facility operations has been adequately defined at the Site based on comparison to MTCA Method A screening levels and is confined to the immediate vicinity of the closed-in-place waste oil UST.

6.2 GROUNDWATER

Table 2 summarizes historical groundwater analytical results for Site monitoring wells. A groundwater contour and chemical concentration map for the third quarter 2010 and a Rose diagram depicting groundwater flow directions since December 2006 are presented in Figures 7A and 7B.

Concentrations of TPHd and TPHo are below MTCA Method A cleanup levels, except in monitoring well MW-8, where the TPHd and TPHo concentrations are likely the result of weathered gasoline eluting in the diesel and oil ranges, and/or the result of hydrocarbon migration from an off-Site source. Monitoring well MW-8 is located approximately 45 feet upgradient (north) of the lube facility release. SPH continues to periodically be reported in monitoring wells MW-3, MW-4, and MW-5, and less frequently in monitoring well MW-8 (Table 2). The concentration of TPHd in two grab samples collected in May 2010 from temporary wells in soil borings SB-3 and SB-4 above the MTCA Method A screening level is also likely weathered gasoline eluting in the diesel range.

Fuel fingerprint analysis conducted in late 2009 concluded that the SPH detected in monitoring wells MW-3, MW-4, and MW-5 (and likely the intermittently detected SPH in MW-8) consists of weathered gasoline; lube oil constituents were absent (Appendix H) [1]. Concentrations of TPHg and BTEX, related to the former service station operations, are persistently detected above the MTCA Method A screening levels in monitoring wells MW-1, MW-2, and MW-10 (Table 2). Benzene in grab groundwater sampled from a temporary well in soil boring SB-3 in May 2010 also was above the MTCA Method A screening level.

6.3 SURFACE WATER

Based on the distance to the nearest surface water bodies, no investigation of surface water associated with this release is necessary.

6.4 AIR/SOIL VAPOR

There have been no investigations of soil vapor at the Site. Based on the distribution of Site contaminants in soil and groundwater beneath the Site associated with the lube facility release, impacts to soil vapor are likely negligible. Soil vapor associated with the former gasoline service station release will require further evaluation.

6.5 SEDIMENT

No sediment has been sampled as there has been no indication that the surface water has been impacted from the Property or Site.

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[1] The fuel fingerprint analysis included as Appendix H refers to results from well MW-6; however, the chain-of-custody included in the memo indicates that samples were taken from MW-3, MW-4, and MW-5. Because SPH has never been present in MW-6, it is clear that the results included in the analysis are in fact from MW-5.

7.0 CONCEPTUAL MODEL

Based on the results of environmental activities, two distinct releases have occurred at the Property; one release associated with the former lube oil facility operations before 1995 (but after UST installation in 1982); and one release associated with the former service station operations at the Property before 1977. The exact circumstances of either release is not known, but the release associated with the lube oil facility is likely sourced from the closed-in-place waste oil UST; and the release associated with the former service station operations is likely sourced from the former dispenser islands and former product conveyance system. The former fuel USTs may also be a source of the release associated with the former service station, but soil and groundwater data at monitoring well MW-7 suggest that the dispenser islands and product conveyance system were the source of the release.

Soil and groundwater data obtained during environmental activities suggests that the release associated with the lube oil facility is limited to soil in the immediate vicinity of the former waste oil UST. Monitoring well MW-10, downgradient of the closed-in-place waste oil UST, has had no detections of TPHo in groundwater above the laboratory reporting limits since installation. Concentrations of TPHd and TPHo reported in groundwater are most likely the result of weathered gasoline eluting in the diesel and heavy oil ranges. Fuel fingerprint analysis of an SPH sample taken from monitoring well MW-3 demonstrated that SPH at the Site is comprised entirely of weathered gasoline; lube oil constituents are absent.

The Property has likely been capped by asphalt and concrete since development in 1959 and therefore has not been exposed to infiltrating surface water. Subsurface soils at the Site consist of several feet of fill overlying weathered till, which is comprised of poorly sorted silts and sands with variable amounts of clay and gravel. At approximately 18 feet bgs, relatively impermeable glacial till is present to the maximum depth explored at the Site of 32.5 feet bgs. The depth to the perched water fluctuates seasonally, and is normally present at the Site from approximately 6.1 to 14.9 feet bgs. SPH is currently present routinely in monitoring wells MW-3, MW-4, and MW-5, and intermittently in monitoring well MW-8, all in the vicinity of the former dispenser islands. In 2009, SPH was periodically removed passively using absorbent socks, and in 2010, SPH was periodically removed by bailing.

8.0 CLEANUP STANDARDS – SOIL AND GROUNDWATER

In accordance with MTCA, development of cleanup levels includes identifying potential exposure pathways for humans and environmental impacts based on the planned land use. The Property is currently zoned for commercial use and zoning is not anticipated to change in the near future. As previously noted, the Property is currently used as a coffee shop.

8.1 SOIL CLEANUP LEVELS

MTCA Method A soil cleanup levels will be used for Jiffy Lube constituents of concern (COCs) beneath the Site. The point of compliance for soil cleanup levels based on protection of groundwater is all soil throughout the Site from the ground surface to the groundwater table. Soil cleanup levels are included in Table 1.

8.2 GROUNDWATER CLEANUP LEVELS

MTCA Method A groundwater cleanup levels will be used for Jiffy Lube COCs. Based on the data collected to date, it does not appear that groundwater has been impacted by any former lube oil operations at the Site. Groundwater cleanup levels are included in Table 2.

9.0 INTERIM ACTION SUMMARY

During the 1995 new oil UST removal, 65 tons of petroleum hydrocarbon impacted soil was reportedly removed and disposed of offsite. In 2009 and 2010, SPH was removed from monitoring wells MW-3, MW-4 and MW-5 using absorbent socks and bailing. No additional interim actions have been identified at the Site.

10.0 AREAS REQUIRING FUTURE MANAGEMENT AND CONCLUSIONS

10.1 CONSTITUENTS OF CONCERN

TPHo in soil is the only COC associated with the Site (former lube facility release).

10.2 SOIL – VERTICAL AND LATERAL

The only area requiring future soil management is around the closed-in-place 500-gallon waste oil UST, beneath the existing on-Site building.

10.3 GROUNDWATER – VERTICAL AND LATERAL

The groundwater associated with the Site has not been impacted by COCs originating from the former lube oil facility, and therefore, future management of groundwater is not required.

11.0 CONCLUSIONS AND RECOMMENDATIONS

Based on all of the data collected to date, residual impacts related to the release originating from the former lube oil operations on the Property is limited to a very small area beneath the existing building. The former lube oil release has not adversely impacted groundwater and is not likely to impact groundwater in the future. The former gasoline service station operations resulted in a much larger release encompassing the majority of the Property and possibly extending off-Property, impacting both soil and groundwater. The small area of remaining soil impacts beneath the building are not accessible for removal or remediation without significant disturbance to the existing business, and much more significant impacts to soil and groundwater associated with the former gasoline service station would still remain beneath the Property. Therefore, CRA recommends the evaluation and execution of an environmental covenant associated with the lube oil facility release for the residual soil impacts beneath the existing building. CRA also recommends that a separate environmental release is opened with Ecology and the appropriate responsible party is identified.

12.0 REFERENCES

City of Lynnwood, *Current Zoning Map,* April 20, 2010.

Environmental Data Resources, Inc., *EDR-Radius Map with GeoCheck,* December 9, 2002.

FINEnvironmental, Inc., Phase I Environmental Site Assessment Limited Compliance Audit, January 28, 2003.

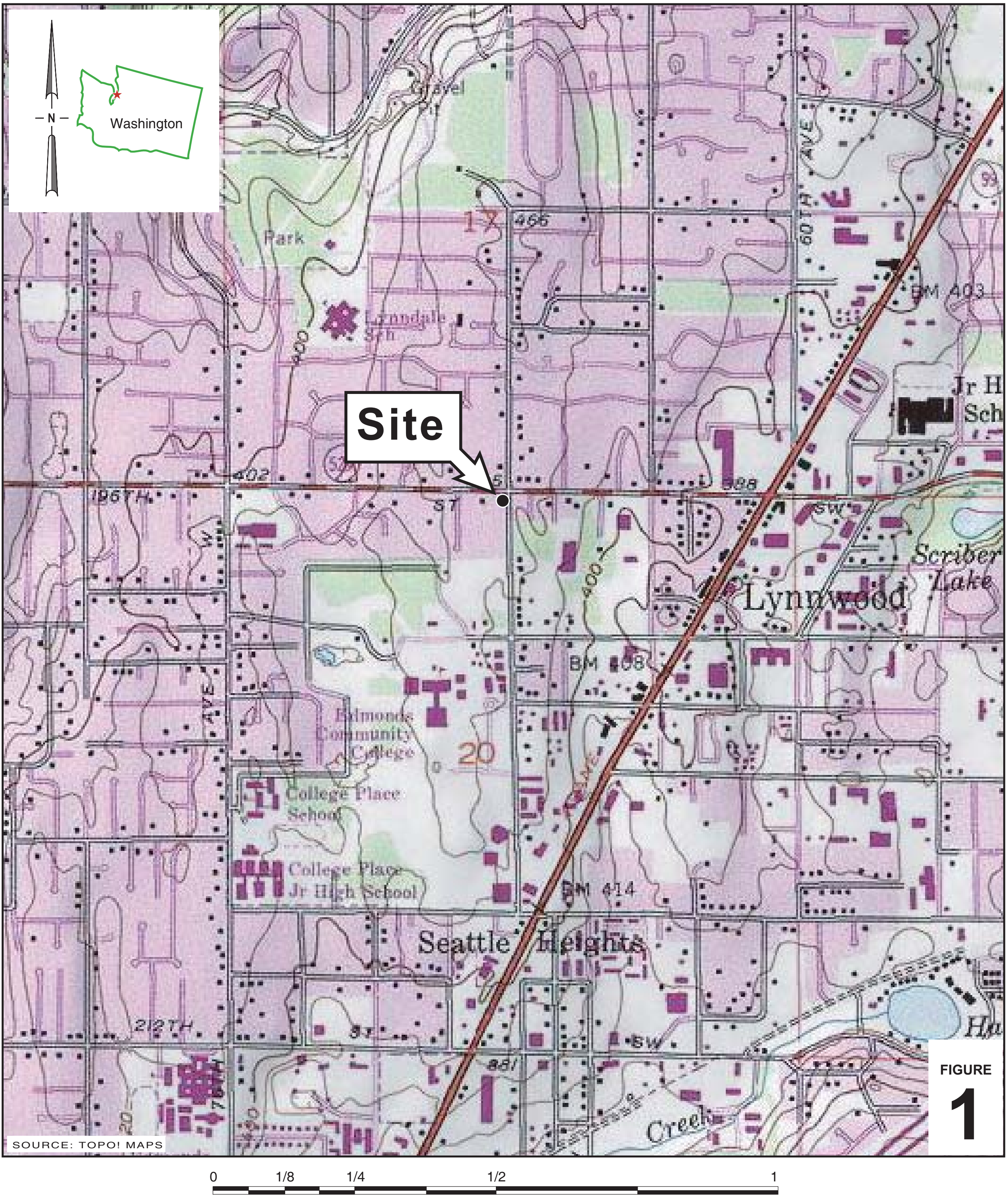
GeoEngineers, Inc., Limited Phase I Environmental Site Assessment, February 11, 2004.

Nowicki and Associates, Lynnwood Quaker State Lube UST Closure Site Characterization, September 27, 1995.

Nowicki and Associates, Waste Oil UST – Characterization Soil Boring, November 20, 1995.

FIGURES

02/03/10



SOURCE: TOPO! MAPS

FIGURE
1

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Former Jiffy Lube Facility
6808 196th Street Southwest
Lynnwood, Washington

CRA
CONESTOGA-ROVERS
& ASSOCIATES

Vicinity Map

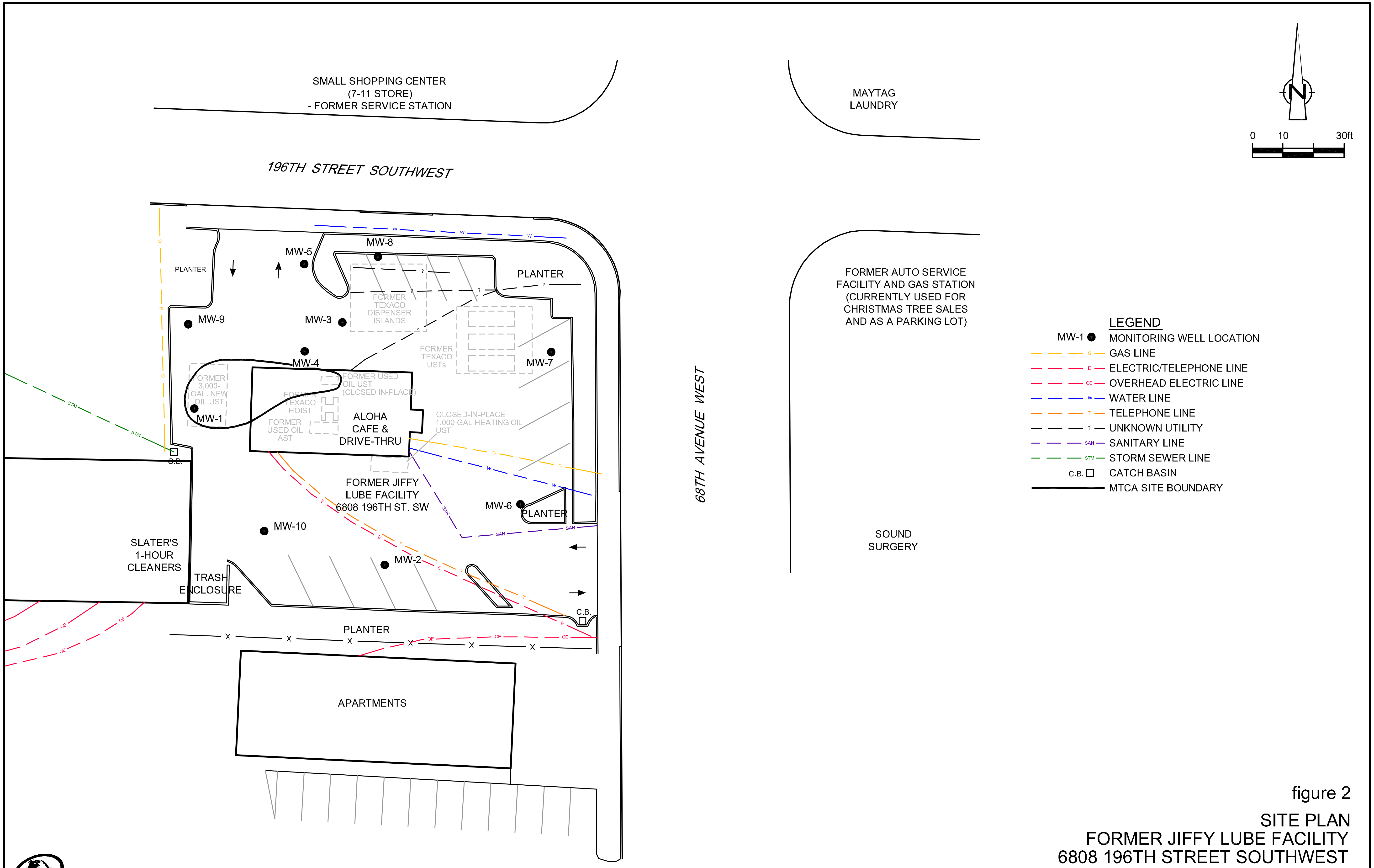


figure 2

SITE PLAN
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington

BASEMAP MODIFIED FROM DRAWING PROVIDED BY GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

241739-95(007)GN-WA001 JUL 27/2011

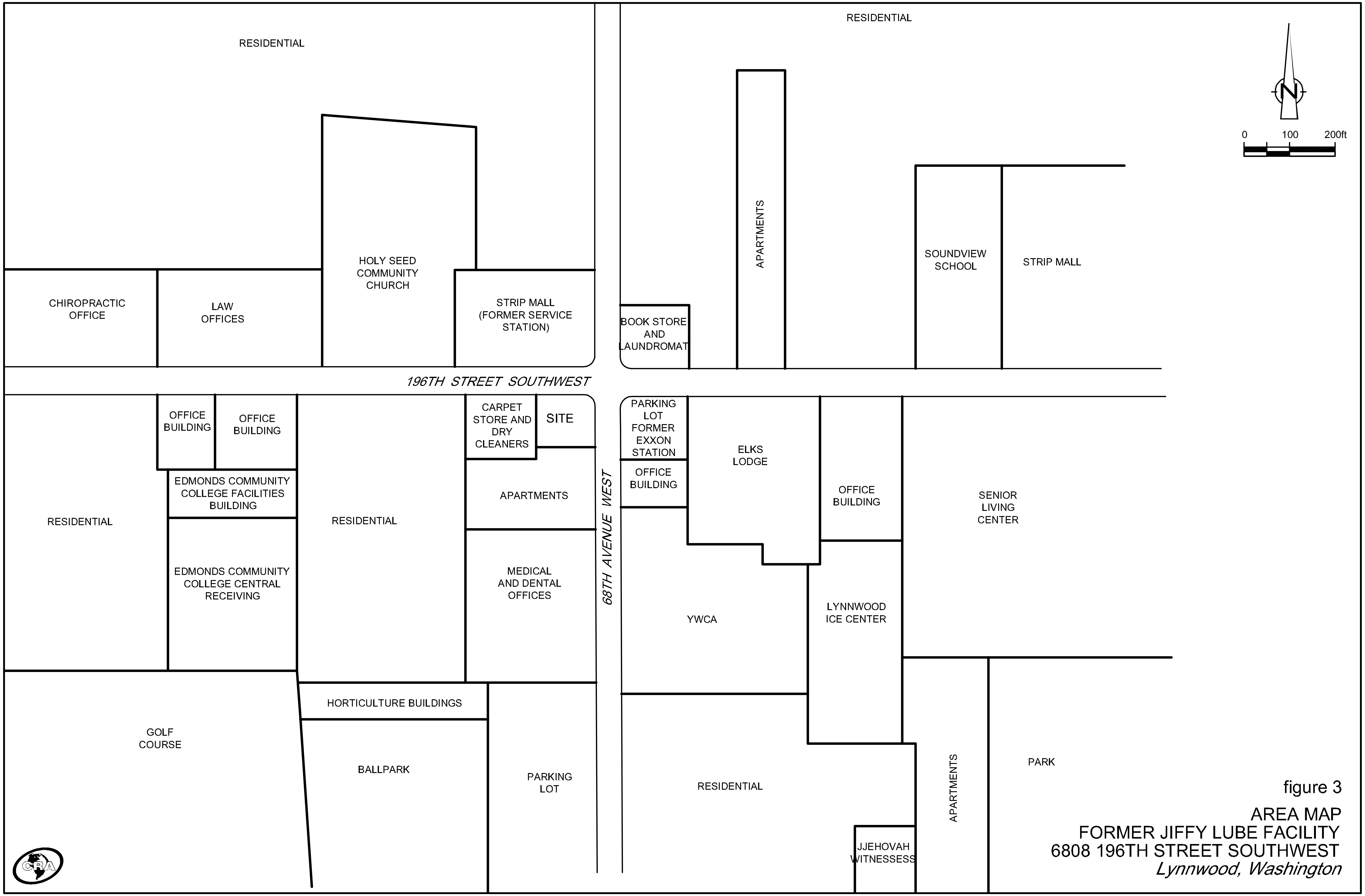
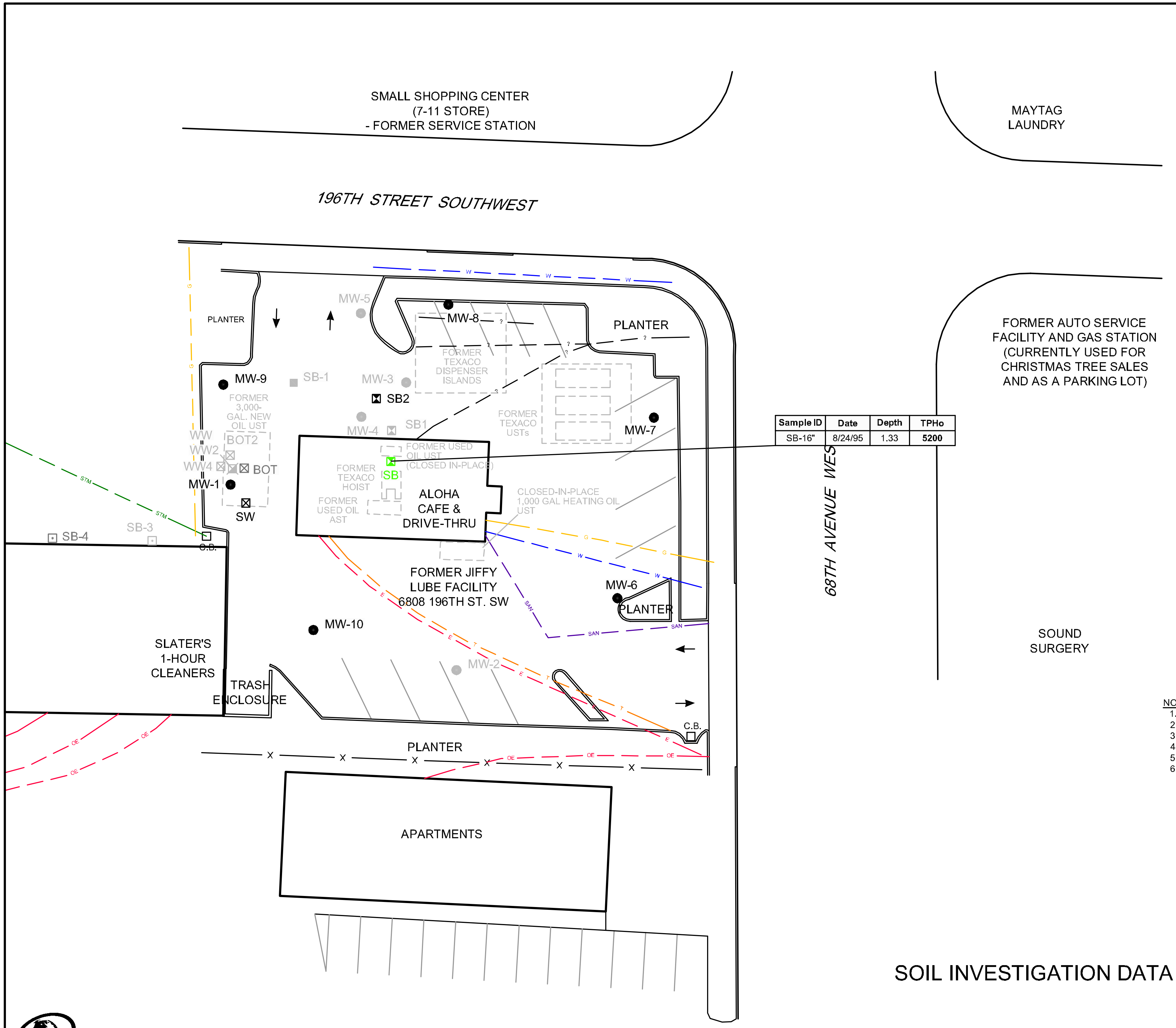


figure 3

AREA MAP
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington



Sample ID	Date	Depth	TPHo
SB-16"	8/24/95	1.33	**5200**

LEGEND

MW-1 ●	MONITORING WELL LOCATION
SB1 ☒	SOIL BORING LOCATION (NOWICKI, 1995)
WW4 ☒	SOIL SAMPLE LOCATION (NOWICKI, 1995)
SB-1 ■	SOIL BORING LOCATION (CAMBRIA, 2006)
SB-3 ⊡	SOIL BORING LOCATION (CRA, 2010)
WW ☒	EXCAVATED SAMPLE LOCATION
— — — G —	GAS LINE
— — — E —	ELECTRIC/TELEPHONE LINE
— — — OE —	OVERHEAD ELECTRIC LINE
— — — W —	WATER LINE
— — — T —	TELEPHONE LINE
— — — ? —	UNKNOWN UTILITY
— — — SAN —	SANITARY LINE
— — — STM —	STORM SEWER LINE
C.B. ☐	CATCH BASIN
▨	INDICATES ALL CONCENTRATIONS WERE BELOW LABORATORY REPORTING LIMITS
▩	INDICATES AT LEAST ONE CONCENTRATION WAS DETECTED ABOVE THE LABORATORY REPORTING LIMITS, BUT NO CONCENTRATION EXCEEDED THE MTCA METHOD A CLEANUP LEVELS
🟩	INDICATES AT LEAST ONE CONCENTRATION EXCEEDED ECOLOGY'S MTCA METHOD A CLEANUP LEVELS

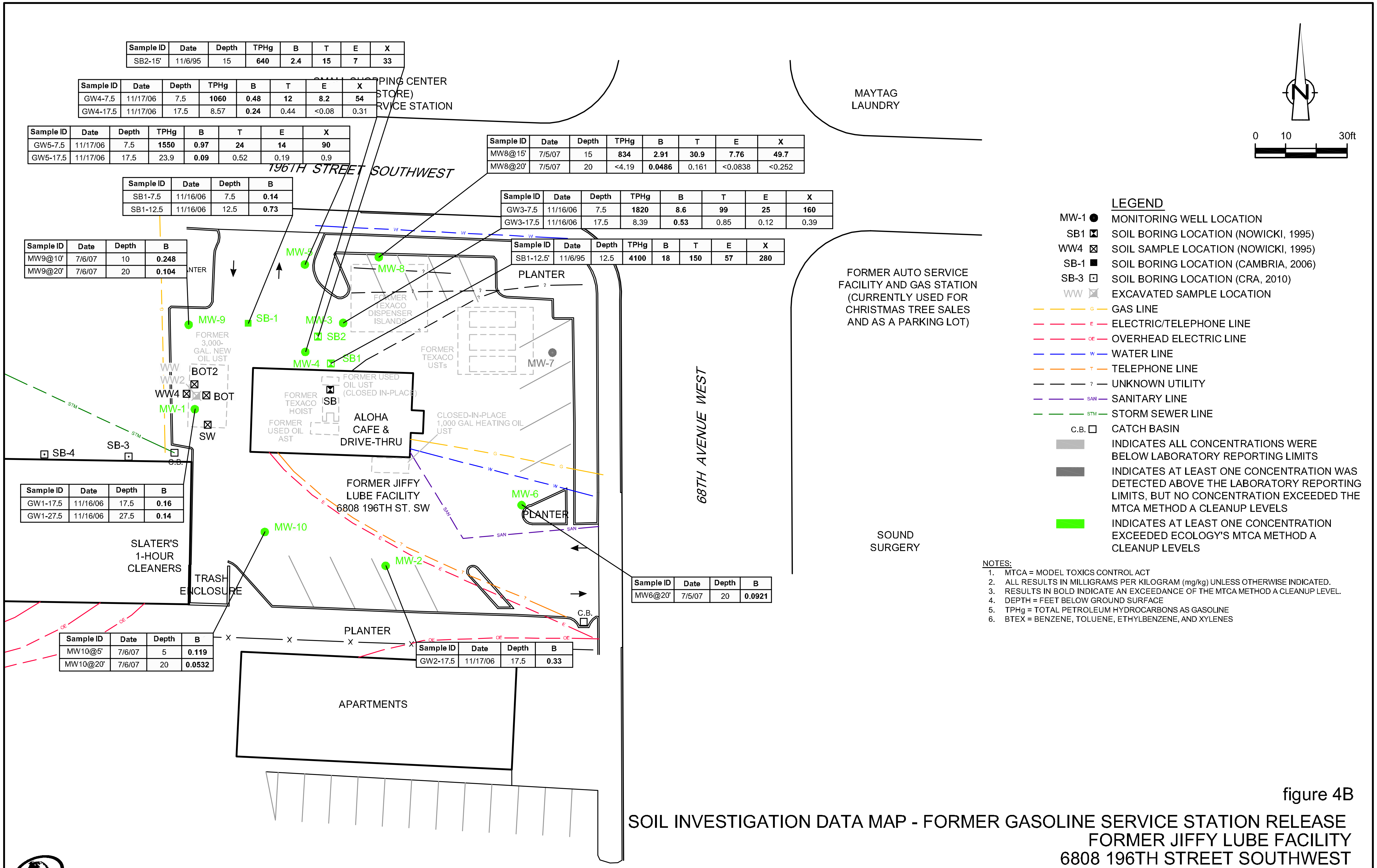
NOTES:
1. MTCA = MODEL TOXICS CONTROL ACT
2. ALL RESULTS IN MILLIGRAMS PER KILOGRAM (mg/kg) UNLESS OTHERWISE INDICATED.
3. RESULTS IN BOLD INDICATE AN EXCEEDANCE OF THE MTCA METHOD A CLEANUP LEVEL.
4. DEPTH = FEET BELOW GROUND SURFACE
5. TPHd = TOTAL PETROLEUM HYDROCARBONS AS DIESEL
6. TPHo = TOTAL PETROLEUM HYDROCARBONS AS MOTOR OIL

figure 4A

SOIL INVESTIGATION DATA MAP - FORMER LUBE FACILITY RELEASE
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington

BASEMAP MODIFIED FROM DRAWING PROVIDED BY GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

241739-95(007)GN-WA002 JUL 27/2011



Sample ID	Date	Depth	TPHg	B	T	E	X
SB2-15'	11/6/95	15	**640**	**2.4**	**15**	**7**	**33**

Sample ID	Date	Depth	TPHg	B	T	E	X
GW4-7.5	11/17/06	7.5	**1060**	**0.48**	**12**	**8.2**	**54**
GW4-17.5	11/17/06	17.5	8.57	**0.24**	0.44	<0.08	0.31

Sample ID	Date	Depth	TPHg	B	T	E	X
GW5-7.5	11/17/06	7.5	**1550**	**0.97**	**24**	**14**	**90**
GW5-17.5	11/17/06	17.5	23.9	**0.09**	0.52	0.19	0.9

Sample ID	Date	Depth	B
SB1-7.5	11/16/06	7.5	**0.14**
SB1-12.5	11/16/06	12.5	**0.73**

Sample ID	Date	Depth	TPHg	B	T	E	X
MW8@15'	7/5/07	15	**834**	**2.91**	**30.9**	**7.76**	**49.7**
MW8@20'	7/5/07	20	<4.19	**0.0486**	0.161	<0.0838	<0.252

Sample ID	Date	Depth	TPHg	B	T	E	X
GW3-7.5	11/16/06	7.5	**1820**	**8.6**	**99**	**25**	**160**
GW3-17.5	11/16/06	17.5	8.39	**0.53**	0.85	0.12	0.39

Sample ID	Date	Depth	TPHg	B	T	E	X
SB1-12.5'	11/6/95	12.5	**4100**	**18**	**150**	**57**	**280**

Sample ID	Date	Depth	B
MW9@10'	7/6/07	10	**0.248**
MW9@20'	7/6/07	20	**0.104**

Sample ID	Date	Depth	B
GW1-17.5	11/16/06	17.5	**0.16**
GW1-27.5	11/16/06	27.5	**0.14**

Sample ID	Date	Depth	B
MW6@20'	7/5/07	20	**0.0921**

Sample ID	Date	Depth	B
MW10@5'	7/6/07	5	**0.119**
MW10@20'	7/6/07	20	**0.0532**

Sample ID	Date	Depth	B
GW2-17.5	11/17/06	17.5	**0.33**

LEGEND

MW-1 ●	MONITORING WELL LOCATION
SB1 ☒	SOIL BORING LOCATION (NOWICKI, 1995)
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NOTES:

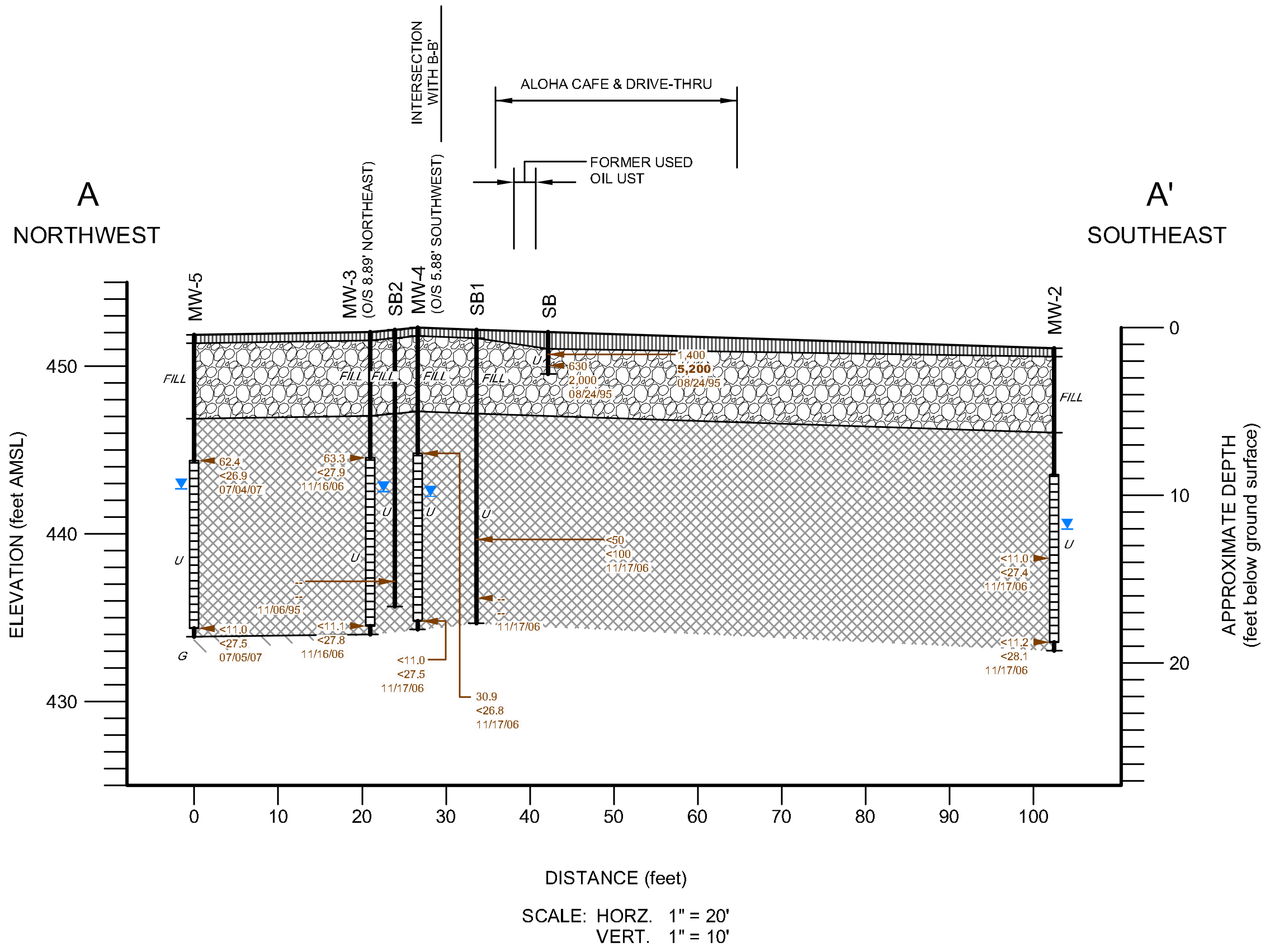
1. MTCA = MODEL TOXICS CONTROL ACT
2. ALL RESULTS IN MILLIGRAMS PER KILOGRAM (mg/kg) UNLESS OTHERWISE INDICATED.
3. RESULTS IN BOLD INDICATE AN EXCEEDANCE OF THE MTCA METHOD A CLEANUP LEVEL.
4. DEPTH = FEET BELOW GROUND SURFACE
5. TPHg = TOTAL PETROLEUM HYDROCARBONS AS GASOLINE
6. BTEX = BENZENE, TOLUENE, ETHYLBENZENE, AND XYLENES

figure 4B

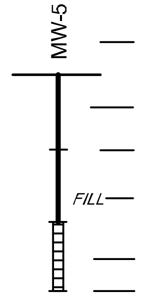
SOIL INVESTIGATION DATA MAP - FORMER GASOLINE SERVICE STATION RELEASE
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington

BASEMAP MODIFIED FROM DRAWING PROVIDED BY GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

241739-95(007)GN-WA003 JUL 27/2011



LEGEND



- WELL DESIGNATION
- GROUND SURFACE
- OBSERVATION WELL INSTALLATION
- STRATIGRAPHIC BOUNDARY
- TYPICAL SOIL CLASSIFICATION
- SCREENED INTERVAL
- BOTTOM OF BORING
- ◄ APPROXIMATE SOIL SAMPLE LOCATION
- TPHd / TPHo / DATE — HYDROCARBON CONCENTRATIONS IN SOIL (mg/kg)
- ▼ GROUNDWATER DEPTH (7/29/10)

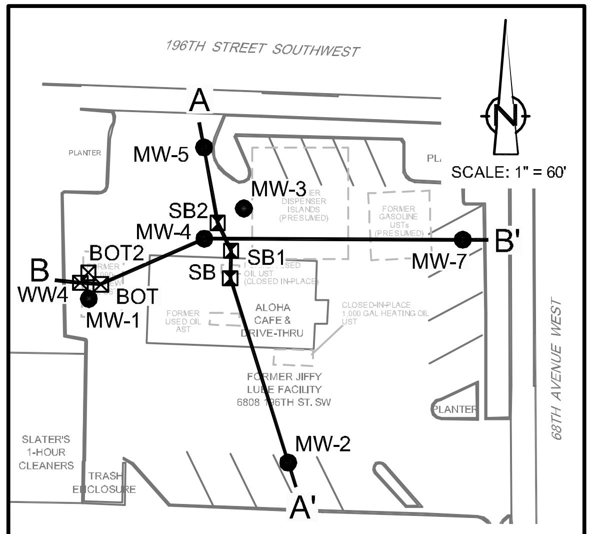
▥ *ASPHALT/CONCRETE*

▨ *FILL*

▩ *U* - UNCONSOLIDATED SEDIMENTS/WEATHERED TILL - LOOSELY ARRANGED OR UNSTRATIFIED SEDIMENTS

▧ *G* - GLACIAL TILL - GLACIALLY REWORKED, DENSE MIXTURE OF CLAY, SILT, SAND, AND GRAVEL

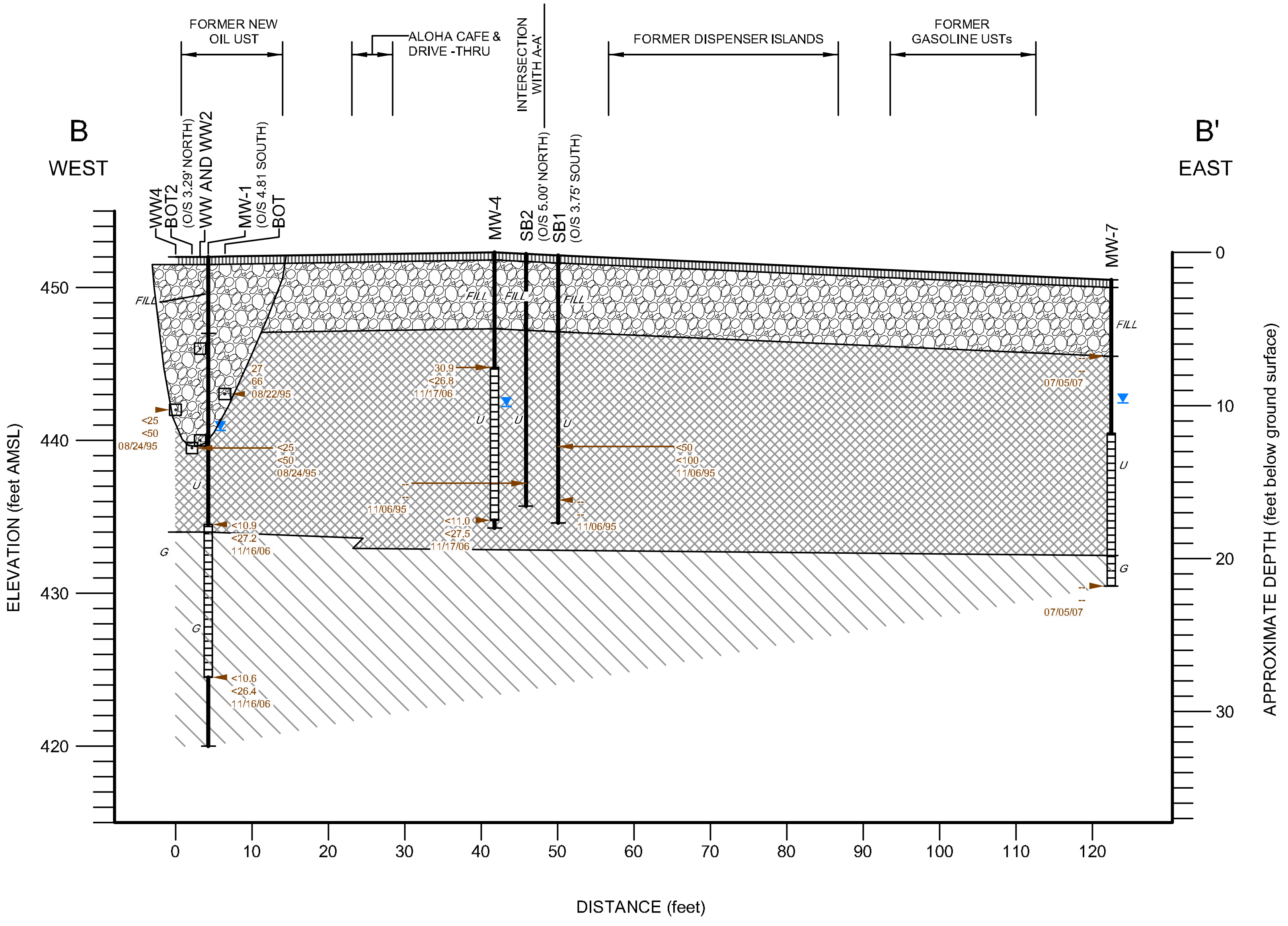
--	NOT ANALYZED
<	ANALYTE CONCENTRATION NOT DETECTED AT OR ABOVE LABORATORY REPORTING LIMIT
O/S	OFFSET
BOLDED VALUE =	CONCENTRATION EXCEEDS THE WASHINGTON STATE DEPARTMENT OF ECOLOGY'S MODEL TOXICS CONTROL ACT (MTCA) METHOD A CLEANUP LEVEL
J	THE SAMPLE CHROMATOGRAPHIC PATTERN FOR TPH DOES NOT MATCH THE CHROMATOGRAPHIC PATTERN OF THE SPECIFIED STANDARD



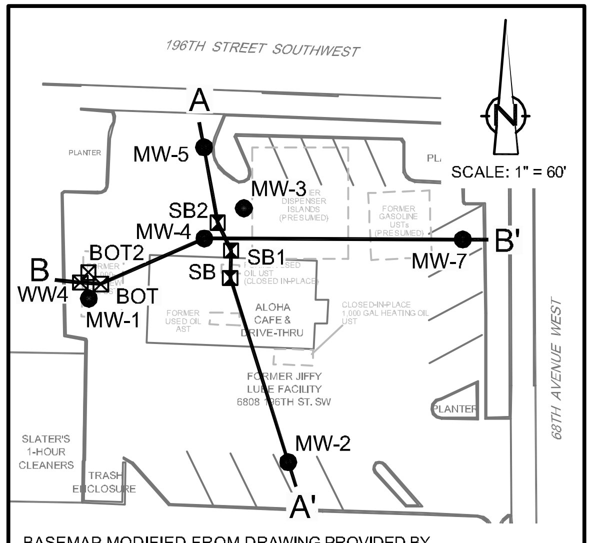
BASEMAP MODIFIED FROM DRAWING PROVIDED BY GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

figure 5A

GEOLOGIC CROSS SECTION A-A' - FORMER LUBE FACILITY RELEASE
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington



SCALE: HORZ. 1" = 20'
VERT. 1" = 10'



BASEMAP MODIFIED FROM DRAWING PROVIDED BY
GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

LEGEND

MW-5 — WELL DESIGNATION
GROUND SURFACE
OBSERVATION WELL INSTALLATION
STRATIGRAPHIC BOUNDARY
FILL — TYPICAL SOIL CLASSIFICATION
SCREENED INTERVAL
BOTTOM OF BORING
◄ APPROXIMATE SOIL SAMPLE LOCATION
TPHd
TPHo
DATE
HYDROCARBON CONCENTRATIONS IN SOIL (mg/kg)
▼ GROUNDWATER DEPTH (7/29/10)
⊡ COMPLIANCE SOIL SAMPLE LOCATION
▥ *ASPHALT/CONCRETE*

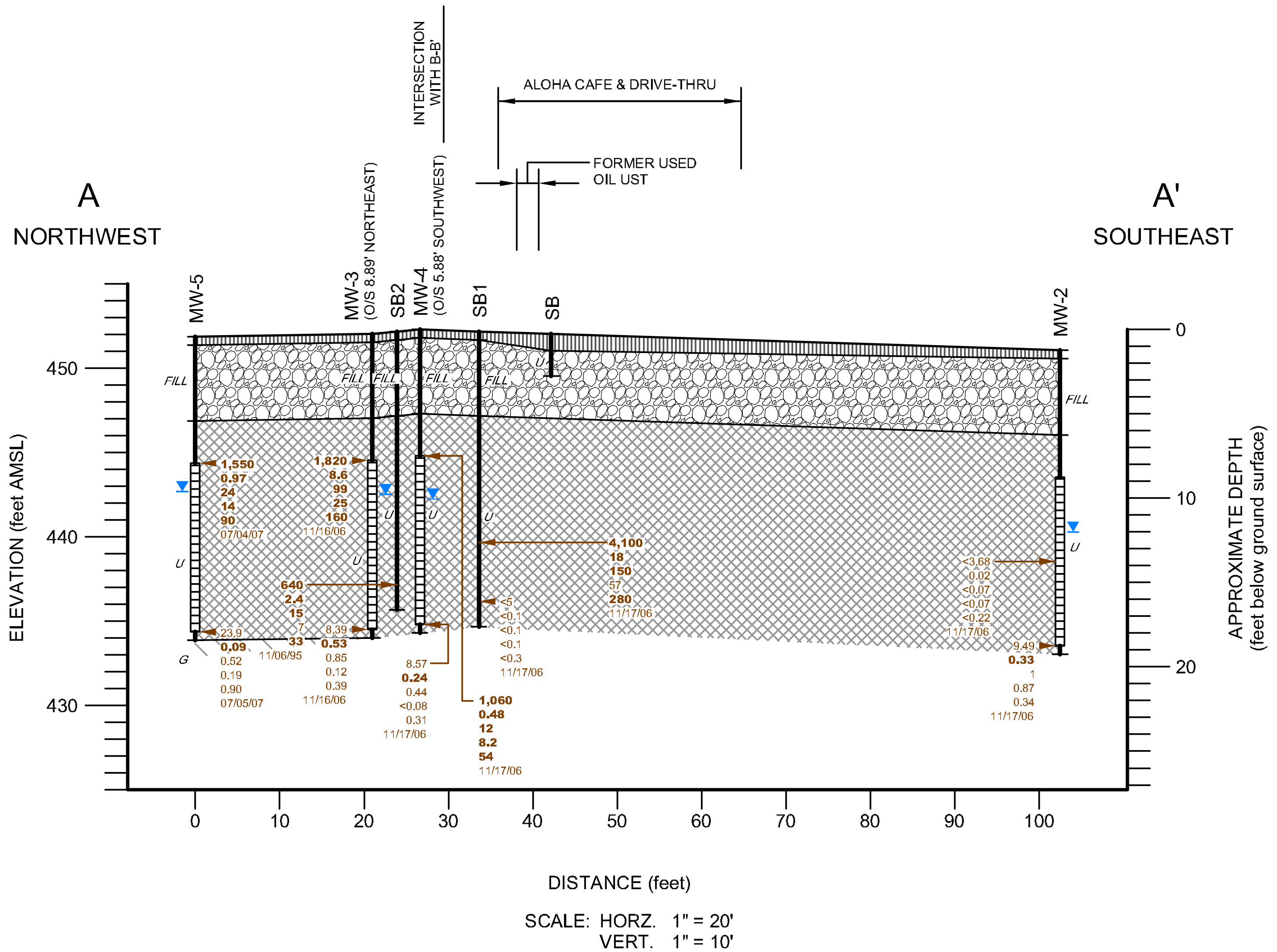
▨ *FILL*
▩ *U* - UNCONSOLIDATED SEDIMENTS/WEATHERED TILL - LOOSELY ARRANGED OR UNSTRATIFIED SEDIMENTS
▧ *G* - GLACIAL TILL - GLACIALLY REWORKED, DENSE MIXTURE OF CLAY, SILT, SAND, AND GRAVEL

--	NOT ANALYZED
<	ANALYTE CONCENTRATION NOT DETECTED AT OR ABOVE LABORATORY REPORTING LIMIT
O/S	OFFSET

BOLDED VALUE = CONCENTRATION EXCEEDS THE WASHINGTON STATE DEPARTMENT OF ECOLOGY'S MODEL TOXICS CONTROL ACT (MTCA) METHOD A CLEANUP LEVEL

figure 5B

GEOLOGIC CROSS SECTION B-B' - FORMER LUBE FACILITY RELEASE
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington



LEGEND

MW-5 — WELL DESIGNATION

GROUND SURFACE

OBSERVATION WELL INSTALLATION

STRATIGRAPHIC BOUNDARY

FILL — TYPICAL SOIL CLASSIFICATION

SCREENED INTERVAL

BOTTOM OF BORING

◄ APPROXIMATE SOIL SAMPLE LOCATION

TPHg
BENZENE
TOLUENE
ETHYLBENZENE
TOTAL XYLENES
DATE
— HYDROCARBON CONCENTRATIONS IN SOIL (mg/kg)

▼ GROUNDWATER DEPTH (7/29/10)

▥ *ASPHALT/CONCRETE*

▨ *FILL*

▩ *U* - UNCONSOLIDATED SEDIMENTS/WEATHERED TILL - LOOSELY ARRANGED OR UNSTRATIFIED SEDIMENTS

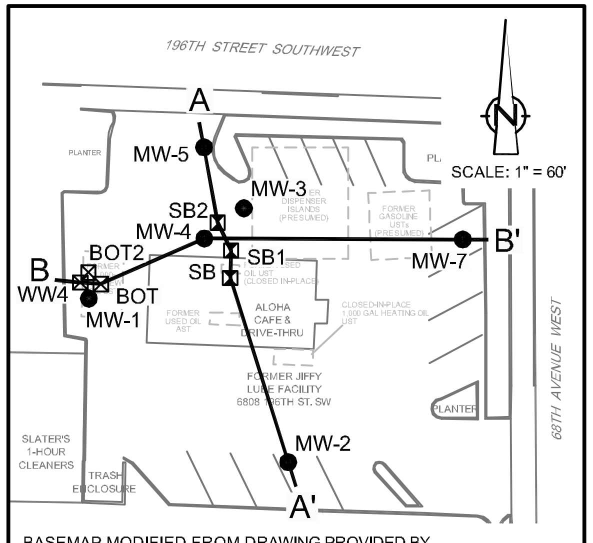
▧ *G* - GLACIAL TILL - GLACIALLY REWORKED, DENSE MIXTURE OF CLAY, SILT, SAND, AND GRAVEL

-- NOT ANALYZED

< ANALYTE CONCENTRATION NOT DETECTED AT OR ABOVE LABORATORY REPORTING LIMIT

O/S OFFSET

BOLDED VALUE = CONCENTRATION EXCEEDS THE WASHINGTON STATE DEPARTMENT OF ECOLOGY'S MODEL TOXICS CONTROL ACT (MTCA) METHOD A CLEANUP LEVEL



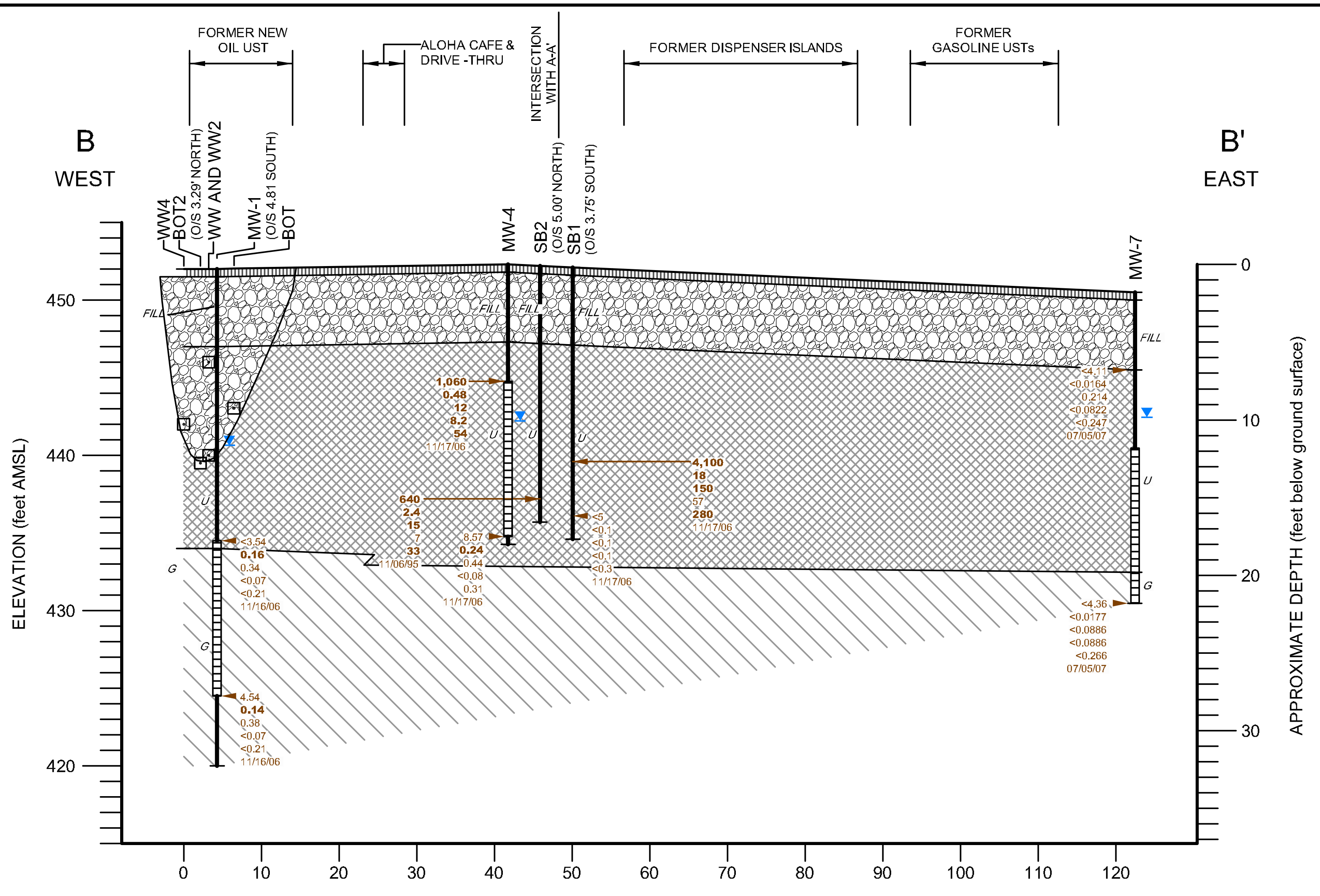
BASEMAP MODIFIED FROM DRAWING PROVIDED BY
GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

figure 6A

GEOLOGIC CROSS SECTION A-A' - FORMER GASOLINE SERVICE STATION RELEASE

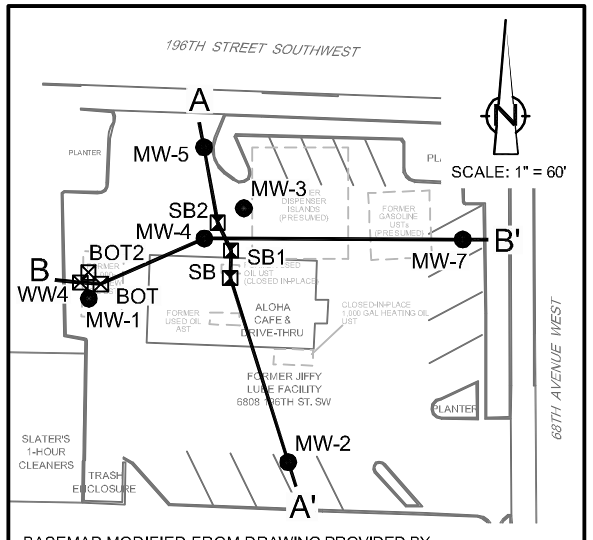
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington

241739-95(007)GN-WA007 JUL 27/2011



DISTANCE (feet)

SCALE: HORZ. 1" = 20'
VERT. 1" = 10'



BASEMAP MODIFIED FROM DRAWING PROVIDED BY
GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

LEGEND

MW-5 — WELL DESIGNATION
GROUND SURFACE
OBSERVATION WELL INSTALLATION
STRATIGRAPHIC BOUNDARY
FILL — TYPICAL SOIL CLASSIFICATION
SCREENED INTERVAL
BOTTOM OF BORING
TPHg BENZENE TOLUENE ETHYLBENZENE TOTAL XYLENES DATE ◄ APPROXIMATE SOIL SAMPLE LOCATION
HYDROCARBON CONCENTRATIONS IN SOIL (mg/kg)
▼ GROUNDWATER DEPTH (7/29/10)
⊡ COMPLIANCE SOIL SAMPLE LOCATION
▥ *ASPHALT/CONCRETE*

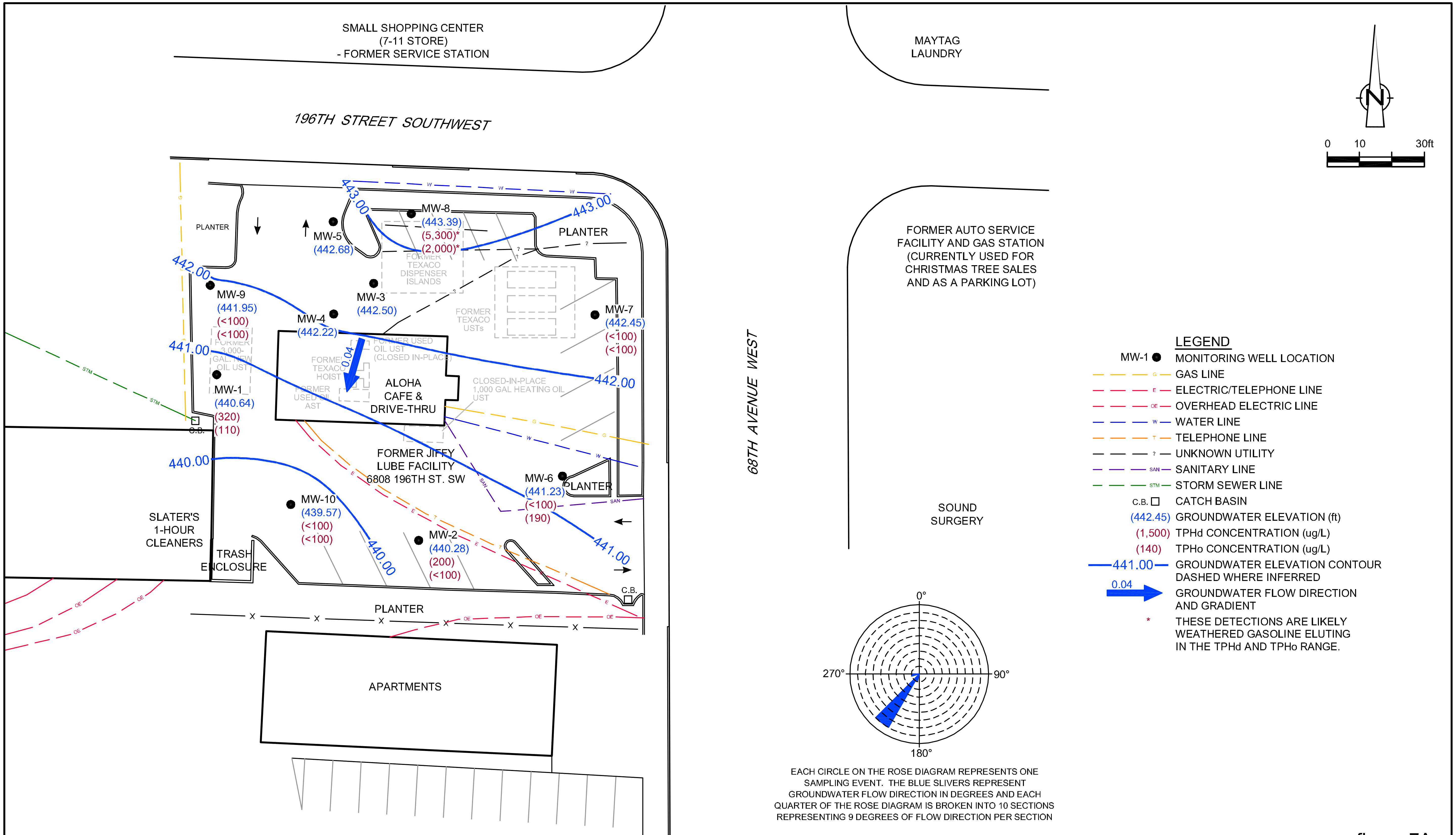
▨ *FILL*
▩ *U* - UNCONSOLIDATED SEDIMENTS/WEATHERED TILL - LOOSELY ARRANGED OR UNSTRATIFIED SEDIMENTS
▧ *G* - GLACIAL TILL - GLACIALLY REWORKED, DENSE MIXTURE OF CLAY, SILT, SAND, AND GRAVEL

--	NOT ANALYZED
<	ANALYTE CONCENTRATION NOT DETECTED AT OR ABOVE LABORATORY REPORTING LIMIT
O/S	OFFSET

BOLDED VALUE = CONCENTRATION EXCEEDS THE WASHINGTON STATE DEPARTMENT OF ECOLOGY'S MODEL TOXICS CONTROL ACT (MTCA) METHOD A CLEANUP LEVEL

figure 6B

GEOLOGIC CROSS SECTION B-B' - FORMER GASOLINE SERVICE STATION RELEASE
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington



EACH CIRCLE ON THE ROSE DIAGRAM REPRESENTS ONE SAMPLING EVENT. THE BLUE SLIVERS REPRESENT GROUNDWATER FLOW DIRECTION IN DEGREES AND EACH QUARTER OF THE ROSE DIAGRAM IS BROKEN INTO 10 SECTIONS REPRESENTING 9 DEGREES OF FLOW DIRECTION PER SECTION

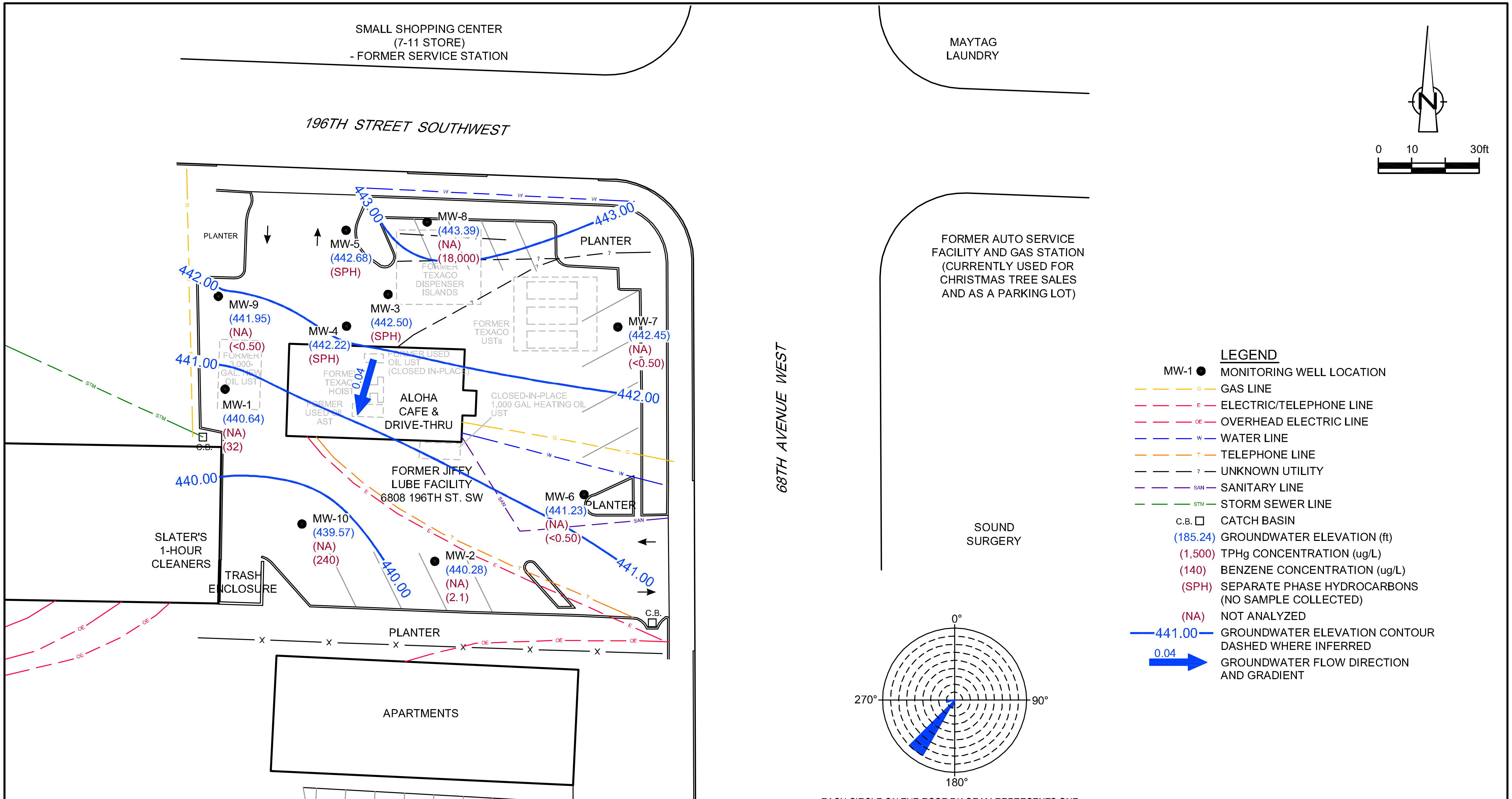
figure 7A

GROUNDWATER ELEVATION AND CHEMICAL CONCENTRATION MAP - FORMER LUBE FACILITY RELEASE - 7/29/10

FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington

BASEMAP MODIFIED FROM DRAWING PROVIDED BY GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

241739-95(007)GN-WA004 JUL 27/2011



EACH CIRCLE ON THE ROSE DIAGRAM REPRESENTS ONE SAMPLING EVENT. THE BLUE SLIVERS REPRESENT GROUNDWATER FLOW DIRECTION IN DEGREES AND EACH QUARTER OF THE ROSE DIAGRAM IS BROKEN INTO 10 SECTIONS REPRESENTING 9 DEGREES OF FLOW DIRECTION PER SECTION

figure 7B

GROUNDWATER ELEVATION AND CHEMICAL CONCENTRATION MAP - FORMER GASOLINE SERVICE STATION RELEASE - 7/29/10

FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST
Lynnwood, Washington

BASEMAP MODIFIED FROM DRAWING PROVIDED BY GEOENGINEERS AND DUNCANSON CO., INC. SURVEYING

241739-95(007)GN-WA005 JUL 27/2011

TABLES

TABLE 1

SUMMARY OF HISTORICAL ANALYTICAL SOIL DATA
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST, LYNNWOOD, WASHINGTON

				HYDROCARBONS			*PRIMARY VOCs*						*LEAD*	*OXYGENATES*	*PAHs*		*PCBs*
Sample ID	*Consultant*	*Sample Date*	*Depth*	*TPHg*[a]	*TPHd*	*TPHo*	*B*	*T*	*E*	*X*	*EDB*	*EDC*	*Total*	*MTBE*	*Naphthalene*	*Total cPAHs*[1]	*PCBs*
		MTCA Method A Cleanup Levels		***30/100***	***2,000***	***2,000***	***0.03***	***7***	***6***	***9***	***0.005***	*N/A*	***250***	***0.1***	*5*	*0.1*	***1***
			feet bgs	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*	*(mg/kg)*
SW	Nowicki & Associates	08/22/95	6	---	<25	<50	---	---	---	---	---	---	---	---	---	---	---
WW	Nowicki & Associates	08/22/95	6	---	**5,100**	**13,000**	---	---	---	---	---	---	---	---	---	---	---
WW2	Nowicki & Associates	08/22/95	NR	---	**---**	**---**	<0.1	<0.1	<0.1	<0.3	---	<0.1	---	---	---	---	---
BOT	Nowicki & Associates	08/22/95	9	---	27	66	---	---	---	---	---	---	---	---	---	---	---
BOT2	Nowicki & Associates	08/24/95	12.5	---	<25	<50	---	---	---	---	---	---	---	---	---	---	---
WW4	Nowicki & Associates	08/24/95	10	---	<25	<50	---	---	---	---	---	---	---	---	---	---	---
SB-16"	Nowicki & Associates	08/24/95	1.33	---	1,400	**5,200**	---	---	---	---	---	---	---	---	---	---	---
SB-24" c	Nowicki & Associates	08/24/95	2	---	630	2,000	---	---	---	---	---	---	---	---	---	---	---
SB1-12.5' b	Nowicki & Associates	11/06/95	12.5	**4,100**	<50	<100	**18**	**150**	**57**	**280**	---	---	---	---	---	---	---
SB1-16'	Nowicki & Associates	11/06/95	16	<5	---	---	<0.1	<0.1	<0.1	<0.3	---	---	---	---	---	---	---
SB2-15'	Nowicki & Associates	11/06/95	15	**640**	---	---	**2.4**	**15**	**7**	**33**	---	---	---	---	---	---	---
GW1-17.5 a	Cambria Environmental Technology, Inc.	11/16/06	17.5	<3.54	<10.9	<27.2	**0.16**	0.34	<0.07	<0.21	<0.04	<0.04	1.48	<0.35	<0.0108	<0.0195	<0.0108
GW1-27.5 a	Cambria Environmental Technology, Inc.	11/16/06	27.5	4.54	<10.6	<26.4	**0.14**	0.38	<0.07	<0.21	<0.04	<0.04	0.962	<0.36	<0.0106	<0.0192	<0.0106
SB1-7.5	Cambria Environmental Technology, Inc.	11/16/06	7.5	4.51	<10.8	<27.1	**0.14**	0.42	<0.08	<0.24	<0.04	<0.04	1.71	<0.41	0.1138	<0.0195	<0.0108
SB1-12.5	Cambria Environmental Technology, Inc.	11/16/06	12.5	12.3	<11.4	<28.6	**0.73**	1.7	0.18	0.9	<0.04	<0.04	2.06	<0.39	0.0152	<0.0208	<0.0115
GW3-7.5 a	Cambria Environmental Technology, Inc.	11/16/06	7.5	**1,820**	63.3	<27.9	**8.6**	**99**	**25**	**160**	<0.04	<0.04	6.69	<0.40	**5.86**	<0.0201	<0.0111
GW3-17.5 a	Cambria Environmental Technology, Inc.	11/16/06	17.5	8.39	<11.1	<27.8	**0.53**	0.85	0.12	0.39	<0.04	<0.04	1.55	<0.39	<0.0111	<0.0201	0.109
GW2-12.5 a	Cambria Environmental Technology, Inc.	11/17/06	12.5	<3.68	<11.0	<27.4	0.02	<0.07	<0.07	<0.22	<0.04	<0.04	1.6	<0.37	<0.0111	<0.0201	<0.0111
GW2-17.5 a	Cambria Environmental Technology, Inc.	11/17/06	17.5	9.49	<11.2	<28.1	**0.33**	1	0.87	0.34	<0.04	<0.04	1.4	<0.43	<0.0113	<0.0205	<0.0113
GW4-7.5 a	Cambria Environmental Technology, Inc.	11/17/06	7.5	**1,060**	30.9	<26.8	**0.48**	**12**	**8.2**	**54**	<0.04	<0.04	2.35	<0.38	4.10	<0.0194	<0.0107
GW4-17.5 a	Cambria Environmental Technology, Inc.	11/17/06	17.5	8.57	<11.0	<27.5	**0.24**	0.44	<0.08	0.31	<0.04	<0.04	1.58	<0.38	<0.0110	<0.01991	<0.0110
GW5-7.5 a	Cambria Environmental Technology, Inc.	11/17/06	7.5	**1,550**	62.4	<26.9	**0.97**	**24**	**14**	**90**	<0.04	<0.04	4.64	<0.39	**6.34**	<0.0195	<0.0108
GW5-17.5 a	Cambria Environmental Technology, Inc.	11/17/06	17.5	23.9	<11.0	<27.5	**0.09**	0.52	0.19	0.9	<0.04	<0.04	1.33	<0.37	0.0127	<0.0201	<0.0111
MW6@15'	CRA	07/05/07	15	<3.95	---	---	<0.0158	<0.0790	<0.0790	<0.237	<0.0790	<0.0790	1.45	<0.39	---	---	---
MW6@20'	CRA	07/05/07	20	<3.54	---	---	**0.0921**	<0.0708	<0.0708	<0.212	<0.0708	<0.0708	1.93	<0.35	---	---	---
MW7@5'	CRA	07/05/07	5	<4.11	---	---	<0.0164	0.214	<0.0822	<0.247	<0.0822	<0.0822	2.34	<0.41	---	---	---
MW7@20'	CRA	07/05/07	20	<4.36	---	---	<0.0177	<0.0886	<0.0886	<0.266	<0.0886	<0.0886	1.85	<0.44	---	---	---
MW8@15'	CRA	07/05/07	15	**834**	---	---	**2.91**	**30.9**	**7.76**	**49.7**	<0.0789	<0.0789	3.29	<0.39	---	---	---
MW8@20'	CRA	07/05/07	20	<4.19	---	---	**0.0486**	0.161	<0.0838	<0.252	<0.0838	<0.0838	1.46	<0.42	---	---	---
MW9@10'	CRA	07/06/07	10	<0.0364	---	---	**0.248**	<0.0854	0.0854	<0.256	<0.0854	<0.0854	1.96	<0.43	---	---	---
MW9@20'	CRA	07/06/07	20	<3.72	---	---	**0.104**	<0.0744	<0.0744	0.327	<0.0744	<0.0744	1.29	<0.37	---	---	---
MW10@5'	CRA	07/06/07	5	8.16	---	---	**0.119**	0.359	<0.0756	<0.227	<0.0756	<0.0756	5.91	<0.38	---	---	---
MW10@20'	CRA	07/06/07	20	3.99	---	---	**0.0532**	0.102	0.131	<0.228	<0.0795	<0.0794	1.54	<0.40	---	---	---
SO-241739-051010-HB-SB-3-5.0	CRA	05/10/10	5	<0.20	<5.0	<5.0	<0.00083	<0.00083	<0.00083	<0.0017	---	---	---	---	---	---	
SO-241739-051010-HB-SB-4-5.0	CRA	05/10/10	5	<0.24	6.1	47	<0.0010	0.0018	<0.0010	0.0020	---	---	---	---	---	---	

TABLE 1

SUMMARY OF HISTORICAL ANALYTICAL SOIL DATA
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST, LYNNWOOD, WASHINGTON

				HYDROCARBONS			PRIMARY VOCs						LEAD	OXYGENATES	PAHs		PCBs
Sample ID	*Consultant*	*Sample Date*	*Depth*	*TPHg*[a]	*TPHd*	*TPHo*	*B*	*T*	*E*	*X*	*EDB*	*EDC*	*Total*	*MTBE*	*Naphthalene*	*Total cPAHs*[1]	*PCBs*
		MTCA Method A Cleanup Levels		30/100	2,000	2,000	0.03	7	6	9	0.005	N/A	250	0.1	5	0.1	1
			feet bgs	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)

Notes:
-- = Not analyzed
All results in milligrams per kilogram (mg/kg) unless otherwise indicated.
Results in bold indicate an exceedance of the Model Toxics Control Act (MTCA) Method A cleanup level.
bgs = below ground surface (in feet)
▨ Shaded soil sample locations were overexcavated per Nowicki (1995).
TPHg = Total petroleum hydrocarbons as gasoline analyzed by NWTPH-Gx
TPHd = Total petroleum hydrocarbons as diesel analyzed by NWTPH-Dx with silica gel cleanup
TPHo = Total petroleum hydrocarbons as motor oil analyzed by NWTPH-Dx with silica gel cleanup
Benzene, toluene, ethylbenzene, and xylenes (BTEX) analyzed by EPA 8260B
EDB = 1,2 Dibromoethane analyzed by EPA 8011
EDC = 1,2 Dichloroethane analyzed by EPA 8260B
MTBE = Methyl tertiary-butyl ether analyzed by EPA Method 8260B
TBA = Tertiary-butanol analyzed by EPA Method 8260B
DIPE = Di-isopropyl ether analyzed by EPA Method 8260B
ETBE = Ethyl tertiary-butyl ether analyzed by EPA Method 8260B
TAME = Tertiary-amyl methyl ether analyzed by EPA Method 8260B
VOCs = Volatile organic compounds analyzed by EPA Method 8260B
Total Lead analyzed by EPA Method 6020
<x = Not detected at reporting limit x
<x* = Not detected, reporting limit x was above MTCA screening level
ND = Report indicates analyte not present above laboratory reporting limit (RL). RL was not provided in lab report.

a = soil sample was collected from the corresponding monitoring well location (e.g., GW1-27.5 was collected from monitoring well MW-1 at a depth of 27.5 feet bgs)
b = Concentration of TPHd and TPHo reported using method WTPH-HCID.
c = Concentration of TPHg reported using method WTPH-HCID.

TABLE 2

SUMMARY OF GROUNDWATER MONITORING DATA
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST,
LYNNWOOD, WASHINGTON

						HYDROCARBONS			*PRIMARY VOCs*						*OXYGENATES*					*LEAD*
Sample ID	*Date*	*TOC*	*DTW*	*GWE*	*SPH Thickness*	*TPHg*	*TPHd*	*TPHo*	*B*	*T*	*E*	*X*	*EDB*	*EDC*	*MTBE*	*TBA*	*DIPE*	*ETBE*	*TAME*	*Total*
	Model Toxics Control Act Method A Cleanup Levels					800/1000	500	500	5	1000	700	1000	0.01	5	20	NE	NE	NE	NE	15
MW-1	12/28/06	451.74	9.75	441.99	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-1	12/29/06	451.74	9.57	442.17	0.00	**42,100**	<255	<510 m	**9,190**	**2,140**	**1,090**	**4,100**	---	---	---	---	---	---	---	---
MW-1	02/15/07	451.74	10.10	441.64	0.00	**41,200**	<269	<538 m	**9,230**	**1,840**	**938**	**3,710**	---	---	<5.00	54.6	<1.00	<1.00	<1.00	---
MW-1	04/06/07	451.74	10.71	441.03	0.00	**30,200**	<258	<515 m	**7,450**	732	**718**	**2,310**	---	---	---	---	---	---	---	---
MW-1	07/09/07	451.74	10.78	440.96	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-1	07/28/07	451.74	11.01	440.73	0.00	**5,850**	<258	<515 m	**2,400**	32.4	131	190	---	---	---	---	---	---	---	---
MW-1	10/01/07	451.74	13.98	437.76	0.00	**23,900**	**1,540 f,g**	<105	**6,270**	196	653	**1,340**	---	---	---	---	---	---	---	---
MW-1	01/10/08	451.74	9.43	442.31	0.00	**73,000**	<243	<485	**16,500**	**4,010**	**1,610**	**6,790**	---	---	---	---	---	---	---	---
MW-1	07/10/08	451.74	10.81	440.93	0.00	**800**	**1,400**	<300	**280**	13	2	33	---	---	---	---	---	---	---	---
MW-1	01/06/09	451.74	10.16	441.58	0.00	<100	190	<380	1	<1.0	<1.0	<1.0	---	---	<1.0	<10	<2.0	<2.0	<2.0	---
MW-1 *	07/13/09	451.74	11.14	440.60	0.00	**7,500**	**2,800 j**	<100	**1,200**	60	220	470	<0.010	<0.29	---	---	---	---	---	3.33
MW-1	07/29/10	451.74	11.10	440.64	0.00	---	320 j	110	**32**	2.9	17	48	---	---	---	---	---	---	---	---
MW-2	12/28/06	450.59	7.26	443.33	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-2	12/29/06	450.59	7.35	443.24	0.00	**2,640**	<253	<505 m	**21.7**	6.75	55.1	9.91	---	---	---	---	---	---	---	---
MW-2	02/15/07	450.59	8.03	442.56	0.00	249	<278	<556 m	2.06	<0.500	4.36	<1.00	---	---	<5.00	<50.0	<1.00	<1.00	<1.00	---
MW-2	04/06/07	450.59	8.50	442.09	0.00	180	<258	<515 m	1.83	0.518	2.61	<1.00	---	---	---	---	---	---	---	---
MW-2	07/09/07	450.59	8.62	441.97	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-2	07/28/07	450.59	8.96	441.63	0.00	**3,200**	<255	<510 m	**66.1**	7.86	137	20.4	---	---	---	---	---	---	---	---
MW-2	10/01/07	450.59	12.54	438.05	0.00	**3,980**	**1,080 g,h**	<105	**175**	13.7	331	47.4	---	---	---	---	---	---	---	---
MW-2	01/10/08	450.59	7.88	442.71	0.00	**5,000**	<243	<485	**214**	9.85	502	71.0	---	---	---	---	---	---	---	---
MW-2	07/10/08	450.59	9.98	440.61	0.00	540	<500	<200	4.9	<1	9.4	<1	---	---	---	---	---	---	---	---
MW-2	01/06/09	450.59	8.18	442.41	0.00	**9,200**	<100	<100	**390**	16	**840**	62.0	---	---	<10	<100	<20	<20	<20	---
MW-2	07/13/09	450.59	10.66	439.93	0.00	320	210 j	<100	3.8	<1.0	3.3	<1.0	<0.010	<0.50	---	---	---	---	---	<1.00
MW-2	07/29/10	450.59	10.31	440.28	0.00	---	200 j	<100	2.1	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	---
MW-3	12/28/06	451.69	8.45	443.24	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-3	12/29/06	451.69	8.51	443.18	0.00	**171,000**	**608**	<510 m	**28,500**	**29,200**	**2,950**	**15,900**	---	---	---	---	---	---	---	---
MW-3	02/15/07	451.69	9.09	442.60	0.00	**263,000 a, b**	**2,580 c**	<2,750 m	**29,200**	**37,400**	**3,140**	**18,600**	---	---	<500 m	<5,000	<100	<100	<100	---
MW-3	04/06/07	451.69	9.66	442.03	0.00	**214,000**	**867 c**	<495	**26,600**	**37,500**	**2,850**	**16,800**	---	---	---	---	---	---	---	---
MW-3	07/09/07	451.69	9.81	441.88	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-3	07/28/07	451.69	10.13	441.56	0.00	**248,000**	**8,340 e**	<5.050 m	**28,600**	**37,400**	**2,810**	**12,800**	---	---	---	---	---	---	---	---
MW-3	10/01/07	451.69	13.96	437.73	0.00	**252,000**	**185,000 g,h**	<10,500 m	**29,300**	**35,200**	**3,260**	**19,300**	---	---	---	---	---	---	---	---
MW-3	01/10/08	451.69	9.34	442.37 d	0.02	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-3	01/14/08	451.69	9.06	442.63	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-3	01/21/08	451.69	8.27	443.42	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-3	02/26/08	451.69	8.40	443.30 d	0.01	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-3	07/10/08	451.69	9.02	442.69 d	0.02	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-3	08/26/08	451.69	9.55	442.16 d	0.02	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-3	09/22/08	451.69	10.00	441.71 d	0.03	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-3	01/06/09	451.69	8.47	443.24 d	0.02	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-3	07/29/10	451.69	9.21	442.50 d	0.03	NOT SAMPLED - SPH PRESENT														
MW-4	12/28/06	452.01	9.41	442.60	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	12/29/06	452.01	9.36	442.65	0.00	**207,000**	**1,810**	<510 m	**32,400**	**39,700**	**3,200**	**18,800**	---	---	---	---	---	---	---	---
MW-4	02/15/07	452.01	9.96	442.05	0.00	**253,000 a, b**	**72,100 c**	<50,000 m	**31,500 a, b**	**40,500 a, b**	**2,990 a, b**	**18,100 a, b**	---	---	<500 m	<5,000	<100	<100	<100	---

TABLE 2

SUMMARY OF GROUNDWATER MONITORING DATA
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST,
LYNNWOOD, WASHINGTON

						HYDROCARBONS			*PRIMARY VOCs*						*OXYGENATES*					*LEAD*
Sample ID	*Date*	*TOC*	*DTW*	*GWE*	*SPH Thickness*	*TPHg*	*TPHd*	*TPHo*	*B*	*T*	*E*	*X*	*EDB*	*EDC*	*MTBE*	*TBA*	*DIPE*	*ETBE*	*TAME*	*Total*
	Model Toxics Control Act Method A Cleanup Levels					800/1000	500	500	5	1000	700	1000	0.01	5	20	NE	NE	NE	NE	15
MW-4	04/06/07	452.01	10.41	441.63 d	0.04	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-4	07/09/07	452.01	10.47	441.56 d	0.03	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	07/28/07	452.01	10.81	441.23 d	0.04	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-4	10/01/07	452.01	14.24	437.87 d	0.13	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-4	11/12/07	452.01	13.83	438.31 d	0.16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	11/20/07	452.01	13.68	438.44 d	0.14	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	11/26/07	452.01	13.52	438.58 d	0.11	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	12/08/07	452.01	12.87	439.22 d	0.10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	12/14/08	452.01	12.41	439.66 d	0.07	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	12/19/07	452.01	12.33	439.72 d	0.05	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	12/28/07	452.01	12.24	439.80 d	0.04	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	01/10/08	452.01	9.61	442.42 d	0.03	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-4	01/14/08	452.01	9.23	442.80 d	0.02	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	01/21/08	452.01	8.07	443.96 d	0.03	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	02/26/08	452.01	9.03	443.00 d	0.03	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	07/10/08	452.01	9.71	442.41 d	0.14	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-4	08/26/08	452.01	10.52	441.68 d	0.24	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	09/22/08	452.01	11.01	441.27 d	0.34	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-4	01/06/09	452.01	9.24	442.79 d	0.02	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-4	07/29/10	452.01	9.81	442.22 d	0.02	NOT SAMPLED - SPH PRESENT														
MW-5	12/28/06	451.38	8.11	443.27	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	12/29/06	451.38	8.17	443.21	---	**122,000**	**603**	<515 m	**7,220**	**24,400**	**2,280**	**13,200**	---	---	---	---	---	---	---	---
MW-5	02/15/07	451.38	8.49	442.89	---	**771,000 a, b**	**49,200 c**	<5,000 m	**12,800 a, b**	**43,600 a, b**	**6,000 a, b**	**40,700 a, b**	---	---	<500 m	<5,000	<100	<100	<100	---
MW-5	04/06/07	451.38	9.08	442.32 d	0.03	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-5	07/09/07	451.38	9.19	442.21 d	0.03	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	07/28/07	451.38	9.58	441.83 d	0.04	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-5	10/01/07	451.38	13.16	438.28 d	0.08	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-5	11/12/07	451.38	12.74	438.69 d	0.06	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	11/20/07	451.38	12.55	438.89 d	0.08	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	11/26/07	451.38	12.48	438.95 d	0.06	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	12/05/07	451.38	11.74	439.72 d	0.10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	12/14/07	451.38	11.53	439.90 d	0.06	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	12/19/07	451.38	11.41	440.00 d	0.04	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	12/28/07	451.38	11.29	440.12 d	0.04	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	01/10/08	451.38	8.70	442.70 d	0.02	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-5	01/14/08	451.38	8.70	442.68	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	01/21/08	451.38	8.00	443.54 d	0.20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	02/26/08	451.38	8.02	443.50 d	0.17	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	07/10/08	451.38	8.68	442.97 d	0.34	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-5	08/26/08	451.38	8.86	442.73 d	0.26	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	09/22/08	451.38	9.18	442.36 d	0.20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-5	01/06/09	451.38	7.80	443.60 d	0.02	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-5	07/29/10	451.38	8.72	442.68 d	0.02	NOT SAMPLED - SPH PRESENT														
MW-6	07/09/07	449.40	8.33	441.07	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

TABLE 2

SUMMARY OF GROUNDWATER MONITORING DATA
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST,
LYNNWOOD, WASHINGTON

						HYDROCARBONS			*PRIMARY VOCs*						*OXYGENATES*					*LEAD*
Sample ID	*Date*	*TOC*	*DTW*	*GWE*	*SPH Thickness*	*TPHg*	*TPHd*	*TPHo*	*B*	*T*	*E*	*X*	*EDB*	*EDC*	*MTBE*	*TBA*	*DIPE*	*ETBE*	*TAME*	*Total*
	Model Toxics Control Act Method A Cleanup Levels					800/1000	500	500	5	1000	700	1000	0.01	5	20	NE	NE	NE	NE	15
MW-6	07/28/07	449.40	8.61	440.79	0.00	52.4	<253	<505 m	<0.500	1.25	<0.500	<1.00	---	---	---	---	---	---	---	---
MW-6	10/01/07	449.40	12.22	437.18	0.00	<250	<105	<105	<1.00	<1.00	<1.00	<3.00	---	---	---	---	---	---	---	---
MW-6	01/10/08	449.40	7.86	441.54	0.00	<50.0	<250	<500	<0.500	<0.500	<0.500	<3.00	---	---	---	---	---	---	---	---
MW-6	07/10/08	449.40	7.87	441.53	0.00	<50	<500	<200	<1	<1	<1	<1	---	---	---	---	---	---	---	---
MW-6	01/06/09	449.40	6.10	443.30	0.00	<100	<100	<100	<0.50	<1.0	<1.0	<1.0	---	---	<1.0	<10	<2.0	<2.0	<2.0	---
MW-6	07/13/09	449.40	8.47	440.93	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	<1.00
MW-6	07/29/10	449.40	8.17	441.23	0.00	---	<100	190	<0.50	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	---
MW-7	07/09/07	450.14	7.81	442.33	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-7	07/28/07	450.14	8.03	442.11	0.00	<50.0	<253	<495	<0.500	<0.500	<0.500	<1.00	---	---	---	---	---	---	---	---
MW-7	10/01/07	450.14	11.71	438.43	0.00	<250	<111	<111	1.78	<1.00	<1.00	<3.00	---	---	---	---	---	---	---	---
MW-7	01/10/08	450.14	7.32	442.82	0.00	51.2	<250	<500	**68.4**	1.26	79.7	110	---	---	---	---	---	---	---	---
MW-7	07/10/08	450.14	7.27	442.87	0.00	<50	<500	<200	<1	<1	<1	<1	---	---	---	---	---	---	---	---
MW-7	01/06/09	450.14	7.07	443.07	0.00	<100	<100	<100	<0.50	<1.0	<1.0	<1.0	---	---	<1.0	<10	<2.0	<2.0	<2.0	---
MW-7	07/13/09	450.14	7.70	442.44	0.00	---	---	---	2.7	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	<1.00
MW-7	07/29/10	450.14	7.69	442.45	0.00	---	<100	<100	<0.50	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	---
MW-8	07/09/07	451.31	8.63	442.68	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-8	07/28/07	451.31	8.97	442.34	0.00	**266,000**	**8,580 e**	<5,210 m	**20,500**	**43,600**	**3,550**	**23,000**	---	---	---	---	---	---	---	---
MW-8	10/01/07	451.31	12.58	438.73	0.00	**181,000**	**6,540 g, i**	<1,110 m	**18,000**	**32,000**	**2,250**	**14,900**	---	---	---	---	---	---	---	---
MW-8	01/10/08	451.31	8.16	443.15	0.00	**202,000**	**9,190 c**	<4,850 m	**13,400**	**29,600**	**2,200**	**14,000**	---	---	---	---	---	---	---	---
MW-8	07/10/08	451.31	8.14	443.18 d	0.01	NOT SAMPLED - SPH PRESENT			---	---	---	---	---	---	---	---	---	---	---	---
MW-8	08/26/08	451.31	8.30	443.03 d	0.02	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-8	09/22/08	451.31	8.80	442.52 d	0.01	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-8	01/06/09	451.31	7.90	443.41	0.00	**22,000**	**6,900**	440	**2,700**	**6,300**	390	**4,300**	---	---	<20	<200	<40	<40	<40	---
MW-8	07/29/10	451.31	7.92	443.39	0.00	---	**5,300 j**	**2,000 j**	**18,000**	**40,000**	**17,000**	**110,000**	---	---	---	---	---	---	---	---
MW-9	07/09/07	451.75	10.83	440.92	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-9	07/28/07	451.75	11.02	440.73	0.00	<50.0	<248	<495	<0.500	<0.500	<0.500	<1.00	---	---	---	---	---	---	---	---
MW-9	10/01/07	451.75	14.07	437.68	0.00	299	174 f,g	<111	**5.52**	<1.00	<1.00	<3.00	---	---	---	---	---	---	---	---
MW-9	01/10/08	451.75	9.76	441.99	0.00	<50.0	<238	<476	<0.500	<0.500	<0.500	<3.00	---	---	---	---	---	---	---	---
MW-9	07/10/08	451.75	9.71	442.04	0.00	<50	<500	<1,000 m	<1	<1	<1	<1	---	---	---	---	---	---	---	---
MW-9	01/06/09	451.75	9.35	442.40	0.00	<100	<100	<100	<0.50	<1.0	<1.0	<1.0	---	---	<1.0	<10	<2.0	<2.0	<2.0	---
MW-9	07/13/09	451.75	9.94	441.81	0.00	---	---	---	<0.50	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	<1.00
MW-9	07/29/10	451.75	9.80	441.95	0.00	---	<100	<100	<0.50	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	---
MW-10	07/09/07	451.43	12.44	438.99	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MW-10	07/28/07	451.43	12.77	438.66	0.00	**6,570**	307 c	<505 m	**299**	179	237	615	---	---	---	---	---	---	---	---
MW-10	10/01/07	451.43	14.87	436.56	0.00	**27,100**	**1,820 g,i**	<556 m	**1,510**	**1,220**	**1,210**	**2,650**	---	---	---	---	---	---	---	---
MW-10	01/10/08	451.43	10.52	440.91	0.00	**11,400**	<248	<495	**316**	237	**842**	604	---	---	---	---	---	---	---	---
MW-10	07/10/08	451.43	11.69	439.74	0.00	**1,400**	<500	<1,000 m	**1,400**	**1,200**	**710**	**2,310**	---	---	---	---	---	---	---	---
MW-10	01/06/09	451.43	10.11	441.32	0.00	**29,000**	120	<100	**4,800**	**1,400**	**1,800**	**5,100**	---	---	<10	<100	<20	<20	<20	---
MW-10 *	07/13/09	451.43	12.31	439.12	0.00	**4,800**	<100	<100	**1,600**	260	190	**1,000**	<0.010	<1.5	---	---	---	---	---	1.02
MW-10	07/29/10	451.43	11.86	439.57	0.00	---	<100	<100	**240**	9.9	45	89	---	---	---	---	---	---	---	---
SB-3 n	05/10/10	---	---	---	0.00	360	**1,600 j**	<100	**170**	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	---

TABLE 2

SUMMARY OF GROUNDWATER MONITORING DATA
FORMER JIFFY LUBE FACILITY
6808 196TH STREET SOUTHWEST,
LYNNWOOD, WASHINGTON

						HYDROCARBONS			*PRIMARY VOCs*						*OXYGENATES*					*LEAD*
Sample ID	*Date*	*TOC*	*DTW*	*GWE*	*SPH Thickness*	*TPHg*	*TPHd*	*TPHo*	*B*	*T*	*E*	*X*	*EDB*	*EDC*	*MTBE*	*TBA*	*DIPE*	*ETBE*	*TAME*	*Total*
	Model Toxics Control Act Method A Cleanup Levels					800/1000	500	500	5	1000	700	1000	0.01	5	20	NE	NE	NE	NE	15
SB-4 n	05/10/10	---	---	---	0.00	180	**2,400 j**	<100	<0.5	<1.0	<1.0	<1.0	---	---	---	---	---	---	---	---

Notes:

DTW = Depth to Water in feet
GWE = Groundwater Elevation in feet above mean sea level
TOC = Top of Casing in feet above mean sea level
SPH = Separate Phase Hydrocarbons
MTCA = Model Toxics Control Act
All results in micrograms per liter (µg/L) unless otherwise indicated.
TPHg = Total petroleum hydrocarbons as gasoline analyzed by NWTPH-Gx unless otherwise noted. The higher value is based on the assumption that no benzene is present in the groundwater sample. If any detectable amount of benzene is present in the groundwater sample, then the lower TPHg cleanup level is applicable.
TPHd = Total petroleum hydrocarbons as diesel, analyzed by NWTPH-Dx with silica gel cleanup unless otherwised noted.
TPHo = Total petroleum hydrocarbons as oil, analyzed by NWTPH-Dx with silica gel cleanup unless otherwised noted.
VOCs = Volatile organic compounds
BTEX = Benzene, toluene, ethylbenzene, and xylenes analyzed by EPA Method 8260B unless otherwise noted.
Xylenes = o-xylene + m,p-xylene
MTBE = Methyl tertiary-butyl ether analyzed by EPA Method 8260B
EDB = 1,2-Dibromoethane analyzed by EPA Method 8011
EDC = 1,2-Dichloroethane analyzed by EPA Method 8260B
TBA = Tertiary-butanol analyzed by EPA Method 8260B
DIPE = Di-isopropyl ether analyzed by EPA Method 8260B
ETBE = Ethyl tertiary-butyl ether analyzed by EPA Method 8260B
TAME = Tertiary-amyl methyl ether analyzed by EPA Method 8260B
Total Lead analyzed by EPA Method 6020 unless otherwise noted.
<x = Not detected at laboratory reporting limit x
NE = Not established
--- = Not analyzed
Concentrations in bold type indicate the analyte was detected above MTCA Method A cleanup levels

a = Due to multiple re-shots required for re-analysis, the aliquot of sample analyzed on the instrument was taken from a VOA vial containing headspace.
b = Sample container contained headspace
c = Results reported in the diesel organics range are primarily due to overlap from a gasoline-range product.
d = Groundwater elevation formula adjusted for the presence of SPH: (TOC - DTW)+ (SPHT*0.80)
e = Hydrocarbon pattern most closely resembles a blend of gasoline and diesel.
f = The primary contamination elutes between C8 and C28, which is in the diesel range.
g = The contamination did not match any standard in our library.
h = The primary contamination elutes between C8 and C14, which is in the mineral spirits range.
i = The primary contamination elutes between C8 and C16, which is in the kerosene range.
j = The sample chromatographic pattern for TPH does not match the chromatographic pattern of the specified standard.
m = The laboratory reporting limit exceeded the MTCA Method A cleanup level.
n = Grab groundwater sample taken from temporary well. Sample ID is abbreviated from *GW-241739-051010-HB-[Unique ID]* .

* = Sample also analyzed for one or more of the following: carcinogenic polycyclic aromatic hydrocarbons (cPAHs) by EPA Method 8270C-SIM, polychlorinated biphenyls (PCBs) by EPA Method 8082, and halogenated volatile organic compounds (HVOCs) by EPA Method 8260B. For those constituents analyzed, no concentrations exceeded the laboratory MDL. Please see applicable laboratory report(s) for more information.

APPENDIX A

ENVIRONMENTAL DOCUMENT LIST

APPENDIX A - ENVIRONMENTAL DOCUMENT LIST

Title	Author	Date	Submitted to Ecology	
			Y/N	Date
Lynnwood Quaker State Lube UST Closure Site Characterization	Nowicki & Associates	9/27/1995	Y	9/27/1995
Waste Oil UST - Characterization Soil Boring	Nowicki & Associates	11/20/1995	Y	11/20/1995
Phase I Environmental Site Assessment Limited Compliance Audit	FINEnvironmental, Inc.	1/28/2003	N	---
Limited Phase I Environmental Site Assessment	GeoEngineers, Inc.	2/11/2004	N	---
Groundwater Monitoring Report - Fourth Quarter 2006	Cambria Environmental Technology, Inc.	5/31/2007	Y	5/31/2007
Site Investigation Report	Conestoga-Rovers & Associates	5/31/2007	Y	5/31/2007
Groundwater Monitoring Report - First Quarter 2007	Conestoga-Rovers & Associates	6/27/2007	Y	6/27/2007
Groundwater Monitoring Report - Second Report 2007	Conestoga-Rovers & Associates	7/24/2007	Y	7/24/2007
Site Investigation Report	Conestoga-Rovers & Associates	10/23/2007	Y	10/23/2007
Groundwater Monitoring Report - Third Quarter 2007	Conestoga-Rovers & Associates	10/31/2007	Y	10/31/2007
Groundwater Monitoring Report - Fourth Quarter 2007	Conestoga-Rovers & Associates	2/29/2008	Y	2/29/2008
Groundwater Monitoring Report - First Quarter 2008	Conestoga-Rovers & Associates	4/17/2008	Y	4/17/2008
Groundwater Monitoring Report - Third Quarter 2008	Conestoga-Rovers & Associates	12/2/2008	Y	12/02/2008
Groundwater Monitoring Report - First Quarter 2009	Conestoga-Rovers & Associates	3/26/2008	Y	3/26/2008
2009 Annual Groundwater Monitoring Report	Conestoga-Rovers & Associates	2/8/2010	Y	2/8/2010
2010 Annual Groundwater Monitoring Report	Conestoga-Rovers & Associates	10/25/2010	Y	10/25/2010

APPENDIX B

LEGAL DESCRIPTION OF PROPERTY, PRESENT OWNER AND OPERATOR, KNOWN PAST OWNERS AND OPERATORS

Known Listing of Owners and Operators

Owner	Business Operator	Approximate Years of Site Occupation
Strickland Real Estate Holdings, LLC	Aloha Café	2006-present
Lorena Strickland Family	Jiffy Lube	2000-2006
Lorena Strickland Family	Quaker Minit Lube	1987-2000
Lorena Strickland Family	Speedi-Lube	1977-1987
Lorena Strickland Family	The Texas Company (Texaco)	1959-1977
Lorena Strickland Family	Unknown (likely undeveloped)	Prior to 1959

Property Account Summary

Parcel Number	27042000200600	Property Address	6808 196TH ST SW , LYNNWOOD, WA 98036-5041

Parties - For changes use 'Other Property Data' menu

Role	Percent	Name	Mailing Address
Taxpayer	100	STRICKLAND-WILLIFORD LORENA M	PO BOX 1004, EVERETT, WA 98206 United States
Owner	100	STRICKLAND REAL ESTATE HOLDINGS LLC	PO BOX 1004, EVERETT, WA 98206 United States

General Information

Property Description	Section 20 Township 27 Range 04 Quarter NW - BEG NE COR NW1/4 TH S 170FT TH W 170FT TH N 170FT TH E 170FT EXC N & E 30FT THOF FOR CO RD & ALSO EXC R/W TO CITY OF LYN ORD NO 752 (PAR 213) DTD 9-23-1974 DAF - BAAP LY 30FT S & 30FT W NE COR NW1/4 SD SEC SD PT BEING TPB TH W 140FT TH S 8FT TH E 128FT TH SE 16.97FT TAP LY 20FT S OF POB TH N 20FT POB
Property Category	Land and Improvements
Status	Active, Host Other Property, Locally Assessed
Tax Code Area	00452

Property Characteristics

Use Code	549 Other Retail Trade - Food NEC
Unit of Measure	Acre(s)
Size (gross)	0.42

Related Properties

2755949 is Located On this property

Active Exemptions

No Exemptions Found

If you wish to pay your property taxes on-line now, select one of the following options and press the button "Add To Payment List". If this property is noted as "Delinquency" in the General Information Status field, additional costs may be added monthly. At certain dates within the delinquency process, all outstanding taxes, assessments, interest, penalties, and costs are due in certified funds. Make Check or Money Order to "Snohomish County Treasurer". Send to Snohomish County Treasurer, 3000 Rockefeller Ave, M/S 501, Everett, WA 98201

Installments Payable

Tax Year	Installment	Due Date	Principal	Interest, Penalties and Costs	Total Due	Cumulative Due	Select to Pay
2009	Delinquent	10/31/2009	2,374.40	688.59	3,062.99	3,062.99	●
2010	Delinquent	04/30/2010	5,105.73	1,327.47	6,433.20	9,496.19	○
2011	1	04/30/2011	2,480.50	297.66	2,778.16	12,274.35	○
2011	2	10/31/2011	2,480.50	0.00	2,480.50	14,754.85	○

Add To Payment List

View Detailed Statement	Detailed information about taxes and all other charges displayed above.
Calculate Future Payoff	Taxes, interest and penalty due on a specific future date.

Statement of Payable/Paid For Tax Year: 2011

Distribution of Current Taxes

District	Rate	Amount
CITY OF LYNNWOOD	2.369523	1,151.59
EDMONDS SCHOOL DISTRICT NO 15	4.149544	2,016.68
PUB HOSP #2	0.057643	28.01
PUB HOSP #2	0.095378	46.35
SNOHOMISH COUNTY-CNT	0.868378	422.03
SNOISLE REGIONAL LIBRARY	0.450643	219.01
STATE	2.206383	1,072.31
SNOHOMISH CONSERVATION DISTRICT		5.02
TOTALS	10.197493	4,961.00

Pending Property Values

Pending Tax Year	Market Land Value	Market Improvement Value	Market Total Value	Current Use Land Value	Current Use Improvement	Current Use Total Value
2012	293,100	71,900	365,000	0	0	0

Property Values

Value Type	Tax Year 2011	Tax Year 2010	Tax Year 2009	Tax Year 2008	Tax Year 2007
Taxable Value Regular	486,000	580,900	581,900	512,000	468,400
Exemption Amount Regular					

Market Total	486,000	580,900	581,900	512,000	468,400
Assessed Value	486,000	580,900	581,900	512,000	468,400
Market Land	342,700	396,900	397,900	312,900	312,900
Market Improvement	143,300	184,000	184,000	199,100	155,500
Personal Property					

Levy Rate History

Tax Year	Total Levy Rate
2010	8.780704
2009	8.160831
2008	8.202782

Real Property Structures

Description	Type	Year Built	More Information
ALOHA CAFE	Commercial	1959	View Detailed Structure Information

Property Sales (since 7/31/1999)

Transfer Date	Receipt Date	Sales Price	Excise Number	Deed Type	Grantor (Seller)	Grantee (Buyer)	Other Parcels
12/31/2002	1/8/2003	$0	175310	QC	WILLIFORD WILLIAM CHESTER	STRICKLAND REAL ESTATE HOLDINGS LLC	No
12/31/2002	1/8/2003	$0	175312	QC	STRICKLAND-WILLIFORD LORENA	STRICKLAND REAL ESTATE HOLDINGS LLC	No
12/18/2002	1/8/2003	$0	175311	QC	STRICKLAND REX THOMAS	STRICKLAND REAL ESTATE HOLDINGS LLC	No

Property Maps

Neighborhood Code	Township	Range	Section	Quarter	Parcel Map
5508000	27	04	20	NW	View parcel maps for this Township/Range/Section

Receipts

Date	Receipt No.	Amount Applied
05/04/2009 00:00	5113048	2,374.39
11/04/2008 00:00	4848484	2,099.91
05/19/2008 13:38	4618725	2,141.91
11/05/2007 00:00	4334806	2,058.11
05/07/2007 00:00	4084292	2,058.10
04/25/2006 00:00	3392693	4,226.87

Events

Effective Date	Entry Date-Time	Type	Remarks
12/31/2002	06/30/2003 12:03	Property Assigned To Transfer/Sale	Property Assigned to Transfer/Sale. Filing No.: 175312, Quit Claim Deed by sasklm
12/31/2002	06/30/2003 11:59	Taxpayer Changed	Property Transfer Filing No.: 175310 12/31/2002 by sasklm
12/31/2002	06/30/2003 11:59	Property Assigned To Transfer/Sale	Property Assigned to Transfer/Sale. Filing No.: 175310, Quit Claim Deed by sasklm
12/31/2002	06/18/2003 14:22	Owner Added	Party/Property Relationship by sassls
12/31/2002	02/10/2003 08:40	Taxpayer Changed	Property Transfer Filing No.: 175310 12/31/2002 by sasset
12/31/2002	01/08/2003 12:09	Excise Processed	Property Transfer Filing No.: 175312, Quit Claim Deed 12/31/2002 by strnls
12/31/2002	01/08/2003 11:53	Taxpayer Changed	Property Transfer Filing No.: 175310 12/31/2002 by strnls
12/31/2002	01/08/2003 11:53	Excise Processed	Property Transfer Filing No.: 175310, Quit Claim Deed 12/31/2002 by strnls
12/30/2002	06/18/2003 14:23	Owner Terminated	Party/Property Relationship by sassls
12/18/2002	06/30/2003 11:58	Property Assigned To Transfer/Sale	Property Assigned to Transfer/Sale. Filing No.: 175311, Quit Claim Deed by sasklm
12/18/2002	01/08/2003 12:01	Excise Processed	Property Transfer Filing No.: 175311, Quit Claim Deed 12/18/2002 by strnls

Printable Version

APPENDIX C

SUMMARY OF PREVIOUS INVESTIGATIONS AND REMEDIAL ACTIVITIES

SUMMARY OF PREVIOUS INVESTIGATIONS AND REMEDIAL ACTIVITIES

1995 Underground Storage Tank Closure: In August 1995, Nowicki and Associates, Inc. (Nowicki) conducted compliance sampling in the process of underground storage tank (UST) decommissioning activities during a conversion to an aboveground storage tank (AST) system at the Property. One 3,000-gallon new oil UST was removed and one 500-gallon waste oil UST was closed-in-place during the conversion at the Property. Soil samples were collected from the sidewalls and bottom of the new oil UST excavation. Laboratory analytical results indicated concentrations of total petroleum hydrocarbons (TPH) as diesel (TPHd) and TPH as heavy oil (TPHo) above the Washington State Department of Ecology (Ecology) Model Toxics Control Act (MTCA) Method A screening levels in soil samples collected from west sidewall. Nowicki overexcavated observed petroleum hydrocarbon impacted soil. Approximately 65 tons of petroleum-hydrocarbon impacted soil was removed from the new oil UST excavation. Final soil sample locations from the sidewalls and bottom of the new oil UST excavation were below laboratory reporting limits for TPHd and TPHo. No other concentrations were reported. Soil samples were collected from one soil boring, SB, advanced just south of the waste oil UST at depths of 1.33 and 2 feet below ground surface (bgs). Laboratory analytical results indicated concentrations of TPHd and TPHo above MTCA Method A screening levels in samples collected from boring SB. The overlying building foundation made removal of petroleum hydrocarbon impacted soil around the waste oil UST untenable, and the soil was left in place. Additional information is available in Nowicki's *Lynnwood Quaker State Lube UST Closure Site Characterization*, dated September 27, 1995.

1995 Soil Characterization Report: In November 1995, Nowicki conducted an additional Site investigation to characterize subsurface impacts to soil and groundwater at the Site. Two soil borings, SB1 and SB2, were advanced to the north of the former waste oil UST. Laboratory analytical results indicated concentrations of TPH as gasoline (TPHg) and benzene, toluene, ethylbenzene, and xylenes (BTEX) above the MTCA Method A screening levels. More information is available in Nowicki's *Waste Oil UST – Characterization Soil Boring*, dated November 20, 1995.

2003 Phase I Environmental Site Assessment: In January 2003, FINEnvironmental, Inc. (FINE) conducted a Phase I Site assessment. Results of the inspection indicated that the subject property formerly operated as a

Texaco-branded gasoline service station prior to 1977. Results also identified Leaking UST (LUST) sites at adjacent properties to the north and east. More information is available in FINE's *Phase I Environmental Site Assessment Limited Compliance Audit*, dated January 28, 2003.

2004 Phase I Environmental Assessment: In December 2003, GeoEngineers, Inc. (GeoEngineers) completed a Phase I Site assessment prior to Shell's purchase of the Jiffy Lube facility operating on the Property. Results of the inspection indicated similar findings of the Phase I conducted by FINE in 2003. More information is available in GeoEngineers' *Limited Phase I Environmental Site Assessment*, dated February 11, 2004.

November 2006 Site Investigation: In November 2006, Cambria Environmental Technology (Cambria) installed five monitoring wells (MW-1 through MW-5) and advanced one soil boring (SB-1) at the Property. Soil samples were collected from each boring and submitted for laboratory analysis. Analytical results indicated benzene concentrations above MTCA Method A screening levels in soil samples collected from each of the soil borings at depths ranging from 7.5 to 27.5 feet bgs. TPHg, toluene, ethylbenzene, and total xylenes were detected above MTCA Method A screening levels in soil samples collected from borings MW-3, MW-4, and MW-5. More information is available in Conestoga-Rovers & Associates' (CRA) *Site Investigation Report*, dated May 31, 2007.

July 2007 Site Investigation: In July 2007, CRA conducted an additional Site investigation, including the installation of five monitoring wells (MW-6 through MW-10). Laboratory analytical results from soil samples collected from four out of five well borings indicated concentrations of benzene above the MTCA Method A screening level. TPHg and total xylenes concentrations were additionally detected above the MTCA Method A screening levels in soil samples collected from boring MW-8 at 15 and 20 feet bgs. More information is available in CRA's *Site Investigation Report*, dated October 23, 2007.

APPENDIX D

AVAILABLE HISTORICAL SOIL BORING LOGS

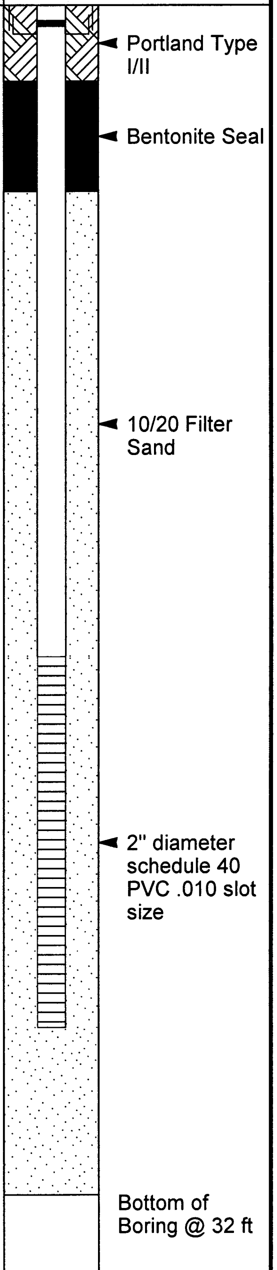
Cambria Environmental Technology, Inc.
8620 Holly Drive, Suite 210
Everett, WA 98208
Telephone: 425.353.6670
Fax: 425.353.6443

BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-1
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	16-Nov-06
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	16-Nov-06
PROJECT NUMBER	248-1739	**WELL DEVELOPMENT DATE (YIELD)**	28-Dec-06 (12/29/2006)
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	452 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	452.00 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	17.5 to 27.5 ft bgs
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	NA ▽
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼
REMARKS			

PID (ppm)	BLOW COUNTS	SAMPLE ID	DEPTH (ft bgs)	U.S.C.S.	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (ft bgs)
					Asphalt	0.5
			5	SW	Gravelly SAND with trace cobbles (FILL): Dark Brown; dry, non plastic, high permeability.	5.0
				SW	Gravelly SAND with trace cobbles: Gray, moist, high permeability.	7.5
0	11 20 23		10	SC	Sandy CLAY with cobbles: Gray, moist, low plsticity, medium permeability.	12.5
0	9 13 24		15	SM	Silty SAND with cobbles: Gray, moist, high permeability.	17.5
2.9	8 38 53	MW1@17.5'	20	SM	Silty SAND with cobbles: Gray, moist, high permeability.	22.5
0	32 50 50		25	SM	Slity SAND with cobbles: Gray, moist, high to medium permeability.	27.5
0	6 23 50	MW1@27.5'	30	SM	Slity SAND with cobbles: Gray, moist, high to medium permeability.	32.5

WELL DIAGRAM



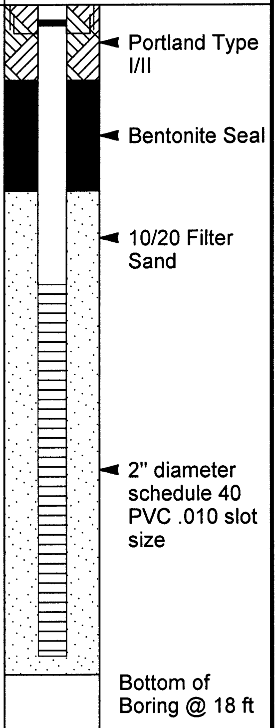
Cambria Environmental Technology, Inc.
8620 Holly Drive, Suite 210
Everett, WA 98208
Telephone: 425.353.6670
Fax: 425.353.6443

BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-2
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	16-Nov-06
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	17-Nov-06
PROJECT NUMBER	248-1739	**WELL DEVELOPMENT DATE (YIELD)**	28-Dec-06 (12/29/2006)
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	451.04 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	451.04 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	7.5 to 17.5 ft bgs
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	NA ▽
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼
REMARKS			

PID (ppm)	BLOW COUNTS	SAMPLE ID	DEPTH (ft bgs)	U.S.C.S.	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (ft bgs)
					Asphalt	0.5
				SW	Gravelly SAND with trace cobbles (FILL): Dark Brown; dry, non plastic, high permeability.	5.0
			5	SW	Gravelly SAND with trace cobbles: Gray, moist, high permeability.	7.5
0.6	11 17 21		10	SC	Clayey SAND with trace gravel: Gray, wet, low placitiy, low permeability.	12.5
0.7	7 21 35	MW2@12.5'	15	CL	Sandy CLAY: Gray, wet, medium plasticity, low permeability.	17.5
2.4	27 50 50	MW2@17.5'				

WELL DIAGRAM



WELL LOG EVERETT C:\DOCUMENTS AND SETTINGS\AVANDERPAARDT\DESKTOP\9-3299 SB-1_MW-1 - MW-5.GPJ DEFAULT.GDT 3/13/07

Cambria Environmental Technology, Inc.
8620 Holly Drive, Suite 210
Everett, WA 98208
Telephone: 425.353.6670
Fax: 425.353.6443

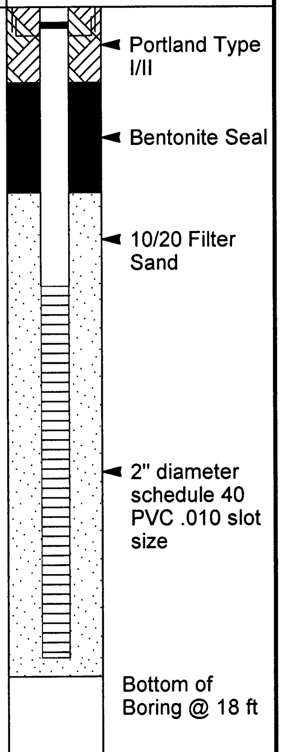
BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-3
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	16-Nov-06
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	16-Nov-06
PROJECT NUMBER	248-1739	**WELL DEVELOPMENT DATE (YIELD)**	28-Dec-06 (12/29/2006)
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	452.01 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	452.01 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	7.5 to 17.5 ft bgs
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	NA ▽
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼

REMARKS

PID (ppm)	BLOW COUNTS	SAMPLE ID	EXTENT	DEPTH (ft bgs)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (ft bgs)
							Asphalt	0.5
					SW		Gravelly SAND with trace cobbles (FILL): Dark Brown; dry, non plastic, high permeability.	5.0
				5	SC		Clayey SAND with cobbles: Gray, wet, low plasticity, low permeability.	7.5
2228	3 8 11	MW3@7.5'		10	ML		Sandy CLAY with gravel: Gray, wet, medium plasticity, low permeability.	12.5
189	6 26 50			15	CL		Sandy Clay with gravel: Gray, wet, low plasticity, low permeability.	17.5
38	14 31 50	MW3@17.5'						

WELL DIAGRAM



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Everett, WA 98208
Telephone: 425.353.6670
Fax: 425.353.6443

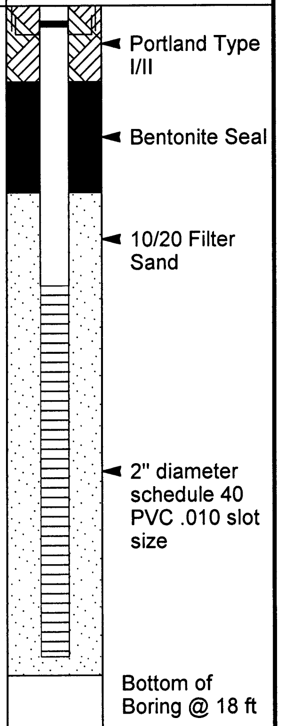
BORING/WELL LOG

CLIENT NAME Shell Oil Products US
JOB/SITE NAME LYNN6808
LOCATION 6808 196th Street, Lynnwood, WA
PROJECT NUMBER 248-1739
DRILLER Boart Longyear Drilling
DRILLING METHOD Hollow-stem auger
BORING DIAMETER 8"
LOGGED BY Bryan Palmer
REVIEWED BY T. Crotwell
REMARKS

BORING/WELL NAME MW-4
DRILLING STARTED 16-Nov-06
DRILLING COMPLETED 16-Nov-06
WELL DEVELOPMENT DATE (YIELD) 28-Dec-06 (12/29/2006)
GROUND SURFACE ELEVATION 452.28 ft above msl
TOP OF CASING ELEVATION 452.28 ft above msl
SCREENED INTERVAL 7.5 to 17.5 ft bgs
DEPTH TO WATER (First Encountered) NA ▽
DEPTH TO WATER (Static) NA ▼

PID (ppm)	BLOW COUNTS	SAMPLE ID	EXTENT	DEPTH (ft bgs)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (ft bgs)
							Asphalt	0.5
					SW		Gravelly SAND with trace cobbles (FILL): Dark Brown; dry, non plastic, high permeability.	5.0
				5	SW		Gravelly Sand: Gray; dry, high permeability.	7.5
2390	7 21 23	MW4@7.5'		10	CL		Clayey SAND: Gray, wet, medium permeability.	12.5
149	7 13 14			15	CL		Silty sandy CLAY: Gray, low plasticity, medium permeability.	17.5
63	19 50	MW4@17.5'						

WELL DIAGRAM



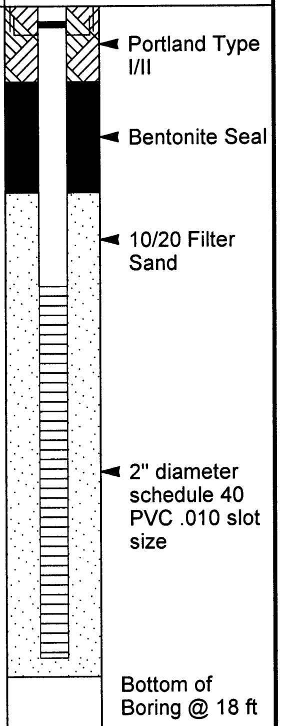
Cambria Environmental Technology, Inc.
8620 Holly Drive, Suite 210
Everett, WA 98208
Telephone: 425.353.6670
Fax: 425.353.6443

BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-5
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	16-Nov-06
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	17-Nov-06
PROJECT NUMBER	248-1739	**WELL DEVELOPMENT DATE (YIELD)**	28-Dec-06 (12/29/2006)
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	451.85 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	451.58 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	7.5 to 17.5 ft bgs
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	NA ▽
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼
REMARKS			

PID (ppm)	BLOW COUNTS	SAMPLE ID	EXTENT	DEPTH (ft bgs)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (ft bgs)
							Asphalt	0.5
					SW		Gravelly SAND with trace cobbles (FILL): Dark Brown; dry, non plastic, high permeability.	5.0
				5	SC		Clayey SAND with gravel: Gray, dry, medium permeability.	7.5
2956	11 17 14	MW5@7.5'		10	CL		Sandy CLAY: Gray, wet, low plasticity, medium permeability.	12.5
499	11 14 9			15	CL		Sandy CLAY: Gray, wet, low plasticity, low permeability.	17.5
72.5	17 32 50	MW5@17.5'						

WELL DIAGRAM



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Fax: 425.353.6443

BORING/WELL LOG

CLIENT NAME Shell Oil Products US
JOB/SITE NAME LYNN6808
LOCATION 6808 196th Street, Lynnwood, WA
PROJECT NUMBER 248-1739
DRILLER Boart Longyear Drilling
DRILLING METHOD Hollow-stem auger
BORING DIAMETER 8"
LOGGED BY Bryan Palmer
REVIEWED BY T. Crotwell
REMARKS

BORING/WELL NAME SB-1
DRILLING STARTED 16-Nov-06
DRILLING COMPLETED 17-Nov-06
WELL DEVELOPMENT DATE (YIELD) NA
GROUND SURFACE ELEVATION Not Surveyed
TOP OF CASING ELEVATION Not Surveyed
SCREENED INTERVAL NA
DEPTH TO WATER (First Encountered) NA ▽
DEPTH TO WATER (Static) NA ▼

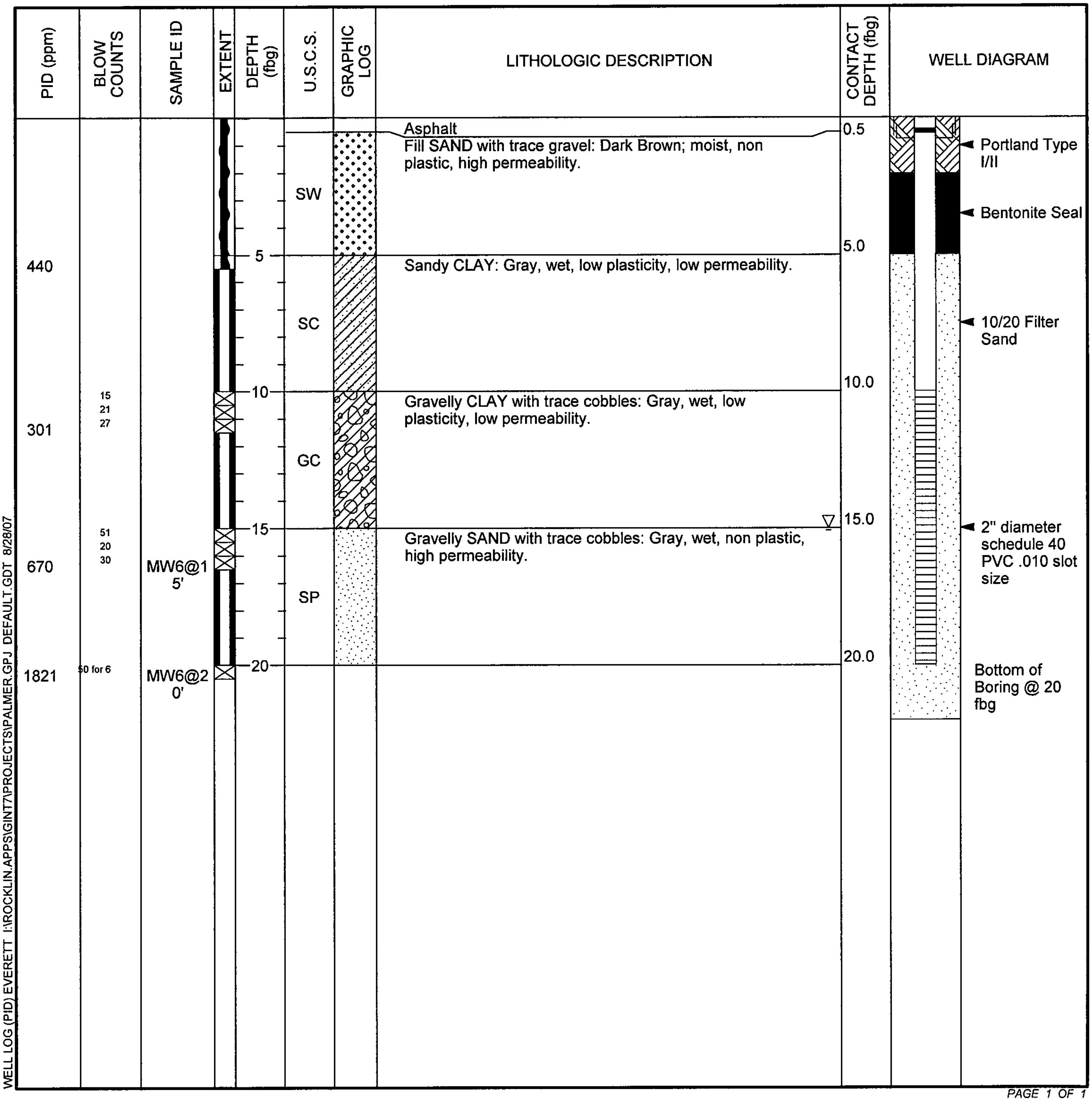
PID (ppm)	BLOW COUNTS	SAMPLE ID	EXTENT	DEPTH (ft bgs)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (ft bgs)	WELL DIAGRAM
0							Asphalt	0.5	Portland Type I/II
					SW		Gravelly SAND with trace cobbles (FILL): Dark Brown; dry, non plastic, high permeability.	5.0	
				5	SW		Gravelly SAND with trace cobbles: Gray; dry, high permeability.	7.5	
7.7	3 8 9			10	SC		Clayey SAND with trace cobbles: Gray; wet, low plasticity, low permeability.	12.5	Bentonite Seal
24.2	3 4 9	SB1@12.5'		15	SW		Gravelly SAND: Gray; moist, low permeability.	17.5	
7	11 24 50	SB1@17.5'							Bottom of Boring @ 18 ft

WELL LOG EVERETT C:\DOCUMENTS AND SETTINGS\AVANDERPAARDT\DESKTOP\9-3299 SB-1_MW-1 - MW-5.GPJ DEFAULT.GDT 3/13/07

Conestoga-Rovers & Associates
526 Commerce Center - Building B
1420 80th Street SW, Suite A
Everett, WA 98203
Telephone: (425) 212-5100
Fax: (425) 212-5199

BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-6
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	05-Jul-07
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	05-Jul-07
PROJECT NUMBER	241739	**WELL DEVELOPMENT DATE (YIELD)**	05-Jul-07
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	449.87 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	452.00 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	10 to 20 fbg
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	15.0 fbg (06-Jul-07) ∇
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼
REMARKS			



PID (ppm)	BLOW COUNTS	SAMPLE ID	DEPTH (fbg)	U.S.C.S.	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (fbg)
					Asphalt	0.5
				SW	Fill SAND with trace gravel: Dark Brown; moist, non plastic, high permeability.	5.0
440			5	SC	Sandy CLAY: Gray, wet, low plasticity, low permeability.	10.0
301	15 21 27		10	GC	Gravelly CLAY with trace cobbles: Gray, wet, low plasticity, low permeability. ∇	15.0
670	51 20 30	MW6@15'	15	SP	Gravelly SAND with trace cobbles: Gray, wet, non plastic, high permeability.	20.0
1821	50 for 6	MW6@20'	20			

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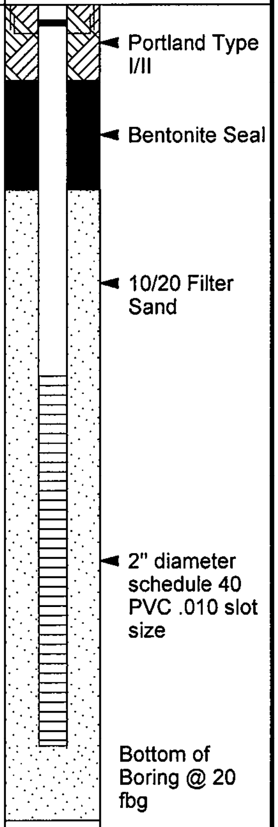
BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-7
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	05-Jul-07
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	05-Jul-07
PROJECT NUMBER	241739	**WELL DEVELOPMENT DATE (YIELD)**	05-Jul-07
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	450.48 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	451.04 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	10 to 20 fbg
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	14.0 fbg (07-Jul-07) ∇
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼
REMARKS			

PID (ppm)	BLOW COUNTS	SAMPLE ID	DEPTH (fbg)	U.S.C.S.	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (fbg)
					Asphalt	0.5
				SW	Fill SAND with trace gravel: Dark Brown; moist, non plastic, high permeability.	5.0
966		MW7@5'	5	SC	Clayey SAND with trace gravel: Gray, moist, non plastic, medium permeability.	10.0
120	9 12 10		10	SP	Gravelly SAND: Gray, moist, non plastic, low permeability. ∇	15.0
60	17 18 20		15	SP	Gravelly SAND wth trace cobbles: Gray, wet, non plastic, high permeability.	20.0
290	26 50	MW7@20'	20			

WELL DIAGRAM



WELL LOG (PID) EVERETT I:\ROCKLIN.APPS\GINT7\PROJECTS\PALMER.GPJ DEFAULT.GDT 8/28/07

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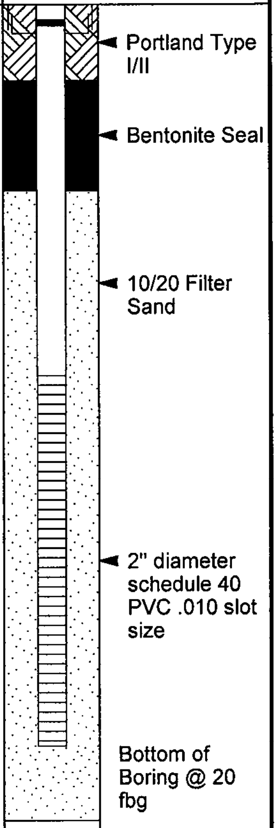
BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-8
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	05-Jul-07
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	06-Jul-07
PROJECT NUMBER	241739	**WELL DEVELOPMENT DATE (YIELD)**	06-Jul-07
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	451.7 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	452.01 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	10 to 20 fbg
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	15.0 fbg (08-Jul-07) ▽
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼
REMARKS			

PID (ppm)	BLOW COUNTS	SAMPLE ID	EXTENT	DEPTH (fbg)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (fbg)
							Asphalt	0.5
					SW		SAND with trace cobbles (FILL): Dark Brown; moist, non plastic, high permeability.	5.0
2000+				5	SC		Clayey SAND with gravel: Gray, moist, non plastic, medium permeability.	10.0
3413	13 19 20			10	CL		Sandy CLAY with gravel: Gray, wet, low plasticity, low permeability.	▽ 15.0
4450	19 20 20	MW8@15'		15	CL		Sandy Clay with gravel: Gray, wet, medium plasticity, low permeability.	20.0
960	30 50	MW8@20'		20				

WELL DIAGRAM



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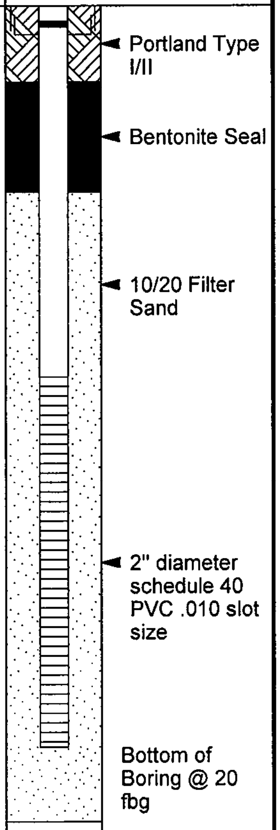
BORING/WELL LOG

CLIENT NAME	Shell Oil Products US	**BORING/WELL NAME**	MW-9
JOB/SITE NAME	LYNN6808	**DRILLING STARTED**	05-Jul-07
LOCATION	6808 196th Street, Lynnwood, WA	**DRILLING COMPLETED**	06-Jul-07
PROJECT NUMBER	241739	**WELL DEVELOPMENT DATE (YIELD)**	06-Jul-07
DRILLER	Boart Longyear Drilling	**GROUND SURFACE ELEVATION**	452.18 ft above msl
DRILLING METHOD	Hollow-stem auger	**TOP OF CASING ELEVATION**	452.28 ft above msl
BORING DIAMETER	8"	**SCREENED INTERVAL**	10 to 20 fbg
LOGGED BY	Bryan Palmer	**DEPTH TO WATER (First Encountered)**	16.0 fbg (09-Jul-07) ▽
REVIEWED BY	T. Crotwell	**DEPTH TO WATER (Static)**	NA ▼
REMARKS			

PID (ppm)	BLOW COUNTS	SAMPLE ID	EXTENT	DEPTH (fbg)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (fbg)
							Asphalt	0.5
					SW		Fill SAND with trace gravel: Dark Brown; dry, non plastic, high permeability.	5.0
201				5	SW		Fill SAND with trace gravel: Dark Brown; moist, non plastic, high permeability.	10.0
2000+	50	MW9@10'	☒	10	CL		Sandy CLAY with trace gravel: Gray, moist, low plasticity, medium permeability.	15.0
1250	50		☒	15	SC		Clayey SAND with gravel: Gray, wet, non plastic, medium permeability. ▽	20.0
300+	50	MW9@20'	☒	20				

WELL DIAGRAM



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Everett, WA 98203
Telephone: (425) 212-5100
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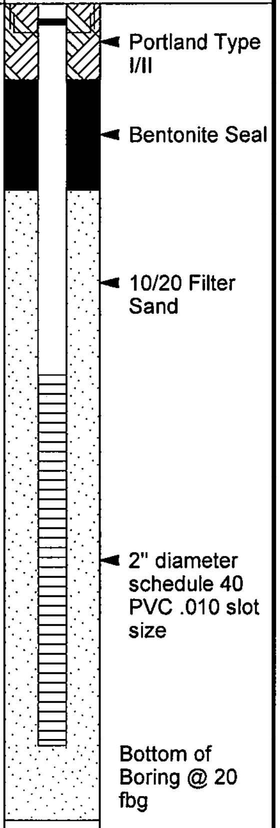
BORING/WELL LOG

CLIENT NAME Shell Oil Products US
JOB/SITE NAME LYNN6808
LOCATION 6808 196th Street, Lynnwood, WA
PROJECT NUMBER 241739
DRILLER Boart Longyear Drilling
DRILLING METHOD Hollow-stem auger
BORING DIAMETER 8"
LOGGED BY Bryan Palmer
REVIEWED BY T. Crotwell
REMARKS

BORING/WELL NAME MW-10
DRILLING STARTED 05-Jul-07
DRILLING COMPLETED 06-Jul-07
WELL DEVELOPMENT DATE (YIELD) 06-Jul-07
GROUND SURFACE ELEVATION 451.72 ft above msl
TOP OF CASING ELEVATION 451.58 ft above msl
SCREENED INTERVAL 10 to 20 fbg
DEPTH TO WATER (First Encountered) 17.0 fbg (10-Jul-07) ▽
DEPTH TO WATER (Static) NA ▼

PID (ppm)	BLOW COUNTS	SAMPLE ID	EXTENT	DEPTH (fbg)	U.S.C.S.	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH (fbg)
							Asphalt	0.5
					SW		Gravelly SAND with trace cobbles (FILL): Dark Brown; moist, non plastic, high permeability.	5.0
900	25 5 5	MW10@ 5'		5	CL		Gravelly SAND with trace cobbles: Gray with Dark Brown streaks; wet, non plastic, high to medium permeability.	10.0
63	39 50			10	CL		Sandy CLAY with trace gravel: Gray, wet, low plasticity, low permeability.	15.0
480	27 50			15	CL		Clayey SAND with trace gravel: Gray, wet, non plastic, medium permeability. ▽	20.0
360	37 50	MW10@ 20'		20				

WELL DIAGRAM



APPENDIX E

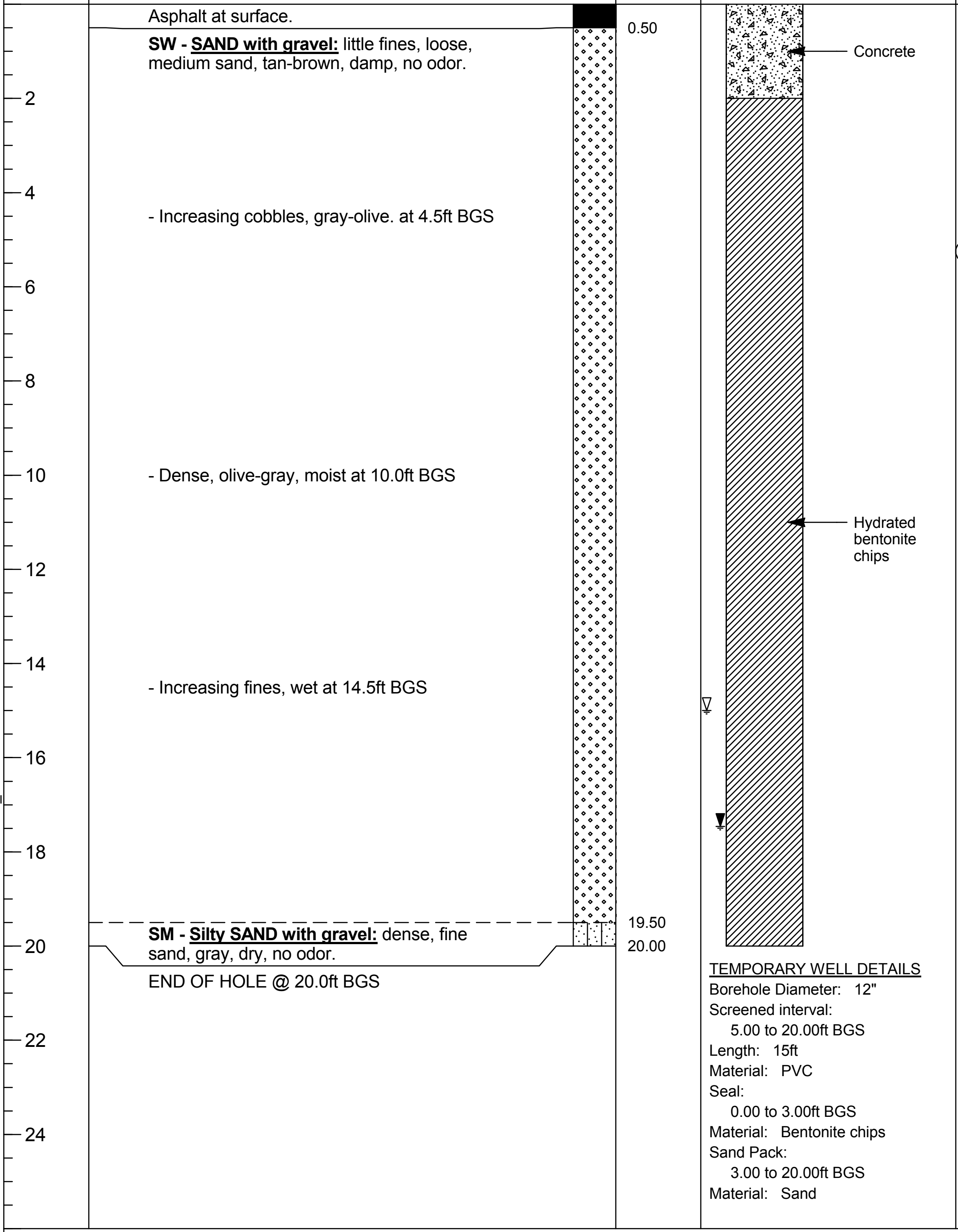
SOIL BORING LOGS FOR SB-3 AND SB-4

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

Page 1 of 1

PROJECT NAME: 6808 Lynnwood
PROJECT NUMBER: 241739
CLIENT: Shell Oil Products US
LOCATION: 6820 196th St. SW, Lynnwood, WA

HOLE DESIGNATION: SB-3
DATE COMPLETED: May 11, 2010
DRILLING METHOD: Hollow-stem Auger
FIELD PERSONNEL: H. Bays
NOTES: Air-knifed to 5.3ft BGS



DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS
	Asphalt at surface.	0.50
	SW - SAND with gravel: little fines, loose, medium sand, tan-brown, damp, no odor.	
	- Increasing cobbles, gray-olive. at 4.5ft BGS	
	- Dense, olive-gray, moist at 10.0ft BGS	
	- Increasing fines, wet at 14.5ft BGS	19.50
	SM - Silty SAND with gravel: dense, fine sand, gray, dry, no odor.	20.00
	END OF HOLE @ 20.0ft BGS	

NUMBER	INTERVAL	REC (ft)	'N' VALUE	PID
	☒			0.2
SB-3-5.0	☒			0.3
	☒	0.4	50	0.6
	☒	0.5	50	0.6
	☒	0.3	50	0.4

TEMPORARY WELL DETAILS
Borehole Diameter: 12"
Screened interval:
5.00 to 20.00ft BGS
Length: 15ft
Material: PVC
Seal:
0.00 to 3.00ft BGS
Material: Bentonite chips
Sand Pack:
3.00 to 20.00ft BGS
Material: Sand

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇ 5/11/2010 STATIC WATER LEVEL ▼ 5/11/2010
CHEMICAL ANALYSIS ○

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

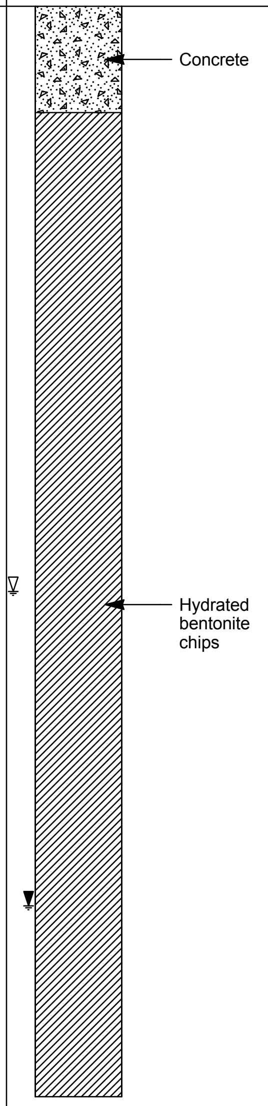
Page 1 of 1

PROJECT NAME: 6808 Lynnwood
PROJECT NUMBER: 241739
CLIENT: Shell Oil Products US
LOCATION: 6820 196th St. SW, Lynnwood, WA

HOLE DESIGNATION: SB-4
DATE COMPLETED: May 11, 2010
DRILLING METHOD: Hollow-stem Auger
FIELD PERSONNEL: H. Bays
NOTES: Air-knifed to 5.0ft BGS

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS
	SW - SAND with gravel and cobbles: little fines, medium sand, dense, damp, reddish light brown, no odor.	
4	- Increase in fines, more olive-gray brown than red at 4.0ft BGS	
	SM - Silty SAND with gravel: dense, medium to fine sand, olive-gray, moist, no odor.	7.50
14	- Some cobbles, dry at 14.5ft BGS	
18	- Increasing cobbles at 17.5ft BGS	
20	- Fine sand, dry at 19.5ft BGS	
	END OF HOLE @ 20.5ft BGS	20.50

Soil Boring



TEMPORARY WELL DETAILS
Borehole Diameter: 12"
Screened interval:
5.00 to 20.00ft BGS
Length: 15ft
Material: PVC
Seal:
0.00 to 3.00ft BGS
Material: Bentonite chips
Sand Pack:
3.00 to 20.50ft BGS
Material: Sand

SAMPLE

NUMBER	INTERVAL	REC (ft)	'N' VALUE	PID
	☒			0.3
SB-4-5.0	☒			0.2
	☒	0.5	50	0.6
	☒	0.3	50	0.3
	☒	0.4	50	0.1

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊽ 5/11/2010 STATIC WATER LEVEL ▼ 5/11/2010
CHEMICAL ANALYSIS ○

APPENDIX F

LABORATORY ANALYTICAL REPORTS

Calscience
Environmental
Laboratories, Inc.

Supplemental Report 1

May 21, 2010

Justin Foslien
Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Subject: **Calscience Work Order No.:** **10-05-0847**
Client Reference: **6808 196th St. SW, Lynwood, WA**

Dear Client:

Enclosed is an analytical report for the above-referenced project. The samples included in this report were received 5/12/2010 and analyzed in accordance with the attached chain-of-custody.

Unless otherwise noted, all analytical testing was accomplished in accordance with the guidelines established in our Quality Systems Manual, applicable standard operating procedures, and other related documentation. The original report of subcontracted analysis, if any, is provided herein, and follows the standard Calscience data package. The results in this analytical report are limited to the samples tested and any reproduction thereof must be made in its entirety.

If you have any questions regarding this report, please do not hesitate to contact the undersigned.

Sincerely,

Philip Samelle for

Calscience Environmental
Laboratories, Inc.
Xuan H. Dang
Project Manager

Analytical Report

Conestoga-Rovers & Associates		Date Received:	05/12/10
1420 80th St. SW, Suite A		Work Order No:	10-05-0847
Everett, WA 98203-6248		Preparation:	EPA 3550B
		Method:	NWTPH-Dx
		Units:	mg/kg

Project: 6808 196th St. SW, Lynwood, WA

Page 1 of 1

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
SO-241739-051010-HB-SB-3-5.0	**10-05-0847-1-A**	**05/10/10 08:28**	**Solid**	**GC 43**	**05/12/10**	**05/12/10 20:56**	**100512B02S**

Comment(s): -The sample extract was subjected to Silica Gel treatment prior to analysis.

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
TPH as Diesel Range	ND	5.0	1		TPH as Motor Oil Range	ND	5.0	1	
Surrogates:	REC (%)	Control Limits	Qual						
Decachlorobiphenyl	105	61-145							

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
SO-241739-051010-HB-SB-4-5.0	**10-05-0847-2-A**	**05/10/10 09:22**	**Solid**	**GC 43**	**05/12/10**	**05/12/10 21:16**	**100512B02S**

Comment(s): -The sample extract was subjected to Silica Gel treatment prior to analysis.

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
TPH as Diesel Range	6.1	5.0	1		TPH as Motor Oil Range	47	5.0	1	
Surrogates:	REC (%)	Control Limits	Qual						
Decachlorobiphenyl	110	61-145							

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
Method Blank	**099-12-838-72**	**N/A**	**Solid**	**GC 43**	**05/12/10**	**05/13/10 09:04**	**100512B02S**

Parameter	Result	RL	DF	Qual
TPH as Diesel Range	ND	5.0	1	
Surrogates:	REC (%)	Control Limits	Qual	
Decachlorobiphenyl	104	61-145		

Calscience Environmental Laboratories, Inc.

Analytical Report

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	05/12/10
Work Order No:	10-05-0847
Preparation:	EPA 3510C
Method:	NWTPH-Dx
Units:	ug/L

Project: 6808 196th St. SW, Lynwood, WA

Page 1 of 1

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
GW-241739-051010-HB-SB-3	**10-05-0847-3-G**	**05/11/10 10:00**	**Aqueous**	**GC 45**	**05/13/10**	**05/14/10 05:08**	**100513B04**

Comment(s): -The sample chromatographic pattern for TPH does not match the chromatographic pattern of the specified standard. Quantitation of the unknown hydrocarbon(s) in the sample was based upon the specified standard.
-The sample extract was subjected to Silica Gel treatment prior to analysis.

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
TPH as Diesel Range	1600	100	1		TPH as Motor Oil Range	ND	100	1	

Surrogates:	REC (%)	Control Limits	Qual
Decachlorobiphenyl	75	68-140	

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
GW-241739-051010-HB-SB-4	**10-05-0847-4-G**	**05/11/10 10:30**	**Aqueous**	**GC 45**	**05/13/10**	**05/14/10 05:25**	**100513B04**

Comment(s): -The sample chromatographic pattern for TPH does not match the chromatographic pattern of the specified standard. Quantitation of the unknown hydrocarbon(s) in the sample was based upon the specified standard.
-The sample extract was subjected to Silica Gel treatment prior to analysis.

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
TPH as Diesel Range	2400	100	1		TPH as Motor Oil Range	ND	100	1	

Surrogates:	REC (%)	Control Limits	Qual
Decachlorobiphenyl	71	68-140	

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
Method Blank	**099-12-840-227**	**N/A**	**Aqueous**	**GC 45**	**05/13/10**	**05/14/10 04:21**	**100513B04**

Parameter	Result	RL	DF	Qual
TPH as Diesel Range	ND	100	1	

Surrogates:	REC (%)	Control Limits	Qual
Decachlorobiphenyl	96	68-140	

Analytical Report

Conestoga-Rovers & Associates		Date Received:	05/12/10
1420 80th St. SW, Suite A		Work Order No:	10-05-0847
Everett, WA 98203-6248		Preparation:	EPA 5030B
		Method:	NWTPH-Gx

Project: 6808 196th St. SW, Lynwood, WA

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Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
GW-241739-051010-HB-SB-3	**10-05-0847-3-D**	**05/11/10 10:00**	**Aqueous**	**GC 5**	**05/12/10**	**05/12/10 14:44**	**100512B01**

Comment(s): -The sample chromatographic pattern for TPH does not match the chromatographic pattern of the specified standard. Quantitation of the unknown hydrocarbon(s) in the sample was based upon the specified standard.

Parameter	Result	RL	DF	Qual	Units
TPH as Gasoline	360	100	1		ug/L

Surrogates:	REC (%)	Control Limits	Qual
1,4-Bromofluorobenzene	89	38-134	

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
GW-241739-051010-HB-SB-4	**10-05-0847-4-D**	**05/11/10 10:30**	**Aqueous**	**GC 5**	**05/12/10**	**05/12/10 15:17**	**100512B01**

Comment(s): -The sample chromatographic pattern for TPH does not match the chromatographic pattern of the specified standard. Quantitation of the unknown hydrocarbon(s) in the sample was based upon the specified standard.

Parameter	Result	RL	DF	Qual	Units
TPH as Gasoline	180	100	1		ug/L

Surrogates:	REC (%)	Control Limits	Qual
1,4-Bromofluorobenzene	93	38-134	

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
Method Blank	**099-12-743-553**	**N/A**	**Aqueous**	**GC 5**	**05/12/10**	**05/12/10 10:45**	**100512B01**

Parameter	Result	RL	DF	Qual	Units
TPH as Gasoline	ND	100	1		ug/L

Surrogates:	REC (%)	Control Limits	Qual
1,4-Bromofluorobenzene	88	38-134	

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

Calscience Environmental Laboratories, Inc.

Analytical Report

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	05/12/10
Work Order No:	10-05-0847
Preparation:	EPA 5035
Method:	NWTPH-Gx

Project: 6808 196th St. SW, Lynwood, WA

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Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
SO-241739-051010-HB-SB-3-5.0	**10-05-0847-1-I**	**05/10/10 08:28**	**Solid**	**GC 1**	**05/10/10**	**05/14/10 20:41**	**100514B01**

Parameter	Result	RL	DF	Qual	Units
TPH as Gasoline	ND	0.20	0.809		mg/kg

Surrogates:	REC (%)	Control Limits	Qual
1,4-Bromofluorobenzene	82	60-126	

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
SO-241739-051010-HB-SB-4-5.0	**10-05-0847-2-I**	**05/10/10 09:22**	**Solid**	**GC 1**	**05/10/10**	**05/14/10 21:13**	**100514B01**

Parameter	Result	RL	DF	Qual	Units
TPH as Gasoline	ND	0.24	0.951		mg/kg

Surrogates:	REC (%)	Control Limits	Qual
1,4-Bromofluorobenzene	82	60-126	

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
Method Blank	**099-12-848-93**	**N/A**	**Solid**	**GC 1**	**05/14/10**	**05/14/10 16:57**	**100514B01**

Parameter	Result	RL	DF	Qual	Units
TPH as Gasoline	ND	0.25	1		mg/kg

Surrogates:	REC (%)	Control Limits	Qual
1,4-Bromofluorobenzene	82	60-126	

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

Analytical Report

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	05/12/10
Work Order No:	10-05-0847
Preparation:	EPA 5035
Method:	EPA 8260B
Units:	mg/kg

Project: 6808 196th St. SW, Lynwood, WA

Page 1 of 1

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
SO-241739-051010-HB-SB-3-5.0	**10-05-0847-1-F**	**05/10/10 08:28**	**Solid**	**GC/MS QQ**	**05/10/10**	**05/15/10 19:45**	**100515L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	ND	0.00083	0.826		Toluene	ND	0.00083	0.826	
Ethylbenzene	ND	0.00083	0.826		Xylenes (total)	ND	0.0017	0.826	
Surrogates:	REC (%)	Control Limits	Qual		Surrogates:	REC (%)	Control Limits	Qual	
Dibromofluoromethane	125	71-137			1,2-Dichloroethane-d4	151	58-160		
1,4-Bromofluorobenzene	103	66-126			Toluene-d8	109	87-111		

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
SO-241739-051010-HB-SB-4-5.0	**10-05-0847-2-F**	**05/10/10 09:22**	**Solid**	**GC/MS QQ**	**05/10/10**	**05/15/10 20:12**	**100515L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	ND	0.0010	0.998		Toluene	0.0018	0.0010	0.998	
Ethylbenzene	ND	0.0010	0.998		Xylenes (total)	ND	0.0020	0.998	
Surrogates:	REC (%)	Control Limits	Qual		Surrogates:	REC (%)	Control Limits	Qual	
Dibromofluoromethane	124	71-137			1,2-Dichloroethane-d4	150	58-160		
1,4-Bromofluorobenzene	103	66-126			Toluene-d8	105	87-111		

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
Method Blank	**095-01-025-19,412**	**N/A**	**Solid**	**GC/MS QQ**	**05/15/10**	**05/15/10 13:04**	**100515L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	ND	0.0010	1		Toluene	ND	0.0010	1	
Ethylbenzene	ND	0.0010	1		Xylenes (total)	ND	0.0020	1	
Surrogates:	REC (%)	Control Limits	Qual		Surrogates:	REC (%)	Control Limits	Qual	
Dibromofluoromethane	119	71-137			1,2-Dichloroethane-d4	130	58-160		
1,4-Bromofluorobenzene	100	66-126			Toluene-d8	106	87-111		

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

Analytical Report

Conestoga-Rovers & Associates		Date Received:	05/12/10
1420 80th St. SW, Suite A		Work Order No:	10-05-0847
Everett, WA 98203-6248		Preparation:	EPA 5030B
		Method:	EPA 8260B
		Units:	ug/L

Project: 6808 196th St. SW, Lynwood, WA

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Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
GW-241739-051010-HB-SB-3	**10-05-0847-3-B**	**05/11/10 10:00**	**Aqueous**	**GC/MS QQ**	**05/13/10**	**05/13/10 12:57**	**100513L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	170	0.50	1		Toluene	ND	1.0	1	
Ethylbenzene	ND	1.0	1		Xylenes (total)	ND	1.0	1	
Surrogates:	REC (%)	Control Limits		Qual	Surrogates:	REC (%)	Control Limits		Qual
Dibromofluoromethane	106	80-132			1,2-Dichloroethane-d4	111	80-141		
Toluene-d8	100	80-120			1,4-Bromofluorobenzene	100	76-120		

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
GW-241739-051010-HB-SB-4	**10-05-0847-4-A**	**05/11/10 10:30**	**Aqueous**	**GC/MS QQ**	**05/13/10**	**05/13/10 14:45**	**100513L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	ND	0.50	1		Toluene	ND	1.0	1	
Ethylbenzene	ND	1.0	1		Xylenes (total)	ND	1.0	1	
Surrogates:	REC (%)	Control Limits		Qual	Surrogates:	REC (%)	Control Limits		Qual
Dibromofluoromethane	105	80-132			1,2-Dichloroethane-d4	108	80-141		
Toluene-d8	102	80-120			1,4-Bromofluorobenzene	99	76-120		

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
TB	**10-05-0847-5-A**	**05/10/10 00:00**	**Aqueous**	**GC/MS FF**	**05/12/10**	**05/12/10 20:46**	**100512L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	ND	0.50	1		Toluene	ND	1.0	1	
Ethylbenzene	ND	1.0	1		Xylenes (total)	ND	1.0	1	
Surrogates:	REC (%)	Control Limits		Qual	Surrogates:	REC (%)	Control Limits		Qual
Dibromofluoromethane	110	80-132			1,2-Dichloroethane-d4	126	80-141		
Toluene-d8	102	80-120			1,4-Bromofluorobenzene	87	76-120		

Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
Method Blank	**099-14-001-755**	**N/A**	**Aqueous**	**GC/MS FF**	**05/12/10**	**05/12/10 12:47**	**100512L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	ND	0.50	1		Toluene	ND	1.0	1	
Ethylbenzene	ND	1.0	1		Xylenes (total)	ND	1.0	1	
Surrogates:	REC (%)	Control Limits		Qual	Surrogates:	REC (%)	Control Limits		Qual
Dibromofluoromethane	92	80-132			1,2-Dichloroethane-d4	118	80-141		
Toluene-d8	99	80-120			1,4-Bromofluorobenzene	90	76-120		

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

Analytical Report

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	05/12/10
Work Order No:	10-05-0847
Preparation:	EPA 5030B
Method:	EPA 8260B
Units:	ug/L

Project: 6808 196th St. SW, Lynwood, WA

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Client Sample Number	Lab Sample Number	Date/Time Collected	Matrix	Instrument	Date Prepared	Date/Time Analyzed	QC Batch ID
Method Blank	**099-14-001-768**	**N/A**	**Aqueous**	**GC/MS QQ**	**05/13/10**	**05/13/10 12:30**	**100513L01**

Parameter	Result	RL	DF	Qual	Parameter	Result	RL	DF	Qual
Benzene	ND	0.50	1		Toluene	ND	1.0	1	
Ethylbenzene	ND	1.0	1		Xylenes (total)	ND	1.0	1	

Surrogates:	REC (%)	Control Limits	Qual	Surrogates:	REC (%)	Control Limits	Qual
Dibromofluoromethane	104	80-132		1,2-Dichloroethane-d4	110	80-141	
Toluene-d8	101	80-120		1,4-Bromofluorobenzene	100	76-120	

RL - Reporting Limit , DF - Dilution Factor , Qual - Qualifiers

Quality Control - Spike/Spike Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received: 05/12/10
Work Order No: 10-05-0847
Preparation: EPA 5030B
Method: EPA 8015B (M)

Project 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	MS/MSD Batch Number
10-05-0353-9	**Aqueous**	**GC 5**	**05/12/10**	**05/12/10**	**100512S01**

Parameter	MS %REC	MSD %REC	%REC CL	RPD	RPD CL	Qualifiers
TPH as Gasoline	97	103	68-122	6	0-18	

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - Spike/Spike Duplicate

Conestoga-Rovers & Associates		Date Received:	05/12/10
1420 80th St. SW, Suite A		Work Order No:	10-05-0847
Everett, WA 98203-6248		Preparation:	EPA 5030B
		Method:	EPA 8260B

Project 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	MS/MSD Batch Number
10-05-0268-1	**Aqueous**	**GC/MS FF**	**05/12/10**	**05/12/10**	**100512S01**

Parameter	MS %REC	MSD %REC	%REC CL	RPD	RPD CL	Qualifiers
Benzene	104	111	72-120	6	0-20	
Carbon Tetrachloride	114	122	63-135	6	0-20	
Chlorobenzene	104	110	80-120	6	0-20	
1,2-Dibromoethane	106	110	80-120	4	0-20	
1,2-Dichlorobenzene	97	107	80-120	9	0-20	
1,2-Dichloroethane	106	114	80-120	7	0-20	
1,1-Dichloroethene	103	109	60-132	6	0-24	
Ethylbenzene	112	118	78-120	5	0-20	
Toluene	104	114	74-122	8	0-20	
Trichloroethene	111	117	69-120	5	0-20	
Vinyl Chloride	87	94	58-130	7	0-20	
Methyl-t-Butyl Ether (MTBE)	93	101	72-126	8	0-21	
Tert-Butyl Alcohol (TBA)	85	98	72-126	15	0-20	
Diisopropyl Ether (DIPE)	88	96	71-137	8	0-23	
Ethyl-t-Butyl Ether (ETBE)	103	112	74-128	9	0-20	
Tert-Amyl-Methyl Ether (TAME)	105	113	76-124	7	0-20	
Ethanol	103	112	35-167	8	0-48	

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - Spike/Spike Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	05/12/10
Work Order No:	10-05-0847
Preparation:	EPA 5030B
Method:	EPA 8260B

Project 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	MS/MSD Batch Number
GW-241739-051010-HB-SB-3	**Aqueous**	**GC/MS QQ**	**05/13/10**	**05/13/10**	**100513S01**

Parameter	MS %REC	MSD %REC	%REC CL	RPD	RPD CL	Qualifiers
Benzene	89	96	72-120	2	0-20	
Carbon Tetrachloride	86	88	63-135	2	0-20	
Chlorobenzene	99	100	80-120	1	0-20	
1,2-Dibromoethane	99	101	80-120	2	0-20	
1,2-Dichlorobenzene	94	93	80-120	1	0-20	
1,1-Dichloroethene	114	109	60-132	5	0-24	
Ethylbenzene	100	102	78-120	2	0-20	
Toluene	98	100	74-122	2	0-20	
Trichloroethene	96	98	69-120	2	0-20	
Vinyl Chloride	90	88	58-130	2	0-20	
Methyl-t-Butyl Ether (MTBE)	103	99	72-126	4	0-21	
Tert-Butyl Alcohol (TBA)	84	82	72-126	2	0-20	
Diisopropyl Ether (DIPE)	106	105	71-137	1	0-23	
Ethyl-t-Butyl Ether (ETBE)	95	95	74-128	0	0-20	
Tert-Amyl-Methyl Ether (TAME)	91	93	76-124	3	0-20	
Ethanol	117	98	35-167	15	0-48	

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - LCS/LCS Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received: N/A
Work Order No: 10-05-0847
Preparation: EPA 3550B
Method: NWTPH-Dx

Project: 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	LCS/LCSD Batch Number
099-12-838-72	**Solid**	**GC 43**	**05/12/10**	**05/13/10**	**100512B02S**

Parameter	LCS %REC	LCSD %REC	%REC CL	RPD	RPD CL	Qualifiers
TPH as Diesel Range	99	98	75-123	1	0-12	

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - LCS/LCS Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received: N/A
Work Order No: 10-05-0847
Preparation: EPA 3510C
Method: NWTPH-Dx

Project: 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	LCS/LCSD Batch Number
099-12-840-227	**Aqueous**	**GC 45**	**05/13/10**	**05/14/10**	**100513B04**

Parameter	LCS %REC	LCSD %REC	%REC CL	RPD	RPD CL	Qualifiers
TPH as Diesel Range	117	107	75-117	9	0-13	

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - LCS/LCS Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	N/A
Work Order No:	10-05-0847
Preparation:	EPA 5030B
Method:	NWTPH-Gx

Project: 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	LCS/LCSD Batch Number
099-12-743-553	**Aqueous**	**GC 5**	**05/12/10**	**05/12/10**	**100512B01**

Parameter	LCS %REC	LCSD %REC	%REC CL	RPD	RPD CL	Qualifiers
TPH as Gasoline	105	102	78-120	2	0-10	

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - LCS/LCS Duplicate

Conestoga-Rovers & Associates	Date Received:	N/A
1420 80th St. SW, Suite A	Work Order No:	10-05-0847
Everett, WA 98203-6248	Preparation:	EPA 5035
	Method:	NWTPH-Gx

Project: 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	LCS/LCSD Batch Number
099-12-848-93	**Solid**	**GC 1**	**05/14/10**	**05/14/10**	**100514B01**

Parameter	LCS %REC	LCSD %REC	%REC CL	RPD	RPD CL	Qualifiers
TPH as Gasoline	108	111	55-139	3	0-18	

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - LCS/LCS Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received: N/A
Work Order No: 10-05-0847
Preparation: EPA 5035
Method: EPA 8260B

Project: 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	LCS/LCSD Batch Number
095-01-025-19,412	**Solid**	**GC/MS QQ**	**05/15/10**	**05/15/10**	**100515L01**

Parameter	LCS %REC	LCSD %REC	%REC CL	ME_CL	RPD	RPD CL	Qualifiers
Benzene	102	101	85-115	80-120	1	0-11	
Carbon Tetrachloride	107	106	68-134	57-145	1	0-14	
Chlorobenzene	98	97	83-119	77-125	1	0-9	
1,2-Dibromoethane	99	98	80-120	73-127	1	0-20	
1,2-Dichlorobenzene	92	90	57-135	44-148	2	0-10	
1,1-Dichloroethene	118	118	72-120	64-128	1	0-10	
Ethylbenzene	101	101	80-120	73-127	1	0-20	
Toluene	99	98	67-127	57-137	1	0-10	
Trichloroethene	97	96	88-112	84-116	2	0-9	
Vinyl Chloride	116	107	57-129	45-141	8	0-16	
Methyl-t-Butyl Ether (MTBE)	106	107	76-124	68-132	1	0-12	
Tert-Butyl Alcohol (TBA)	81	80	31-145	12-164	2	0-23	
Diisopropyl Ether (DIPE)	116	116	74-128	65-137	0	0-10	
Ethyl-t-Butyl Ether (ETBE)	99	99	77-125	69-133	0	0-9	
Tert-Amyl-Methyl Ether (TAME)	91	90	81-123	74-130	1	0-10	
Ethanol	100	99	44-152	26-170	2	0-24	

Total number of LCS compounds : 16
Total number of ME compounds : 0
Total number of ME compounds allowed : 1
LCS ME CL validation result : Pass

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - LCS/LCS Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	N/A
Work Order No:	10-05-0847
Preparation:	EPA 5030B
Method:	EPA 8260B

Project: 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	LCS/LCSD Batch Number
099-14-001-755	**Aqueous**	**GC/MS FF**	**05/12/10**	**05/12/10**	**100512L01**

Parameter	LCS %REC	LCSD %REC	%REC CL	ME_CL	RPD	RPD CL	Qualifiers
Benzene	104	103	80-122	73-129	1	0-20	
Carbon Tetrachloride	115	110	68-140	56-152	5	0-20	
Chlorobenzene	108	104	80-120	73-127	3	0-20	
1,2-Dibromoethane	112	107	80-121	73-128	4	0-20	
1,2-Dichlorobenzene	105	104	80-120	73-127	1	0-20	
1,1-Dichloroethene	105	103	72-132	62-142	3	0-25	
Ethylbenzene	117	114	80-126	72-134	3	0-20	
Toluene	106	106	80-121	73-128	0	0-20	
Trichloroethene	111	114	80-123	73-130	3	0-20	
Vinyl Chloride	87	88	67-133	56-144	1	0-20	
Methyl-t-Butyl Ether (MTBE)	103	95	75-123	67-131	8	0-20	
Tert-Butyl Alcohol (TBA)	101	98	75-123	67-131	3	0-20	
Diisopropyl Ether (DIPE)	114	112	71-131	61-141	2	0-20	
Ethyl-t-Butyl Ether (ETBE)	107	103	76-124	68-132	5	0-20	
Tert-Amyl-Methyl Ether (TAME)	107	108	80-123	73-130	1	0-20	
Ethanol	103	94	61-139	48-152	8	0-27	

Total number of LCS compounds : 16
Total number of ME compounds : 0
Total number of ME compounds allowed : 1
LCS ME CL validation result : Pass

RPD - Relative Percent Difference , CL - Control Limit

Quality Control - LCS/LCS Duplicate

Conestoga-Rovers & Associates
1420 80th St. SW, Suite A
Everett, WA 98203-6248

Date Received:	N/A
Work Order No:	10-05-0847
Preparation:	EPA 5030B
Method:	EPA 8260B

Project: 6808 196th St. SW, Lynwood, WA

Quality Control Sample ID	Matrix	Instrument	Date Prepared	Date Analyzed	LCS/LCSD Batch Number
099-14-001-768	**Aqueous**	**GC/MS QQ**	**05/13/10**	**05/13/10**	**100513L01**

Parameter	LCS %REC	LCSD %REC	%REC CL	ME_CL	RPD	RPD CL	Qualifiers
Benzene	99	99	80-122	73-129	0	0-20	
Carbon Tetrachloride	81	84	68-140	56-152	4	0-20	
Chlorobenzene	98	98	80-120	73-127	0	0-20	
1,2-Dibromoethane	99	99	80-121	73-128	0	0-20	
1,2-Dichlorobenzene	96	93	80-120	73-127	3	0-20	
1,1-Dichloroethene	83	108	72-132	62-142	26	0-25	X
Ethylbenzene	99	99	80-126	72-134	0	0-20	
Toluene	97	97	80-121	73-128	0	0-20	
Trichloroethene	97	96	80-123	73-130	1	0-20	
Vinyl Chloride	97	99	67-133	56-144	2	0-20	
Methyl-t-Butyl Ether (MTBE)	102	101	75-123	67-131	1	0-20	
Tert-Butyl Alcohol (TBA)	85	103	75-123	67-131	19	0-20	
Diisopropyl Ether (DIPE)	106	105	71-131	61-141	1	0-20	
Ethyl-t-Butyl Ether (ETBE)	98	98	76-124	68-132	0	0-20	
Tert-Amyl-Methyl Ether (TAME)	95	94	80-123	73-130	0	0-20	
Ethanol	131	133	61-139	48-152	2	0-27	

Total number of LCS compounds : 16
Total number of ME compounds : 0
Total number of ME compounds allowed : 1
LCS ME CL validation result : Not Pass(See Narrative)

RPD - Relative Percent Difference , CL - Control Limit

Glossary of Terms and Qualifiers

Work Order Number: 10-05-0847

Qualifier	Definition
*	See applicable analysis comment.
<	Less than the indicated value.
>	Greater than the indicated value.
1	Surrogate compound recovery was out of control due to a required sample dilution, therefore, the sample data was reported without further clarification.
2	Surrogate compound recovery was out of control due to matrix interference. The associated method blank surrogate spike compound was in control and, therefore, the sample data was reported without further clarification.
3	Recovery of the Matrix Spike (MS) or Matrix Spike Duplicate (MSD) compound was out of control due to matrix interference. The associated LCS and/or LCSD was in control and, therefore, the sample data was reported without further clarification.
4	The MS/MSD RPD was out of control due to matrix interference. The LCS/LCSD RPD was in control and, therefore, the sample data was reported without further clarification.
5	The PDS/PDSD or PES/PESD associated with this batch of samples was out of control due to a matrix interference effect. The associated batch LCS/LCSD was in control and, hence, the associated sample data was reported without further clarification.
B	Analyte was present in the associated method blank.
E	Concentration exceeds the calibration range.
J	Analyte was detected at a concentration below the reporting limit and above the laboratory method detection limit. Reported value is estimated.
ME	LCS Recovery Percentage is within LCS ME Control Limit range.
ND	Parameter not detected at the indicated reporting limit.
Q	Spike recovery and RPD control limits do not apply resulting from the parameter concentration in the sample exceeding the spike concentration by a factor of four or greater.
X	% Recovery and/or RPD out-of-range.
Z	Analyte presence was not confirmed by second column or GC/MS analysis.
	Solid - Unless otherwise indicated, solid sample data is reported on a wet weight basis, not corrected for % moisture.

Shell Oil Products Chain Of Custody Record

LAB (LOCATION)
☒ CALSCIENCE (Garden Grove, CA)
☐ SPL Houston ( )
☐ XENCO ( )
☐ TEST AMERICA ( )
☐ OTHER ( )

Please Check Appropriate Box:
☐ ENV. SERVICES ☐ MOTIVA RETAIL ☐ SHELL RETAIL
☐ MOTIVA SD&CM ☑ CONSULTANT ☐ LUBES
☐ SHELL PIPELINE ☐ OTHER

Print Bill To Contact Name: Justin Foslien 241739.95.10.03
PO #: 46-4021318
INCIDENT # (ENV SERVICES): 97605410
SAP #: 172152
☐ CHECK IF NO INCIDENT # APPLIES
DATE: 5/11/10
PAGE: 1 of 1

SAMPLING COMPANY: Conestoga-Rovers & Associates
LOG CODE: CRAW
ADDRESS: 1420 80th St SW, Suite , Everett, WA 98203
PROJECT CONTACT (Hardcopy or PDF Report to): Justin Foslien & copy to Shell.lab.billing@CRAWORLD.Com
TELEPHONE: 425-212-5100
FAX: 425-212-5199
E-MAIL: jfoslien@CRAWORLD.com

SITE ADDRESS: Street and City: 6808 196th St. SW Lynwood
State: WA
GLOBAL ID NO.:
EDF DELIVERABLE TO (Name, Company, Office Location): Christine Schweigert, CRA, Everett
PHONE NO.: 425-212-5100
E-MAIL: cschweigert@CRAworld.com
CONSULTANT PROJECT NO.: 241793.95.10.03
SAMPLER NAME(S) (Print): Heather Boys
LAB USE ONLY: 05-0847

TURNAROUND TIME (CALENDAR DAYS):
☒ STANDARD (14 DAY) ☐ 5 DAYS ☐ 3 DAYS ☐ 2 DAYS ☒ 24 HOURS ☐ RESULTS NEEDED ON WEEKEND

☐ LA - RWQCB REPORT FORMAT ☐ UST AGENCY:

SPECIAL INSTRUCTIONS OR NOTES :

Copy final report to Shell.Lab.Billing@craworld.com

See SPL PM for WA Dept. of Ecology MTCA Method A cleanup levels for minimum detection limits

☑ SHELL CONTRACT RATE APPLIES
☐ STATE REIMBURSEMENT RATE APPLIES
☐ EDD NOT NEEDED
☑ RECEIPT VERIFICATION REQUESTED

REQUESTED ANALYSIS

TEMPERATURE ON RECEIPT C°

LAB USE ONLY	Field Sample Identification	SAMPLING DATE	SAMPLING TIME	MATRIX	PRESERVATIVE HCL	HNO3	H2SO4	NONE	OTHER	NO. OF CONT.	NWTPH-Gx	NWTPH-Dx w/Silica Gel Cleanup	BTEX (8260B)	5 Oxygenates, MTBE, TBA, DIPE, TAME, ETBE (8260B)	EDC (8260B)	EDC (8011)	Total Lead (6020)	PCBs (8082)	PAHs (8070 SIM)	VOCs Full list (8260B)	Pest (8080)	NWTPH-VPH	NWTPH-EPH	n-Hexane (9071B)	Container PID Readings or Laboratory Notes
1	SO-241739-051010-HB-SB-3-5.0	5/10	0828	SO						9	X	X	X												Soil is Standard Turnaround
2	SO-241739-051010-HB-SB-4.-5.0	5/10	0922	SO						9	X	X	X												
3	GW-241739-051110-HB-~~HB~~SB-3	5/11	1060	GW						7	X	X	X												GW are 24hr turnaround
4	GW-241739-051110-HB-SB-4	5/11	1030	GW						7	X	X	X												

Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Heather Boys	Fedex	5-11-10	1315
FEDEX		5/12/10	10:00

05/2/06 Revision

FedEx Express *US Airbill*

FedEx Tracking Number 8653 2796 6447

Form ID No. 0200

Recipient's Copy

rom [redacted]

ate [illegible]

ender's ame [illegible] Phone [illegible]

ompany [illegible]

ddress [illegible]

Dept./Floor/Suite/Room

ity [illegible] State WA ZIP [illegible]

our Internal Billing Reference

o

ecipient's ame Sample Control Phone 714 [illegible]

ompany [illegible]

ecipient's ddress 744 Lincoln Way

cannot deliver to P.O. boxes or P.O. ZIP codes. Dept./Floor/Suite/Room

ddress

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

ty [illegible] State CA ZIP [illegible]

8653 2796 6447

4a Express Package Service

Packages up to 150 lbs.

☒ FedEx Priority Overnight Next business morning.* Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.

☐ FedEx Standard Overnight Next business afternoon.* Saturday Delivery NOT available.

☐ FedEx First Overnight Earliest next business morning delivery to select locations.* Saturday Delivery NOT available.

☐ FedEx 2Day Second business day.* Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.

☐ FedEx Express Saver Third business day.* Saturday Delivery NOT available.

FedEx Envelope rate not available. Minimum charge: One-pound rate.

* To most locations.

4b Express Freight Service

Packages over 150 lbs.

☐ FedEx 1Day Freight* Next business day.** Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.

☐ FedEx 2Day Freight Second business day.** Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.

☐ FedEx 3Day Freight Third business day.** Saturday Delivery NOT available.

* Call for Confirmation:

** To most locations.

5 Packaging

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

* Declared value limit $500.

6 Special Handling

Include FedEx address in Section 3.

☐ **SATURDAY Delivery** Not available for FedEx Standard Overnight, FedEx First Overnight, FedEx Express Saver, or FedEx 3Day Freight.

☐ **HOLD Weekday** at FedEx Location Not available for FedEx First Overnight.

☐ **HOLD Saturday** at FedEx Location Available ONLY for FedEx Priority Overnight and FedEx 2Day to select locations.

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

☒ No ☐ Yes As per attached Shipper's Declaration. ☐ Yes Shipper's Declaration not required. ☐ Dry Ice Dry Ice, 9, UN 1845 ______ x ______ kg

Dangerous goods (including dry ice) cannot be shipped in FedEx packaging. ☐ Cargo Aircraft Only

7 Payment *Bill to:*

Enter FedEx Acct. No. or Credit Card No. below.

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

Obtain Recip. Acct. No. ☐

[redacted] [redacted]

Total Packages	Total Weight	Total Declared Value†	
1	44	$ 0 .00	Credit Card Auth.

†Our liability is limited to $100 unless you declare a higher value. See back for details.

8 Residential Delivery Signature Options

If you require a signature, check Direct or Indirect.

☐ No Signature Required Package may be left without obtaining a signature for delivery.

☐ Direct Signature Someone at recipient's address may sign for delivery. *Fee applies.*

☐ Indirect Signature If no one is available at recipient's address, someone at a neighboring address may sign for delivery. *Fee applies.*

520

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fedex.com 1.800.GoFedEx 1.800.463.3339

0847

Calscience Environmental Laboratories, Inc.

WORK ORDER #: 10-05-0847

SAMPLE RECEIPT FORM

Cooler 1 **of** 1

CLIENT: CRA

DATE: 05/12/10

TEMPERATURE: **Thermometer ID: SC1 (Criteria: 0.0 °C – 6.0 °C, not frozen)**

Temperature 2 . 6 °C + **0.5 °C** (CF) = 3 . 1 °C ☑ **Blank** ☐ **Sample**

☐ Sample(s) outside temperature criteria (PM/APM contacted by: ________).

☐ Sample(s) outside temperature criteria but received on ice/chilled on same day of sampling.

☐ **Received at ambient temperature, placed on ice for transport by Courier.**

Ambient Temperature: ☐ Air ☐ Filter ☐ Metals Only ☐ PCBs Only **Initial:** PS

CUSTODY SEALS INTACT:

☑ Cooler	☐ ____________	☐ No (Not Intact)	☐ Not Present	☐ N/A	**Initial:** PS
☐ Sample	☐ ____________	☐ No (Not Intact)	☑ Not Present		**Initial:** PS

SAMPLE CONDITION:	Yes	No	N/A
Chain-Of-Custody (COC) document(s) received with samples..................	☑	☐	☐
COC document(s) received complete..	☑	☐	☐
☐ Collection date/time, matrix, and/or # of containers logged in based on sample labels.			
☐ No analysis requested. ☐ Not relinquished. ☐ No date/time relinquished.			
Sampler's name indicated on COC..	☑	☐	☐
Sample container label(s) consistent with COC..................................	☐	☑	☐
Sample container(s) intact and good condition..................................	☑	☐	☐
Proper containers and sufficient volume for analyses requested..............	☑	☐	☐
Analyses received within holding time..	☑	☐	☐
pH / Residual Chlorine / Dissolved Sulfide received within 24 hours..........	☐	☐	☑
Proper preservation noted on COC or sample container.........................	☑	☐	☐
☐ Unpreserved vials received for Volatiles analysis			
Volatile analysis container(s) free of headspace..................................	☑	☐	☐
Tedlar bag(s) free of condensation...	☐	☐	☑

CONTAINER TYPE:

Solid: ☐4ozCGJ ☑8ozCGJ ☐16ozCGJ ☐Sleeve (_____) ☐EnCores® ☑TerraCores® 6 ☑60 mL PJ (2)

Water: ☐VOA ☑VOAh 5 ☐VOA**na₂** ☐125AGB ☐125AGB**h** ☐125AGB**p** ☐1AGB ☐1AGB**na₂** ☐1AGB**s**

☐500AGB ☑500AGJ 2 ☐500AGJ**s** ☐250AGB ☐250CGB ☐250CGB**s** ☐1PB ☐500PB ☐500PB**na**

☐250PB ☐250PB**n** ☐125PB ☐125PB**znna** ☐100PJ ☐100PJ**na₂** ☐_______ ☐_________ ☐_______

Air: ☐Tedlar® ☐Summa® **Other:** ☐______ **Trip Blank Lot#:** 100505A **Labeled/Checked by:** PS

Container: C: Clear **A:** Amber **P:** Plastic **G:** Glass **J:** Jar **B:** Bottle **Z:** Ziploc/Resealable Bag **E:** Envelope **Reviewed by:** WSC

Preservative: h: HCL **n:** HNO_3 **na₂:** $Na_2S_2O_3$ **na:** NaOH **p:** H_3PO_4 **s:** H_2SO_4 **znna:** $ZnAc_2$+NaOH **f:** Field-filtered **Scanned by:** PS

Calscience Environmental Laboratories, Inc.

WORK ORDER #: 10-05-0847

SAMPLE ANOMALY FORM

SAMPLES - CONTAINERS & LABELS:

- ☐ **Sample(s)/Container(s) NOT RECEIVED but listed on COC**
- ☑ **Sample(s)/Container(s) received but NOT LISTED on COC**
- ☐ **Holding time expired** – list sample ID(s) and test
- ☐ **Insufficient quantities for analysis** – list test
- ☐ **Improper container(s) used** – list test
- ☐ **Improper preservative used** – list test
- ☐ **No preservative noted on COC or label** – list test & notify lab
- ☐ **Sample labels illegible** – note test/container type
- ☐ **Sample label(s) do not match COC** – Note in comments
  - ☐ **Sample ID**
  - ☐ **Date and/or Time Collected**
  - ☐ **Project Information**
  - ☐ **# of Container(s)**
  - ☐ **Analysis**
- ☐ **Sample container(s) compromised** – Note in comments
  - ☐ **Water present in sample container**
  - ☐ **Broken**
  - ☐ **Without Label(s)**
- ☐ **Air sample container(s) compromised** – Note in comments
  - ☐ **Flat**
  - ☐ **Low in volume**
  - ☐ **Leaking (Not transferred - duplicate bag submitted)**
  - ☐ **Leaking (transferred into Calscience Tedlar® Bag*)**
  - ☐ **Leaking (transferred into Client's Tedlar® Bag*)**
- ☐ **Other:** __________

Comments:

(-5) TB RECEIVED 1 VIALS W/ HCL
NOT ON COC (NO PREP DATE & TIME
PER LABEL).

HEADSPACE – Containers with Bubble > 6mm or ¼ inch:

Sample #	Container ID(s)	# of Vials Received	Sample #	Container ID(s)	# of Vials Received	Sample #	Container ID(s)	# of Cont. received	Analysis

Comments: __________

*Transferred at Client's request.

Initial / Date: PS 05/12/10

APPENDIX G

TERRESTRIAL ECOLOGICAL EVALUATION EXCLUSION FORM

DEPARTMENT OF
ECOLOGY
State of Washington

Voluntary Cleanup Program

Washington State Department of Ecology
Toxics Cleanup Program

TERRESTRIAL ECOLOGICAL EVALUATION EXCLUSION FORM

Under the Model Toxics Control Act (MTCA), a Terrestrial Ecological Evaluation (TEE) is not required if the Site meets the criteria in WAC 173-340-7491 for an exclusion. If you determine that your Site does not require a TEE, please complete this form and submit it to the Department of Ecology (Ecology) at the appropriate time, either with your VCP Application or with a subsequent request for a written opinion. Please note that exclusion from the TEE does not exclude the Site from an evaluation of aquatic or sediment ecological receptors.

If your Site does not meet the criteria for exclusion under WAC 173-340-7491, then you may have to conduct a simplified TEE in accordance with WAC 173-340-7492 or a site-specific TEE in accordance with WAC 173-340-7493. If you have questions about conducting a simplified or site-specific TEE, please contact the Ecology site manager assigned to your Site or the appropriate Ecology regional office.

Step 1: IDENTIFY HAZARDOUS WASTE SITE AND EVALUATOR

Please identify below the hazardous waste site for which you are documenting an exclusion from conducting a TEE and the name of the person who conducted the evaluation.

Facility/Site Name: Former Jiffy Lube Facility No. 171152

Facility/Site Address: 6808 196th Street Southwest, Lynnwood, WA

Facility/Site No: 27496218	VCP Project No.: NW2070

Name of Evaluator: Timothy C. Mullin

Step 2: DOCUMENT BASIS FOR EXCLUSION

The bases for excluding a site from a terrestrial ecological evaluation are set forth in WAC 173-340-7491(1). Please identify below the basis for excluding your Site from further evaluation. Please check all that apply.

POINT OF COMPLIANCE – WAC 173-340-7491(1)(A)

1-☐ No contamination present at site.

2-☐ All contamination is 15 feet below ground level prior to remedial activities.

3-☐ All contamination is six feet below ground level and an institutional control has been implemented as required by WAC 173-340-440.

4-☐ All contamination is below a site-specific point of compliance established in compliance with WAC 173-340-7490(4)(b) with an institutional control implemented as required by WAC 173-340-440. ***Please provide documentation that describes the rationale for setting a site-specific point of compliance.***

BARRIERS TO EXPOSURE – WAC 173-340-7491(1)(b)

5-☐ All contaminated soil, is or will be, covered by physical barriers (such as buildings or paved roads) that prevent exposure to plants and wildlife and an institutional control has been implemented as required by WAC 173-340-440. *An exclusion based on future land use must have a completion date for future development that is acceptable to Ecology.*

Step 2: DOCUMENT BASIS FOR EXCLUSION continued

UNDEVELOPED LAND – WAC 173-340-7491(1)(c)

"Undeveloped land" is land that is not covered by building, roads, paved areas, or other barriers that would prevent wildlife from feeding on plants, earthworms, insects, or other food in or on the soil.

"Contiguous" undeveloped land is an area of undeveloped land that is not divided into smaller areas of highways, extensive paving, or similar structures that are likely to reduce the potential use of the overall area by wildlife.

6-☐ There is less than one-quarter acre of contiguous undeveloped land on or within 500 feet of any area of the Site and any of the following chemicals is present: chlorinated dioxins or furans, PCB mixtures, DDT, DDE, DDD, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, benzene hexachloride, toxaphene, hexachlorobenzene, pentachlorophenol, or pentachlorobenzene.

7-☒ For sites not containing any of the chemicals mentioned above, there is less than one-and-a-half acres of contiguous undeveloped land on or within 500 feet of any area of the Site.

BACKGROUND CONCENTRATIONS – WAC 173-340-7491(1)(d)

8-☐ Concentrations of hazardous substances in soil do not exceed natural background levels as described in WAC 173-340-200 and 173-340-709.

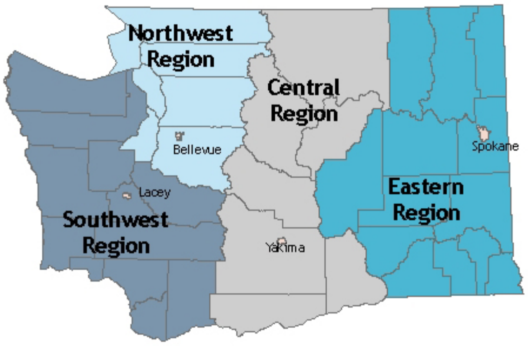
Step 3: PROVIDE EXPLANATION FOR EXCLUSION (IF NECESSARY)

The Site is fully paved with asphalt or concrete. None of the chemicals listed in point 6 (above) are present at the site. Less than 1.5 acres of undeveloped land is on or within 500 feet of any area of the Site.

Attach additional pages if necessary.

Step 4: SUBMITTAL

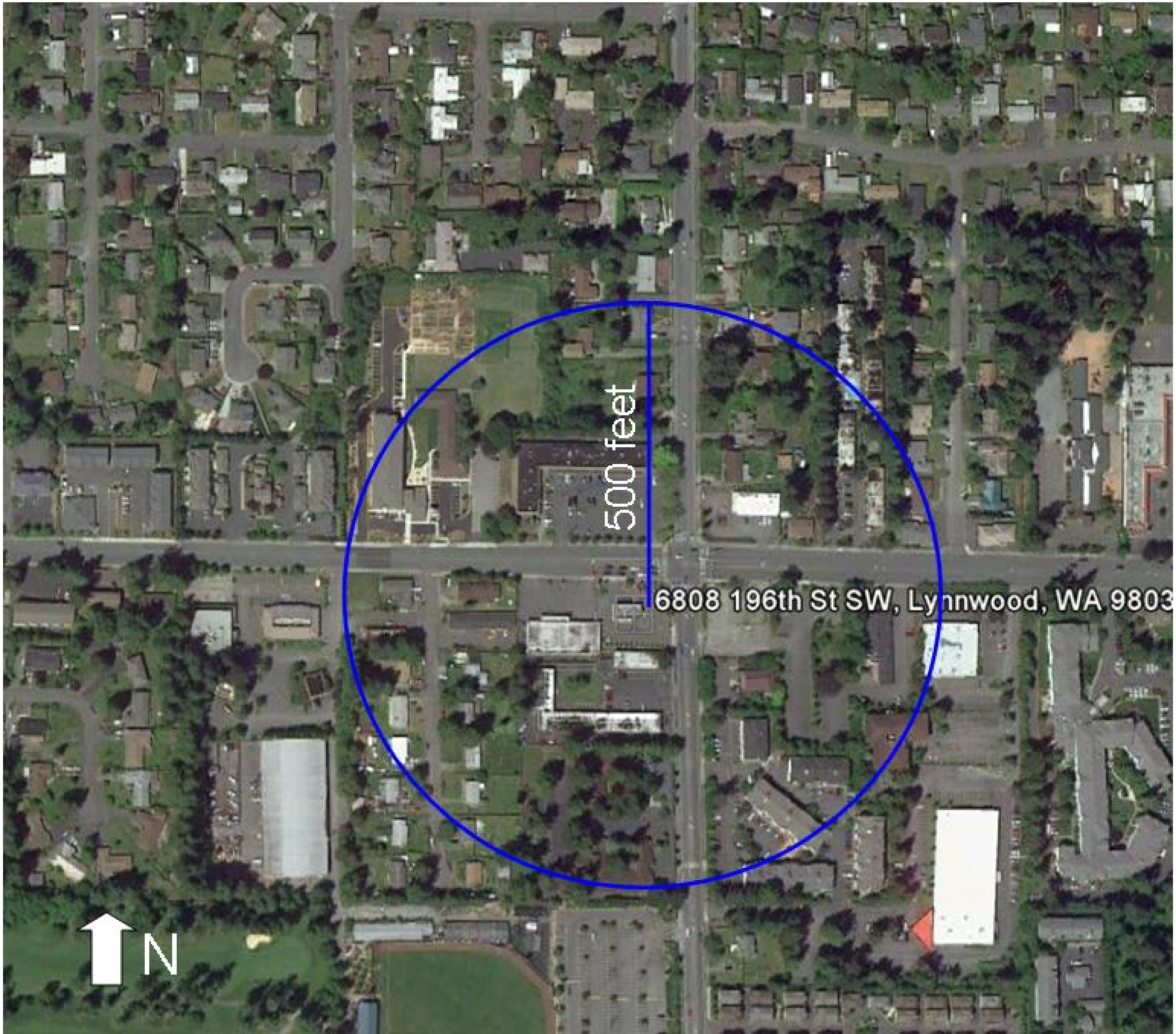
Please mail your completed form to Ecology at the appropriate time, either with your VCP Application or with a subsequent request for a written opinion. If you complete the form after you enter the VCP, please mail your completed form to the Ecology site manager assigned to your Site. If a site manager has not yet been assigned, please mail your completed form to the Ecology regional office for the County in which your Site is located.



Northwest Region: Attn: Sara Maser 3190 160th Ave. SE Bellevue, WA 98008-5452	**Central Region:** Attn: Mark Dunbar 15 W. Yakima Ave., Suite 200 Yakima, WA 98902
Southwest Region: Attn: Scott Rose P.O. Box 47775 Olympia, WA 98504-7775	**Eastern Region:** Patti Carter N. 4601 Monroe Spokane WA 99205-1295

If you need this publication in an alternate format, please call the Toxics Cleanup Program at 360-407-7170. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.

241739(7). TEE aerial with 500 foot radius.



APPENDIX H

SEPARATE PHASE HYDROCARBON FUEL FINGERPRINT ANALYSIS

Shell Global Solutions

Shell Global Solutions (US) Inc.
Westhollow Technology Center
3333 Highway 6 South
Houston, TX 77082-3101
USA
Tel +1 281-544 8215
Fax +1 281-544 8727
Email: Ileana.Rhodes@Shell.com

Carol Campagna
Shell Oil Products US
Carson, California
USA

December 21, 2009

Re: Analysis of Phase Separate Hydrocarbons from MW-3, MW-4 and MW-6 from a Site Located in 6808 196th St., SW, Lynnwood, WA

Dear Carol:

We analyzed samples from MW-3, MW-4 and MW-6 collected 11/5/2009 at a site in Lynnwood, WA. All three samples contain weathered leaded gasoline with a mixture of lead alkyls that were only available from the mid-1960s to the mid-1980s. All samples have partial loss of volatiles and no oxygenates were detected. Table 1 includes a summary of selected target compounds. The chromatograms are shown in Figures 1 – 3. There is no indication of presence any lubricating oils in the sample.

According to historical documents from the City of Lynnwood, this property was developed in 1958 and operated as a Texaco-branded gasoline service station from 1959 to 1977. In 1977, the station building was remodeled and the property was converted to a Speedi-Lube automobile oil change service facility until sometime between 2003 and 2006 when the property became a restaurant. The former service station facilities included a station building, three gasoline underground storage tanks (USTs) located in the northeast corner of the property, two dispenser islands, a heating oil UST, and a waste oil UST. Facilities associated with the former oil change service station included a 500-gallon used oil UST, a 3,000-gallon new oil UST, and two service bays. Both USTs were installed in 1982 and decommissioned in 1995 during a conversion to an aboveground storage tank (AST) system; the used oil UST was abandoned in place and the new oil UST was removed from the Site.

The weathered leaded gasoline found in these wells is unequivocally from releases during the site use as a gasoline service station prior to 1977. Speedi-Lube operations did not dispense or stored gasoline onsite. Releases of waste oil from gasoline engines contain residual gasoline (<10%) but the primary component is the lubricating oil which is totally absent in the samples analyzed.

Figure 4 shows a comparison of chromatograms from analysis of the sample from MW-3 and samples of fresh and used motor oil. Note there is no motor oil detected at all in the sample from

MW-3. The mechanism of fuel transfer into motor oil and fate in with engine operation is described in Figure 5.

Please let me know if you have any questions.

Best regards,

Rhodes

Ileana Rhodes, Ph.D.
Team Lead – Environmental Chemistry

cc Cristin Bruce

Table 1: Selected Target Compounds

			11/5/2009	11/5/2009	11/5/2009
Compound	**Method**	**Units**	**MW-3**	**MW-4**	**MW-6**
Ethanol	GC/MS	wt%	ND(<0.01)	ND(<0.01)	ND(<0.01)
MTBE	GC/MS	wt%	ND(<0.01)	ND(<0.01)	ND(<0.01)
DIPE	GC/MS	wt%	ND(<0.01)	ND(<0.01)	ND(<0.01)
ETBE	GC/MS	wt%	ND(<0.01)	ND(<0.01)	ND(<0.01)
TAME	GC/MS	wt%	ND(<0.01)	ND(<0.01)	ND(<0.01)
Isopentane	GC/FID	wt%	0.90	0.82	1.3
Methylcyclohexane	GC/FID	wt%	2.6	3.0	3.1
Isooctane	GC/MS	wt%	0.15	0.12	0.1
Benzene	GC/MS	wt%	0.88	0.59	0.34
Toluene	GC/MS	wt%	5.2	5.1	4.7
Ethylbenzene	GC/MS	wt%	1.2	1.3	1.3
p&m-Xylene	GC/MS	wt%	5.7	6.0	5.8
o-Xylene	GC/MS	wt%	2.0	2.2	1.9
1,2,4-Trimethylbenzene	GC/FID	wt%	3.4	3.4	3.2
Total Sulfur	XRF	ppm	215	152	127
Total Lead	XRF	g/gallon	0.79	0.22	0.17
Organic Lead	GC/MS	g/gallon	0.68	0.21	0.13

GC/MS: Gas chromatography with mass spectrometry detection

GC/FID: Gas chromatography with flame ionization detection

XRF: X-ray fluorescence

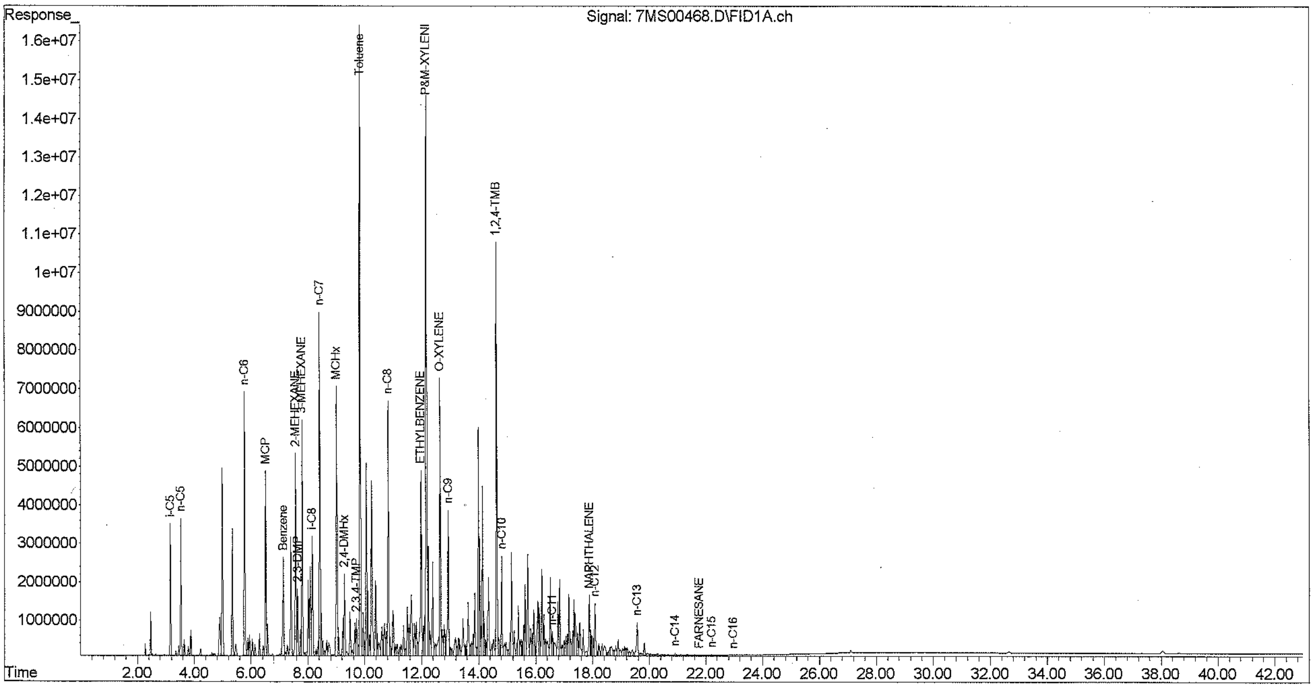


Figure 1: Gas chromatogram from analysis of a sample from MW-3.

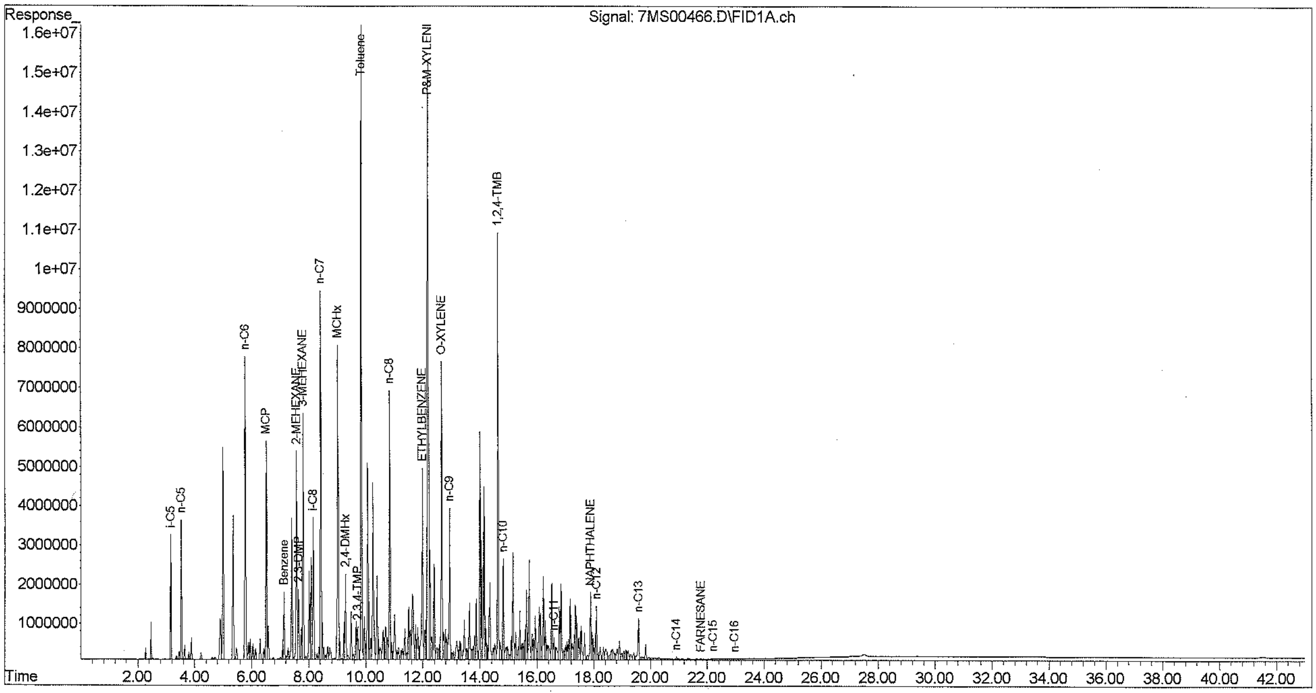


Figure 2: Gas chromatogram from analysis of a sample from MW-4.

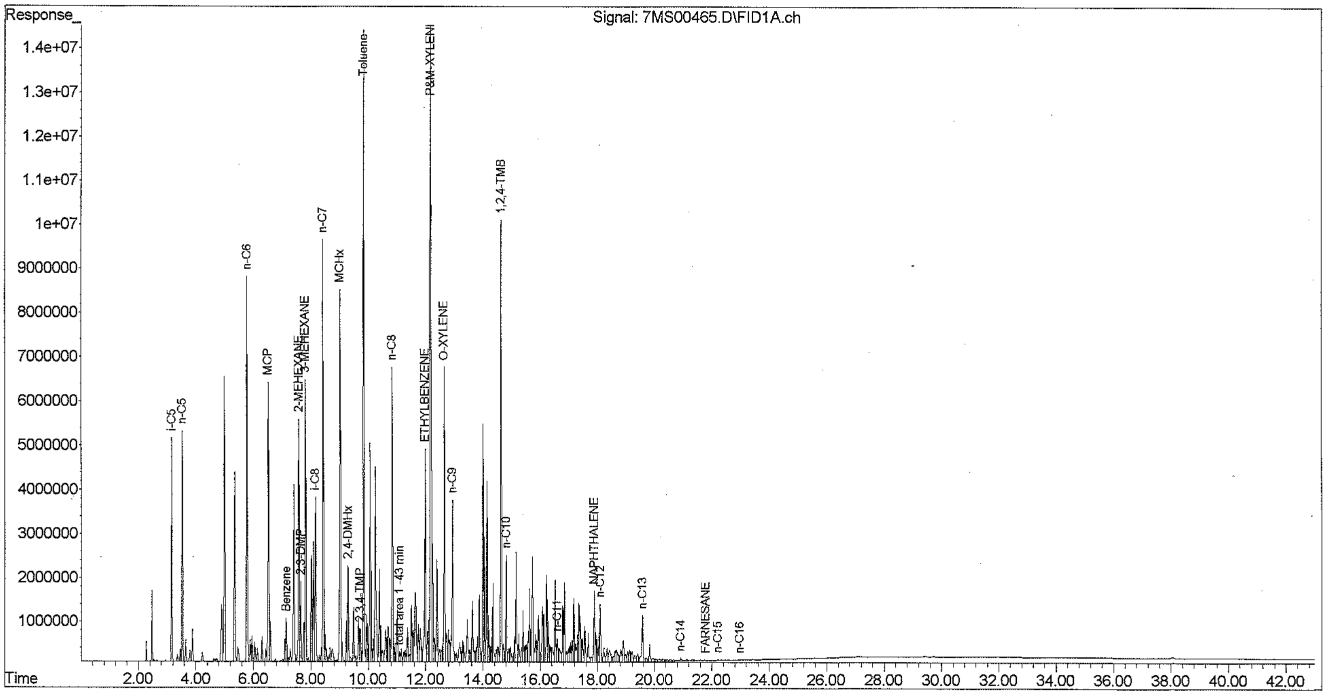
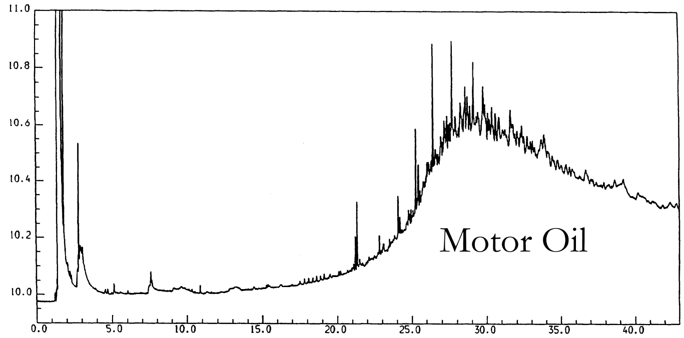
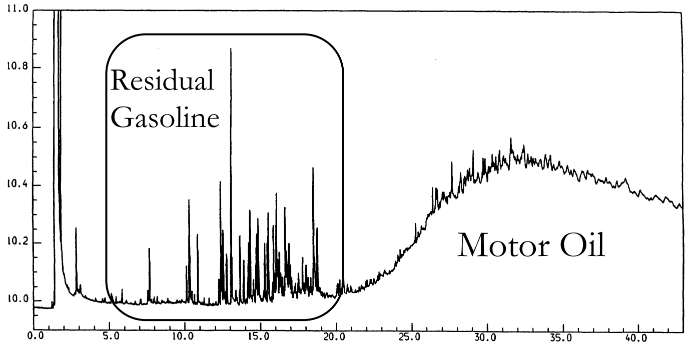


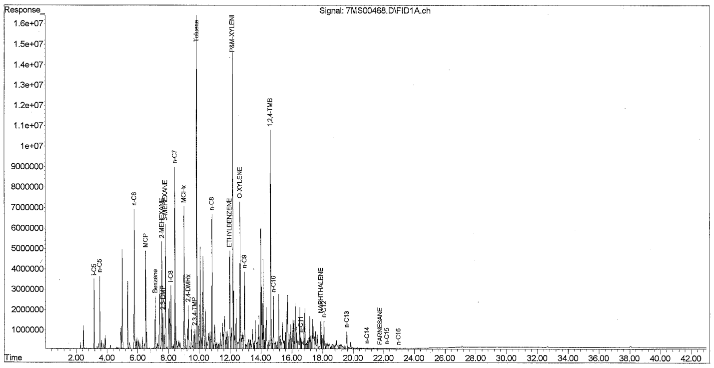
Figure 3: Gas chromatogram from analysis of a sample from MW-6.



Chromatogram from analysis of a sample of unused lubricating motor oill spiked in soil

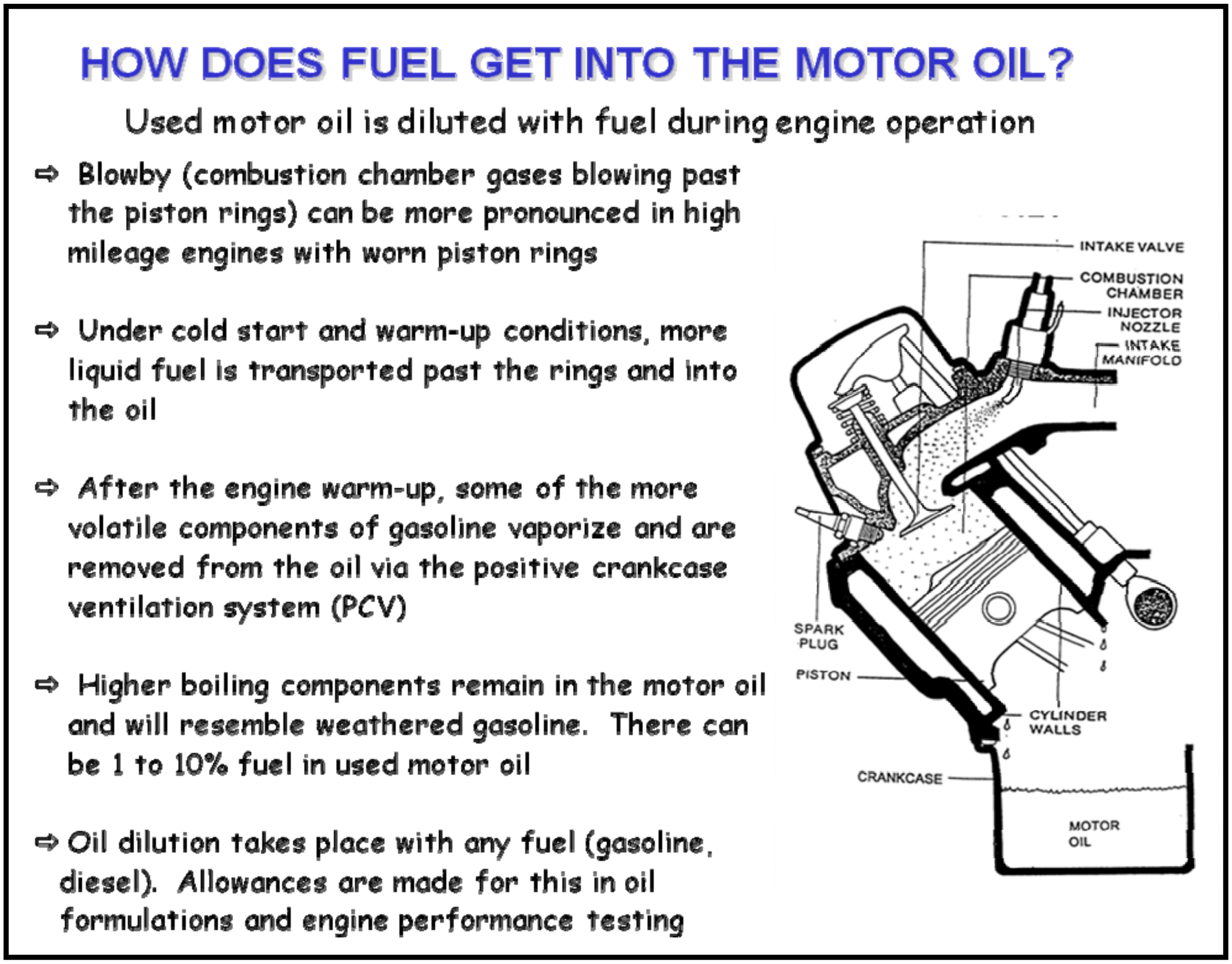


Chromatogram from analysis of a sample of used lubricating motor oil from a test engine



Chromatogram from analysis of a sample from MW-3. No evidence of oil at all.

Figure 4: Comparison of chromatograms from analysis of the sample from MW-3 and samples of fresh and used motor oil. Note there is no motor oil detected at all in the sample from MW-3.



HOW DOES FUEL GET INTO THE MOTOR OIL?

Used motor oil is diluted with fuel during engine operation

⇨ Blowby (combustion chamber gases blowing past the piston rings) can be more pronounced in high mileage engines with worn piston rings

⇨ Under cold start and warm-up conditions, more liquid fuel is transported past the rings and into the oil

⇨ After the engine warm-up, some of the more volatile components of gasoline vaporize and are removed from the oil via the positive crankcase ventilation system (PCV)

⇨ Higher boiling components remain in the motor oil and will resemble weathered gasoline. There can be 1 to 10% fuel in used motor oil

⇨ Oil dilution takes place with any fuel (gasoline, diesel). Allowances are made for this in oil formulations and engine performance testing

Figure 5: Mechanism of fuel transfer into motor oil and fate in with engine operation.

Shell Oil Products Chain Of Custody Record

LAB (LOCATION)
☐ CALSCIENCE ( )
☐ SPL Houston ( )
☐ XENCO ( )
☐ TEST AMERICA ( )
☑ OTHER (Shell, Houston, TX)

Please Check Appropriate Box:
☑ ENV. SERVICES ☐ MOTIVA RETAIL ☐ SHELL RETAIL
☐ MOTIVA SD&CM ☐ CONSULTANT ☐ LUBES
☐ SHELL PIPELINE ☐ OTHER

Print Bill To Contact Name: Carol Campagna
INCIDENT # (ENV SERVICES) 9 7 6 0 5 4 1 0
☐ CHECK IF NO INCIDENT # APPLIES
PO #
SAP # 1 7 1 1 5 2
DATE: 11/5/09
PAGE: 1 of 1

SAMPLING COMPANY: Conestoga-Rovers & Associates
LOG CODE:
ADDRESS: 1420 80th St SW, Suite , Everett, WA 98203
PROJECT CONTACT (Hardcopy or PDF Report to): Justin Foslien
TELEPHONE: 425-212-5100
FAX: 425-212-5199
E-MAIL: jfoslien@craworld.com

SITE ADDRESS: Street and City: 6808 196th St SW, Lynnwood WA
State: WA
GLOBAL ID NO.:
EDF DELIVERABLE TO (Name, Company, Office Location): Diel TM 11/5/09 Christine ~~Schweigert~~, CRA, Everett
PHONE NO.: 425-212-5100
E-MAIL: cdiel TM 11/5/09 ~~cschweigert~~@CRAworld.com
CONSULTANT PROJECT NO.: 241739-2009-2
SAMPLER NAME(S) (Print): Tom Mullen, CRA
LAB USE ONLY

TURNAROUND TIME (CALENDAR DAYS):
☑ STANDARD (14 DAY) ☐ 5 DAYS ☐ 3 DAYS ☐ 2 DAYS ☐ 24 HOURS ☐ RESULTS NEEDED ON WEEKEND

☐ LA - RWQCB REPORT FORMAT ☐ UST AGENCY:

SPECIAL INSTRUCTIONS OR NOTES :

VERY IMPORTANT!!!

See Laboratory PM for WA Dept. of Ecology MTCA Method A cleanup levels for <u>minimum</u> detection limits

☑ SHELL CONTRACT RATE APPLIES
☐ STATE REIMBURSEMENT RATE APPLIES
☐ EDD NOT NEEDED
☑ RECEIPT VERIFICATION REQUESTED

REQUESTED ANALYSIS

TEMPERATURE ON RECEIPT C°

LAB USE ONLY	Field Sample Identification	SAMPLING DATE	SAMPLING TIME	MATRIX	PRESERVATIVE HCL	PRESERVATIVE HNO3	PRESERVATIVE H2SO4	PRESERVATIVE NONE	PRESERVATIVE OTHER	NO. OF CONT.	NWTPH-Gx	NWTPH-Dx w/Silica Gel Cleanup	BTEX (8260B)	5 Oxygenates, MTBE, TBA, DIPE, TAME, ETBE (8260B)	EDC (8260B)	EDC (8011)	Total Lead (6020)	PCBs (8082)	PAHs (8070 SIM)	VOCs Full list (8260B)	Pest (8080)	NWTPH-VPH	NWTPH-EPH	n-Hexane (9071B)	Sulfates						Container PID Readings or Laboratory Notes
	241739-110509-TM-MW-4	11/05/09	1215	LNAPL/AQ	X					1	X	X	X	X			X								X						
	241739-110509-TM-MW-3	|	1230	LNAPL/AQ	X					1	X	X	X	X			X								X						Please run TPHg
	241739-110509-TM-MW-5	|	1245	LNAPL/AQ	X					1	X	X	X	X			X								X						TPHd, TPHo, BTEX
	Trip Blank	—	—	AQ				X			X		X																		5 oxys, Total lead/
																															and sulfates for
																															fingerprint
																															analysis
																															cc: Carol.
																															Campagna@ shell.com

Relinquished by: (Signature)	Received by: (Signature) To FedEx	Date: 11/05/09	Time: 1445
Relinquished by: (Signature)	Received by: (Signature)	Date: 11/6/09	Time: 1315
Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:

05/2/06 Revision

APPENDIX C

Limited Subsurface Sampling and Testing (EAI, 2016a)

LIMITED SUBSURFACE SAMPLING AND TESTING

Chri-Mar Apartments
19618-19624 68th Avenue West
Lynnwood, Washington

MILESTONE PROPERTIES

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue Northeast, Suite 300
Bellevue, Washington 98004
(425) 455-9025 Office
(888) 453-5394 Toll Free
(425) 455-2316 Fax

February 19, 2016 JN-36005

Ms. Rhoda Altom
Milestone Properties
P.O. Box 18379
Seattle, Washington 98118

Subject: **LIMITED SUBSURFACE SAMPLING & TESTING**
Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Dear Ms. Altom:

Environmental Associates, Inc. (EAI) has performed limited sampling and testing of subsurface soils, groundwater, and soil-vapor at selected localities on the subject property. The purpose of this work was to make a preliminary assessment of the potential for the presence of chlorinated volatile organic compounds (cVOCs) and petroleum and associated constituent compounds in subsurface materials potentially relating to a former adjacent dry cleaning operation (Slaters 1 Hour Cleaners) and a former gas station, adjacent to the north of the subject. This report, prepared in accordance with the terms of our proposal dated January 21, 2016, summarizes our approach to the project along with results and conclusions.

The contents of this report are confidential and are intended solely for your use and the use of your representatives. Two (2) copies of this report are being distributed to you. No other distribution or discussion of this report will take place without your prior approval in writing.

We appreciate the opportunity to be of service on this assignment. If you have any questions or if we may be of additional service, please do not hesitate to contact us.

Respectfully submitted,
ENVIRONMENTAL ASSOCIATES, INC.

Don W. Spencer

Don W. Spencer, M.Sc., P.G., R.E.A.
Principal

License: 604	(Washington)
License: 11464	(Oregon)
License: 876	(California)
License: 5195	(Illinois)
License: 0327	(Mississippi)

Hydrogeologist
604
DON W. SPENCER

LIMITED SUBSURFACE SAMPLING AND TESTING

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Prepared for:

Milestone Properties
P.O. Box 18379
Seattle, Washington 98118

Questions regarding this investigation, the conclusions reached and the recommendations given should be addressed to one of the following undersigned.

Eric Zuern
Environmental Geologist / Project Manager

Don W. Spencer, M.Sc., P.G., R.E.A.
Principal

License: 604	(Washington)
License: 11464	(Oregon)
License: 876	(California)
License: 5195	(Illinois)
License: 0327	(Mississippi)

State of Washington
Hydrogeologist
604
Licensed Geologist
DON W. SPENCER

Reference Job Number: JN 36005

February 19, 2016

ENVIRONMENTAL ASSOCIATES, INC.

TABLE OF CONTENTS

INTRODUCTION/SCOPE OF WORK

SITE/PROJECT DESCRIPTION

The subject property is comprised of two (2) rectangular-shaped parcels (tax parcel numbers 27042000201000, 27042000200900) covering approximately 1.41 acres of land. The property is currently occupied by four (4) two-story apartment buildings constructed between 1962 and 1963. The approximate location of the site is shown on the Vicinity/Topographic Map, Plate 1, appended herewith.

Background

Milestone Properties presented EAI with a report summarizing the findings of a Phase I Environmental Site Assessment for the subject prepared by Cardno ATC (Cardno) for the subject site dated March 22, 2015. That report identified a former lube shop/gas station adjacent to the northeast portion of the property (currently a café) which has reported releases of petroleum products and associated constituents to the Washington Department of Ecology (WDOE) in the past as well as a north adjacent dry cleaning operation which reportedly utilized perchloroethene (PCE/PERC). Those two off-site operations were considered "recognized environmental conditions" (RECs) associated with the subject property. Cardno recommended subsurface investigation of the subject to characterize potential impacts from those off-site facilities.

While not noted directly as a concern to the site, EAI's review of materials presented in Cardno's report revealed another off-site gas station historically located across 68th Avenue West, northeast of the subject site in an inferred up-gradient hydrologic position.

Between the publication date of the Phase I report (March 22, 2015) and EAI's proposal date (January 21, 2016), the adjacent northern dry cleaner appears to have vacated its tenant space however signage and the empty unit revealed its location.

Current Study

Your expressed interests to conduct a preliminary evaluation of subsurface conditions to assess the potential for the presence of petroleum and volatile organic compounds as memorialized in EAI's proposal dated January 21, 2016, formed the basis for the following scope of work:

- Drilled and sampled five (5) borings along the northern accessible portions of the property. Soil and groundwater samples were obtained from each boring and a log of subsurface conditions encountered was prepared for each boring by the EAI project geologist. Soil-vapor was collected at two of the boring locations at shallow depths below the asphalt surface. Prior to drilling, a Health & Safety Plan was reviewed and signed by the on-site driller and project manager.

- Laboratory analysis of selected soil, groundwater, or soil-vapor samples for volatile organic compounds and petroleum products typical of dry cleaning operations and gas stations.

- Preparation of this summary report documenting the methodology and results of the investigation.

FINDINGS

SUBSURFACE INVESTIGATION

Soil Boring Sampling

Five (5) soil borings were made on February 4, 2016 at the approximate locations identified as B-1, B-2, B-3, B-4, and B-5 on the attached Site Plan, Plate 2. The logs appear as Plates 3 through 7 in the back of this report. Borings B-1 and B-2 were placed along the western half of the northern property line near to or directly behind the former off-site dry cleaning business. Boring B-3 was placed along a northern gated area between the off-site dry cleaner and gas station. Due to limited access and caution regarding water lines potentially extending along the narrow exterior access along the northeastern on-site building addressed at 19618 68th Ave. West, borings B-4 and B-5 were installed south of building 19618, generally south/downgradient, south of the historic north adjacent gas station. The borings were extended to a depths between 10 to 17.5 feet below ground surface (bgs). Groundwater was not initially encountered in borings B-1 and B-2, thus both borings were left open for a period of time to allow for groundwater to gradually infiltrate as controlled by local permeability and available head. Groundwater was found in B-3 and B-5 between 4 to 5 feet bgs. Groundwater at B-4 was encountered at approximately 9.5 feet.

Soil and Groundwater Sampling Procedure

Under the observation of the EAI field geologist, a truck mounted push-robe drill rig was brought into position over each selected boring location. Following set-up preparations, the push-probe boring/sampling technique consisted of advancing a five (5) foot length plastic lined sampler into the ground. The sampler was then withdrawn and the liner was removed and cut open for examination and transfer of the soil sample to laboratory prepared glassware. Soil samples were collected by EPA Method 5035A.

After soil sampling within the borings had been completed and as groundwater was observed in the borings, a temporary well screen was installed in an attempt to sample the groundwater. Small plastic tubing was extended from a peristaltic pump into each well to recover groundwater samples.

Soil and groundwater samples were transferred from the sampler directly to sterilized laboratory prepared glassware which were then stored in an iced chest maintained at approximately 4 degrees centigrade at the site and taken to the laboratory in this condition in an effort to preserve sample integrity.

Each sample container was clearly labeled as to boring and sample number/depth, date, time, project, etc. EPA-recommended sample-management protocol was observed at each stage of the project. During drilling, a field log was made by EAI for each boring. Information recorded versus corresponding depth included soil classification (Unified Soil Classification System), color, texture, relative moisture, odors (if present), etc.

Soil-Vapor Sampling Procedure

Upon reaching the allowable depths of between 2 to 5 feet bgs at localities B-1 and B-3, soil vapor samples were collected through a temporary screen and casing rod inserted into the ground by the drill rig. Hydrated bentonite clay was used to seal the annulus of the bore hole around the upper casing rod to inhibit dilution from of atmospheric air in the soil vapor sample. A laboratory-prepared "summa canister" (vacuum cylinder) was then utilized to collect a sample of the subsurface soil-vapor at the specified locations. Utilizing flow controllers and gauge-vacuum provided by Eurofins Air Toxics of California, soil-vapor was collected over a span of thirty minutes to over an hour.

Each sample container was clearly labeled as to sample number/location, date, time, project, etc. EPA-recommended sample-management protocol was observed at each stage of the project.

Subsurface Conditions

Generally interpreted as glacial till, soils encountered within the borings generally consisted of a mixture of sand, silts, and gravels with the subsurface matrix becoming denser with increasing depth. As mentioned previously, potentially owing to low permeability, groundwater was not initially encountered in borings B-1 and B-2. Both of these were left open for a period of time to allow for groundwater to gradually infiltrate the borings. Groundwater was found in B-3 and B-5 between 4 to 5 feet bgs. Groundwater at B-4 was encountered at approximately 9.5 feet.

LABORATORY ANALYSIS

Laboratory analysis of soil and groundwater samples was conducted by Environmental Service Network (ESN), Olympia, Washington, a WDOE-accredited analytical laboratory. Select soil and groundwater samples were submitted for analysis of chlorinated volatile organic compounds (VOCs) gasoline, diesel, and heavy oil range petroleum hdyrocarbons as well as benzene, toluene, ethylbenzene, and xylenes (BTEX). Laboratory analysis of soil-vapor samples was conducted by Eurofins Air Toxics of California. Laboratory analysis was performed on each soil vapor sample for VOCs by EPA Method TO-15

As summarized in Table 1 attached to this report, select soils sampled from each boring contained no detectable concentrations of petroleum products or BTEX (benzene, toluene, ethylbenzene, xylenes) compounds.

As depicted in Table 2 appended to this report, groundwater from each boring also contained no detectable concentrations of petroleum products or BTEX (benzene, toluene, ethylbenzene, xylenes) compounds.

As summarized in Table 3, attached to this report, soil sampled from B-2 at a depth of 15 feet bgs contained concentrations of perchloroethene (PCE/PERC) at 0.095 parts per million (ppm) which is above the MTCA Method-A compliance limit of 0.05 ppm. Soil sampled from B-3 at a depth of 5 feet bgs contained PCE at a concentration of 0.031, below (i.e. compliant with) the MTCA Method-A cleanup level while soil sampled at a greater depth at that locality (B-3) at 15 feet bgs contained PCE at 0.10 ppm, above its compliance limit.

As shown in Table 4 appended to this report, Groundwater sampled from B-2 contained PCE at a concentration of 14 parts per billion (ppb) while groundwater sampled from B-3 detected PCE at 35 ppb. Those concentrations are above the MTCA Method-A compliance limit for that analyte in groundwater, currently established at 5 ppb. Trichloroethene (TCE), a degradation product of PCE, was detected in groundwater from B-3 at 5.3 ppb, slightly above the established Method-A cleanup limit for that analyte (currently established at 5 ppb). Finally, (cis) 1,2 Dichloroethene, another degradation product of PCE was found at 1 ppb in B-3, well below (i.e. compliant with) its current Method-B cleanup limit (16 ppb).

As shown in Table 5 appended to this report, results of soil-vapor testing from borings B-1 and B-3 revealed detections of benzene at 48 and 59 ug/m^3 respectively as well as 1,3-butadiene at 59, and 160 ug/m^3 respectively which are above the MTCA Method B screening levels for those analytes listed in the 2015-dated guidance table document published by the Washington Department of Ecology. Additionally, PCE and TCE were detected in soil-vapor at B-3 at 38 and 20 ug/m^3 respectively. While that PCE concentration is below its applicable MTCA Method-B screening level, the concentration of TCE is above its applicable screening limit. Other detections of various analytes encountered which do not have established soil vapor screening levels or were compliant with published levels within the samples are depicted in the attached laboratory data.

CONCLUSIONS

Relying upon the results of limited soil, groundwater, and soil-vapor sampling and laboratory testing documented in this preliminary effort, PCE was found above its applicable MTCA Method-A cleanup level in soils and groundwater at boring locations B-2 and B-3. TCE was also encountered in groundwater at B-3 above its applicable MTCA Method-A cleanup limit. Finally, benzene, 1,3-butadiene, and TCE were observed in various soil-vapor samples at concentrations above their applicable MTCA

PCE and its associated degradation product TCE are typically utilized as dry cleaning solvents. Acknowledging that work performed by others confirmed the use of PCE at the former adjacent dry cleaning facility and that locations B-2 and B-3 are located directly behind or near the former cleaner, it would be reasonable to infer that on-site impacts by chlorinated solvents may have originated at the former adjacent dry cleaning operation.

Additionally, acknowledging the documented historic petroleum release at the north-adjacent former gas station, the detection of benzene in soil-vapor appears to likely relate to that documented release. Detections in soil-vapor for 1,3-butadiene are generally related to wood or diesel fuel combustion and that analyte is monitored by the Puget Sound Clean Air Agency as a background low-level contaminant in the Puget Sound region. Detections of 1,3-butadiene found in on-site soil-vapor were present at concentrations generally higher than listed background levels. The exact source of the 1,3-butadiene detections remains unknown at this time.

Recommendations

While the detections of chlorinated solvents in soils and groundwater adjacent to the northern property line indicate an off-site source, the horizontal and vertical extent of on-site impacts currently remain undefined. Such definition was not envisioned as part of this initial limited scope sampling and testing work. If further delineation of the on-site impacts is desired by the client and/or other involved parties, additional soil and groundwater sampling should be performed to evaluate the extent of chlorinated solvent impacts.

Acknowledging that certain provisions of Washington law (RCW 70.105D.020, par. (12), sec. (iii), et seq, often referenced as the "plume clause" provide exemption from liability to a property owner for cleanup costs relating to water-borne contaminants migrating onto a site from off-site source(s), the noted clause does little to mitigate such problems as potential risks to public health or the environment, nor does it ameliorate potential "impacts" to property valuation on a comparative basis to similar properties not affected by such environmental issues. Recognizing the potential complexities which often attend situations such as this, the following actions may provide a useful framework potentially leading (at some point) toward productive resolutions:

- At such time as on-site impacts are characterized to the extent practicable, property ownership may wish to consider formal disclosure of these findings to owners/operators of the north-adjacent site(s) so that they may be apprised of this discovery in a timely manner. Such communication(s) may benefit substantially from use of appropriate legal counsel familiar with adjudication of environmental liability matters.

- Provisions of the Model Toxics Control Act (MTCA), Chapter 173-340 -300 require "any owner or operator" who has information that a hazardous substance has been released to the environment ...... and may be a threat to human health or the environment" shall report such information to the department (WDOE) within ninety (90) days of discovery.

- As the north-adjacent former gas station property appears to have some reporting history relating to releases, transmittal of new information as discussed in the current report may be useful to WDOE so as to enable them to fulfill their obligations as to protection of health and environment.

- With respect to the recently ceased north-adjacent dry cleaner operation, as no listings suggestive of releases for that operation were discovered in the databases reviewed, disclosure of the current findings to WDOE would potentially represent the first notice that operator might receive with respect to the discovery of dry cleaning solvent (perchloroethylene/PCE) in the subsurface environment.

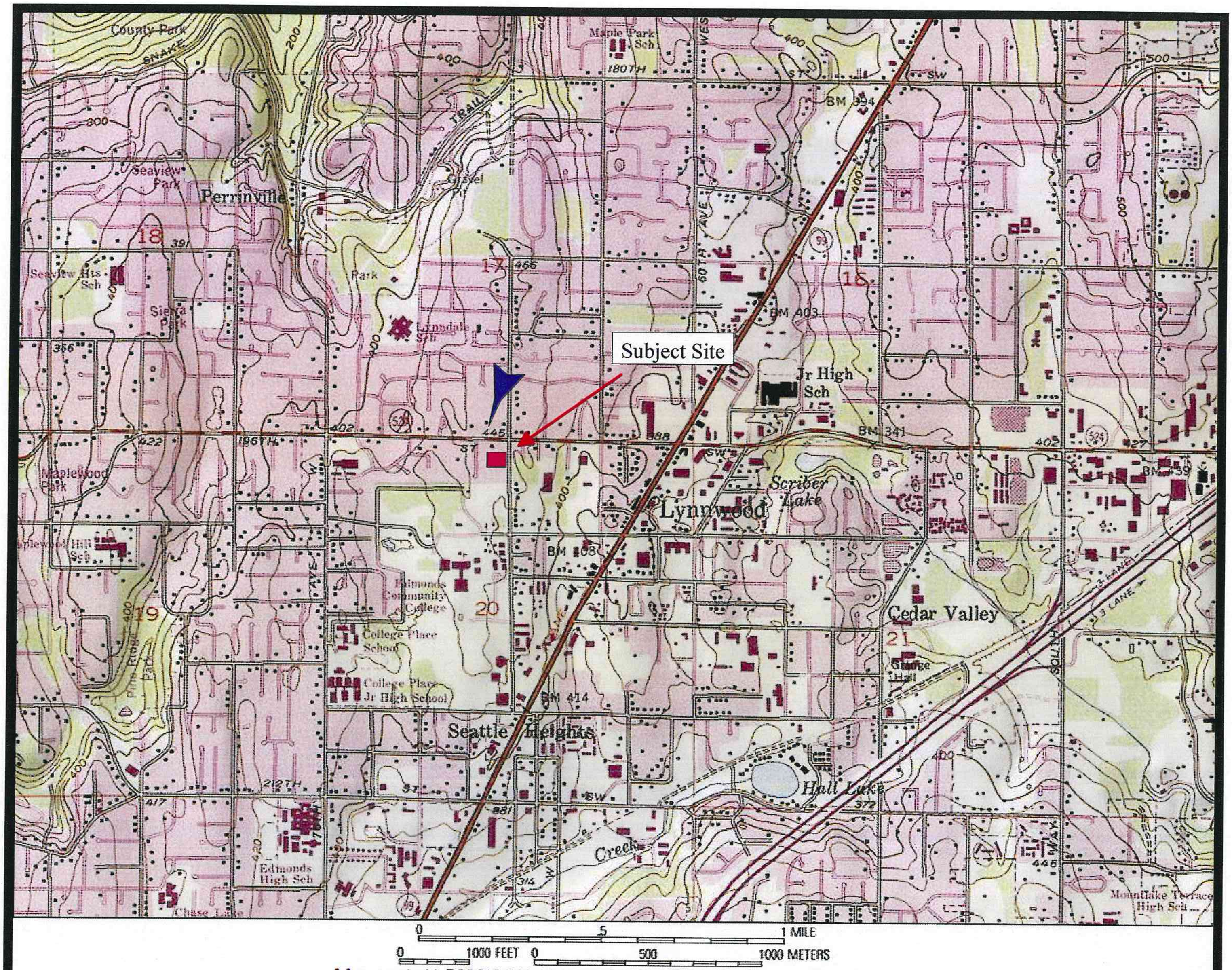
Finally, in an effort to determine whether soil-vapor impacts may potentially affect on-site residential tenants, indoor and outdoor air sampling should be conducted to assess whether soil-vapors are (or are not) migrating through building foundations and potentially accumulating in occupied areas. Outdoor samples would be collected and tested in an effort to compare outdoor "ambient" conditions relative to indoor measurements.

LIMITATIONS

This report has been prepared for the exclusive use of Milstone Properties along with Chase Bank (Lender) and their several representatives for specific application to this site. Our work for this project was conducted in a manner consistent with that level of care and skill normally exercised by members of the environmental science profession currently practicing under similar conditions in the area, and in accordance with the terms and conditions set forth in our proposal dated January 21, 2016. The findings and conclusions of this study are based upon the results of laboratory testing of selected samples obtained from separated boring localities and conditions may vary between those locations or at other locations, media, depths, or date. No other warranty, expressed or implied, is made. If new information is developed in future site work which may include excavations, borings, studies, etc., Environmental Associates, Inc., must be retained to reevaluate the conclusions of this report and to provide amendments as required.

REFERENCES

Cardno ATC, March 22, 2015, Phase I Environmental Site Assessment, 19618-19624 68th Avenue West, Lynnwood, Washington.



Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

🟥 **Site Location**

➤ **Inferred Approximate Direction of Groundwater Flow at Subject**

N

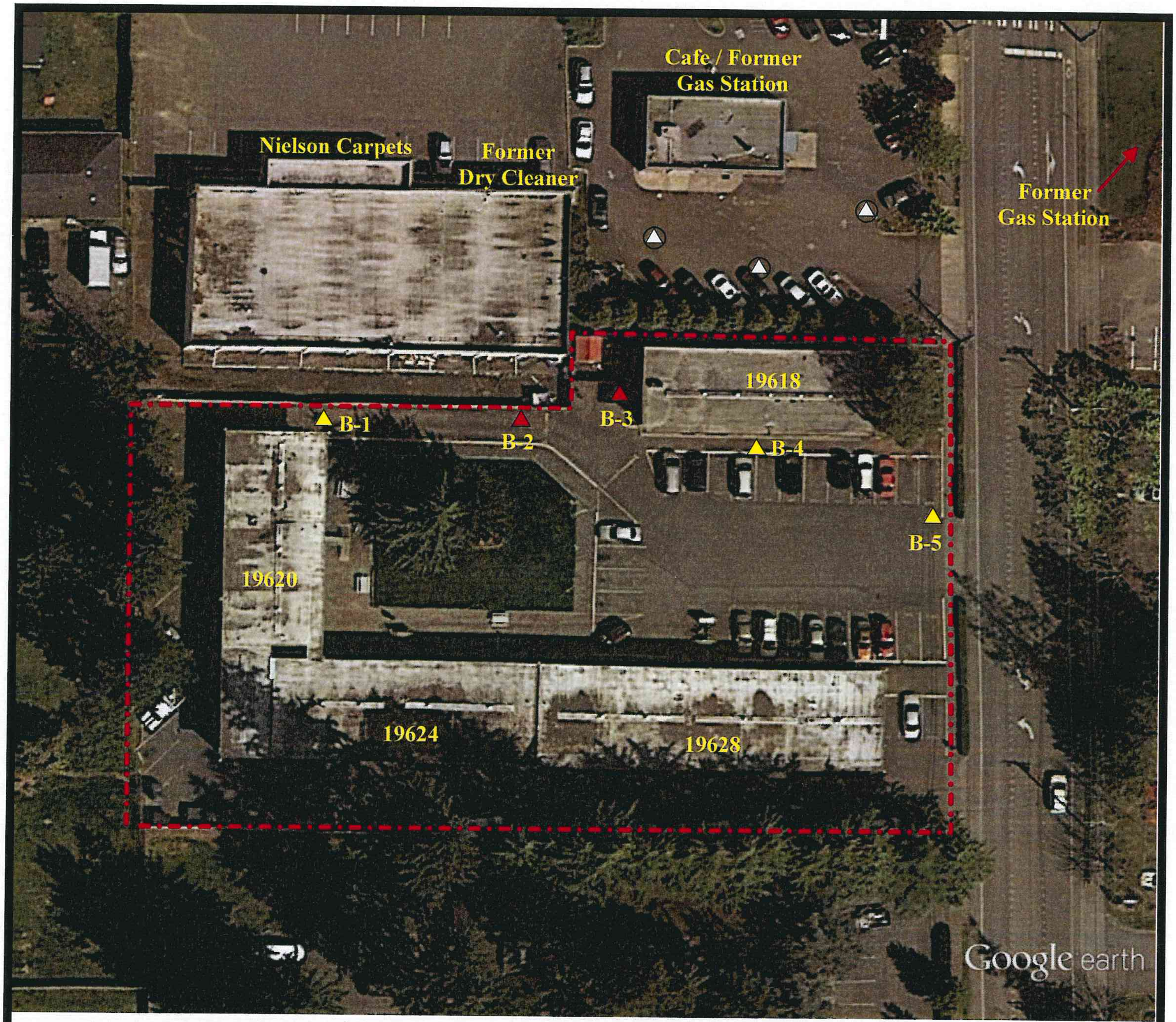
ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

VICINITY/TOPOGRAPHIC MAP

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number: JN 36005	*Date:* February 2016		*Plate:* 1



◬ Approximate Monitoring Well Locations

▲ ▲ Approximate Boring Locations (yellow=compliant, red=non-compliant)

▭ Approximate Site Boundary

➤ Inferred Approximate Direction of Groundwater Flow at Subject

N

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

SITE PLAN

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	*Date:*		*Plate:*
JN 36005	February 2016		2

BORING B1

Depth/ Sample	Well Design	Moisture/ Water Table	Blows / Foot	USCS	DESCRIPTION
0					
5	None	Dry		GM	Brown silt and gravels, dry, no odors or discoloration, PID=0
10		Moist		SP	Brown/grey sand and cobbles, moist, no odors or discoloration, PID=0
15		Moist		GM	Grey compact silt and gravels, moist, no odors or discoloration, PID=0.3
		Dry		SM	Grey silt, sand, and gravels, dry, no odors or discoloration, PID=0.2
					Boring refusal at 17.5 feet below grade on February4, 2016.
20					
25					
30					
35					
40					

Hammer Weight: N/A
Driller: Environmental Services Network, Inc.

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

Boring: B1

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	Date:	Logged by:	Plate:
JN 36005	February 2016	EAZ	3

BORING B2

Depth/ Sample	Well Design	Moisture/ Water Table	Blows / Foot	USCS	DESCRIPTION
0					
5	None	Dry		SM	Brown silt, sand, and gravels, dry, no odors or discoloration, PID=0.2
10		Dry		GM	Grey silt and gravels, dry, no odors or discoloration, PID=0.2
15		Dry		SM	Grey/brown dense sand, silt, and gravels, dry, no odors or discoloration, PID=0.3
					Boring terminated at 15 feet below grade on February4, 2016.
20					
25					
30					
35					
40					

Hammer Weight: N/A
Driller: Environmental Services Network, Inc.

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

Boring: B2

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	Date:	Logged by:	Plate:
JN 36005	February 2016	EAZ	4

BORING B3

Depth/ Sample	Well Design	Moisture/ Water Table	Blows / Foot	USCS	DESCRIPTION
0					
		▽			
5 ☐	None	Wet		GM	Brown silt and gravels, wet, no odors or discoloration, PID=0.3
10 ☐		Moist		SM	Brown sand, silt, and gravels, moist, no odors or discoloration, PID=0.2
15 ☐		Moist		SM	Brown sand, silt, and gravels, moist, no odors or discoloration, PID=0.5
					Boring terminated at 15 feet below grade on February4, 2016.
20					
25					
30					
35					
40					

Hammer Weight: N/A
Driller: Environmental Services Network, Inc.

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

Boring: B3

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	*Date:*	*Logged by:*	*Plate:*
JN 36005	February 2016	EAZ	5

BORING B4

Depth/ Sample	Well Design	Moisture/ Water Table	Blows / Foot	USCS	DESCRIPTION
0					
5 ☐	None	Dry		SM	Dark brown silt, sand, and gravels, dry, no odors or discoloration, PID=0.5
10 ☐		▽ Moist		SW	Grey sands and gravels, moist, no odors or discoloration, PID=0.3
15 ☐		Wet		SM	Brown sand, silt, and gravels, wet, no odors or discoloration, PID=0.3
					Boring terminated at 15 feet below grade on February4, 2016.
20					
25					
30					
35					
40					

Hammer Weight: N/A
Driller: Environmental Services Network, Inc.

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

Boring: B4

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	Date:	Logged by:	Plate:
JN 36005	February 2016	EAZ	6

BORING B5

Depth/ Sample	Well Design	Moisture/ Water Table	Blows / Foot	USCS	DESCRIPTION
0					
5 ☐	None	▽ Moist		ML	Brown silt (fill), moists, no odors or discoloration, PID=0.3
10 ☐		Dry		SM	Grey silt, sands, and gravels, wet, no odors or discoloration, PID=0.3
					Boring terminated at 10 feet below grade on February4, 2016.
15					
20					
25					
30					
35					
40					

Hammer Weight: N/A
Driller: Environmental Services Network, Inc.

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

Boring: B5

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	Date:	Logged by:	Plate:
JN 36005	February 2016	EAZ	7

TABLE 1 - Petroleum Hydrocarbons and BTEX - Soil Sampling Results
All results and limits in parts per million (ppm)

Strataprobe Boring	Gasoline (TPH)	Diesel	Heavy Oil	Benzene	Toluene	Ethylbenzene	Total Xylenes
B1-15 @ 15'	ND	ND	ND	ND	ND	ND	ND
B1-15 @ 15' DUPLICATE	NA	ND	ND	NA	NA	NA	NA
B2-15 @ 15'	ND	ND	ND	ND	ND	ND	ND
B2-15 @ 15' DUPLICATE	ND	NA	NA	ND	ND	ND	ND
B3-5 @ 5'	ND	ND	ND	ND	ND	ND	ND
B4-10 @ 10'	ND	ND	ND	ND	ND	ND	ND
B5-10 @ 10'	ND	ND	ND	ND	ND	ND	ND
Reporting Limit [3]	10	50	100	0.02	0.05	0.05	0.15
WDOE Target Compliance Level[4]	**30 or 100 [5]**	**2000**	**2000**	**0.03**	**7**	**6**	**9**

Notes:
1 - "ND" denotes analyte not detected at or above listed Reporting Limit.
2- "NA" denotes sample not analyzed for specific analyte.
3- "Reporting Limit" represents the laboratory lower quantitation limit.
4- Soil samples were field screened using a GasTech combustible gas meter to measure the concentration of combustible gas, such as petroleum VOCs. Headspace VOC concentrations were measured after placing the soil sample in a sealed plastic bag and allowing soil and air inside the bag to equilibrate.
5- The MTCA gasoline TPH cleanup level is 30 ppm for soils with benzene otherwise it is 100 ppm.

Bold and Italics denotes concentrations above MTCA Method A soil cleanup levels.

BGS - Below ground surface.

TABLE 2- Petroleum Hydrocarbons and BTEX- Groundwater Sampling Results
All results and limits in parts per billion (ppb)

Strataprobe Boring	Gasoline (TPH)	Diesel (TPH)	Heavy Oil (TPH)	Benzene	Toluene	Ethylbenzene	Total Xylenes
B1-Water	ND	ND	ND	ND	ND	ND	ND
B2-Water	ND	ND	ND	ND	ND	ND	ND
B3-Water	ND	ND	ND	ND	ND	ND	ND
B4-Water	ND	ND	ND	ND	ND	ND	ND
B5-Water	ND	ND	ND	ND	ND	ND	ND
Reporting Limit [3]	100	250	500	1	1	1	3
MTCA-Method-A Cleanup Levels[4]	**800 or 1000[5]**	**500**	**500**	**5**	**1000**	**700**	**1000**

Notes:

1 - "ND" denotes analyte not detected at or above listed Reporting Limit.
2- "NA" denotes sample not analyzed for specific analyte.
3- "Reporting Limit" represents the laboratory lower quantitation limit.
4- Method A groundwater cleanup levels as published in the Model Toxics Control Act (MTCA) 173-340-WAC.
5- The MTCA gasoline TPH cleanup level is 800 ppb for groundwater with benzene. Otherwise, the cleanup level is 1000 ppb.

Bold and Italics denotes concentrations above existing or proposed MTCA Method A groundwater cleanup levels.

TABLE 3- VOCs - Soil Sampling Results
All results and limits in parts per million (ppm)

Strataprobe Boring	Tetrachloroethene (PCE)	Trichloroethene (TCE)	(cis) 1,2 Dichloroethene	(trans) 1,2 Dichloroethene	Vinyl Chloride
B1-15 @ 15'	ND	ND	ND	ND	ND
B2-15 @ 15'	***0.095***	ND	ND	ND	ND
B3-5 @ 5'	0.031	ND	ND	ND	ND
B3-15 @ 15'	***0.10***	ND	ND	ND	ND
B4-10 @ 10'	ND	ND	ND	ND	ND
Reporting Limit [3]	0.02	0.02	0.05	0.05	0.02
Cleanup Level for Unrestricted Land Use (Method-A)[4]	0.05	0.03	---	---	---
Cleanup Level - (Method-B)[5]	476	12	160	1600.0	0.667

Notes:

1 - "ND" denotes analyte not detected at or above listed Reporting Limit.

2- "NA" denotes sample not analyzed for specific analyte.

3- "Reporting Limit" represents the laboratory lower quantitation limit.

4- Method A soil cleanup levels for unrestricted land use as published in the Model Toxics Control Act (MTCA) 173-340-WAC, Table 740-1.

5- Method-B soil cleanup levels for the "direct contact pathway", as published in Ecology's CLARC May 2014 database.

Bold and Italics denotes concentrations above existing MTCA Method A or B soil cleanup levels.

TABLE 4- VOCs - Groundwater Sampling Results
All results and limits in parts per billion (ppb)

Boring	Tetrachloroethene (PCE)	Trichloroethene (TCE)	(cis) 1,2 Dichloroethene	(trans) 1,2 Dichloroethene	Vinyl Chloride
B1-Water	ND	ND	ND	ND	ND
B2-Water	***14***	ND	ND	ND	ND
B3-Water	***35***	***5.3***	1	ND	ND
B4-Water	ND	ND	ND	ND	ND
B5-Water	ND	ND	ND	ND	ND
Reporting Limit [3]	1	1	1	1	0.2
Existing Cleanup Level[4]	5 (A)	5 (A)	16 (B)	160 (B)	0.2 (A)

Notes:
1 - "ND" denotes analyte not detected at or above listed Reporting Limit.
2- "NA" denotes sample not analyzed for specific analyte.
3- "Reporting Limit" represents the laboratory lower quantitation limit.
4- Method A or B groundwater cleanup levels as published in the Model Toxics Control Act (MTCA) 173-340-WAC, amended May 2014.

Bold and Italics denotes concentrations above existing MTCA Method A groundwater cleanup levels.

TABLE 5 - Select VOCs - Soil Vapor Sampling Results
All results and limits in micro-grams per cubic meter (ug/M^3)

Sample Name	Location & Depth	Tetrachloroethene (PCE)	Trichloroethene (TCE)	1,1,1 Trichloroethane	1,1 Dichloroethene	Vinyl Chloride	Benzene	1, 3-Butadiene
B-1	B-1 @ 5 feet	ND	ND	ND	ND	ND	***48***	***59***
B-3	B-3 @ 2.5 feet	38	***20***	ND	ND	ND	***59***	***160***
WDOE - Soil Gas Screening Levels[4]		321	12.3	76,200	3,050	9.33	10.7	2.78

Notes:
1 - "ND" denotes analyte not detected at or above listed Reporting Limit.
2- "NA" Not applicable.
3- "Reporting Limit" represents the laboratory lower quantitation limit.
4 - Soil gas screening level that concentrations in the soil gas just beneath a building expected to not result in exceedance of the air cleanup level in the overlying structure, per the WDOE's Guidance For Evaluating Soil Vapor Intrusion - (April, 2015).

Bold and Italics indicate concentrations of soil vapor that exceed the WDOE soil gas screening level and/or concentrations that exceed the WDOE Standard Method-B Air Target Compliance Levels.

APPENDIX A

Lab Reports

ESN NORTHWEST, INC. Environmental Services Network

CHAIN-OF-CUSTODY RECORD

CLIENT: Environmental Associates, Inc.
ADDRESS: 1380 112th ave NE, Suite 300 Bellevue, WA 98004
PHONE: 425-455-9025 **FAX:** 425-455-2316
CLIENT PROJECT #: 36005 **PROJECT MANAGER:** Eric Zuem

DATE: 2-4-16 **PAGE** 1 **OF** 2
PROJECT NAME: Chri-Mar APTS
LOCATION: Lynnwood
COLLECTOR: Eric Zuem **DATE OF COLLECTION:** 2-4-16

Sample Number	Depth	Time	Sample Type	Container Type	TPH - HCID	TPH - Diesel & Oil	TPH - Gasoline	BTEX	VOC 8260CL	VOC 8260	SemiVol 8270	PAH's 8270	PCB's 8082	CL Pesticides 8081	RCRA 8 Metals	MTCA 5 Metals	Pb	Asbestos - PLM	GRO Suite	DRO Suite	WO Suite				NOTES	Total Number of Containers	Laboratory Note Number
1. B1-5	5'	10:00	Soil																							3	
2. B1-10	10'	10:05	↓																							3	
3. B1-15	15'	10:15	↓			X	X	X	X																	3	
4. B1-17.5	17.5'	10:35	↓																							3	
5. B1-water	13.5-17.5	2:00	Water			X	X	X	X																	3	
6. B1-SV	5'	9:15	Soil vapor							X															on seperate chain	1	
7. B2-5	5 ~~10~~	10:55	Soil																							3	
8. B2-10	10'	11:00	↓																							3	
9. B2-15	15'	11:10	↓			X	X	X	X																	3	
10. B2-water	15'	11:30	water			X	X	X	X																	3	
11. B3-5	5'	2:20	Soil			X	X	X																		3	
12. B3-10	10'	2:30	↓																							3	
13. B3-15	15'	2:40	↓																							2	
14. B3-water	7-11'	2:30	water			X	X	X	X																	3	
15. B3-SV	2.5'	~~[illegible]~~ 1:35	soil vapor							X															on seperate chain	1	
16. B4-5	5'	12:05	Soil																							3	
17. B4-10	10'	12:10	↓			X	X	X																		3	
18. B4-15	15'	12:15	↓																							3	

RELINQUISHED BY (Signature)	DATE/TIME	RECEIVED BY (Signature)	DATE/TIME
	2-4-16 3:30		2-4-16 330
RELINQUISHED BY (Signature)	DATE/TIME	RECEIVED BY (Signature)	DATE/TIME

SAMPLE RECEIPT	
TOTAL NUMBER OF CONTAINERS	61
CHAIN OF CUSTODY SEALS Y/N/NA	
SEALS INTACT? Y/N/NA	
RECEIVED GOOD COND./COLD	
NOTES:	

LABORATORY NOTES: Call Eric for billing info

Turn Around Time: 24 HR 48 HR [✓ 5 DAY]

1210 Eastside Street SE, Suite 200
Olympia, Washington 98501

Phone: 360-459-4670
Fax: 360-459-3432

Website: www.esnnw.com
E-Mail: info@esnnw.com

ESN NORTHWEST, INC. Environmental Services Network

CHAIN-OF-CUSTODY RECORD

CLIENT: EAI

ADDRESS:

PHONE: FAX:

CLIENT PROJECT #: PROJECT MANAGER:

DATE: 2-4-16 PAGE 2 OF 2

PROJECT NAME: Chris-Mar Apts

LOCATION: Lynnwood

COLLECTOR: Eric Zuern

DATE OF COLLECTION: 2-4-16

	Sample Number	Depth	Time	Sample Type	Container Type	ANALYSES	TPH - HCID	TPH - Diesel & Oil	TPH - Gasoline	BTEX	VOC 8260CL	VOC 8260	SemiVol 8270	PAH's 8270	PCB's 8082	CL Pesticides 8081	RCRA 8 Metals	MTCA 5 Metals	Pb	Asbestos - PLM	GRO Suite	DRO Suite	WO Suite			NOTES	Total Number of Containers	Laboratory Note Number
1.	B4-water	8'-13'	12:30	Water			X	X	X	X																	3	
2.	BS-5	5'	1:15	Soil																							3	
3.	BS-10	10'	1:25	↓			X	X	X																		3	
4.	BS-water	4'-8'	1:30	Water			X	X	X	X																	3	
5.																												
6.																												
7.																												
8.																												
9.																												
10.																												
11.																												
12.																												
13.																												
14.																												
15.																												
16.																												
17.																												
18.																												

RELINQUISHED BY (Signature)	DATE/TIME	RECEIVED BY (Signature)	DATE/TIME
	2-4-16 3:30		2-4-16 30

RELINQUISHED BY (Signature)	DATE/TIME	RECEIVED BY (Signature)	DATE/TIME

SAMPLE RECEIPT

TOTAL NUMBER OF CONTAINERS	61
CHAIN OF CUSTODY SEALS Y/N/NA	
SEALS INTACT? Y/N/NA	
RECEIVED GOOD COND./COLD	

NOTES:

LABORATORY NOTES:
Call Eric for billing info

Turn Around Time: 24 HR 48 HR [✓ 5-DAY]

1210 Eastside Street SE, Suite 200
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ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
CHRI-MAR APTS PROJECT
Client Project #36005
Lynnwood, Washington

ESN Northwest
1210 Eastside Street SE Suite 200
Olympia, WA 98501
(360) 459-4670 (360) 459-3432 Fax
lab@esnnw.com

Analysis of Diesel Range Organics & Lube Oil Range Organics in Soil by Method NWTPH-Dx Extended

Sample Number	Date Prepared	Date Analyzed	Surrogate Recovery (%)	Diesel Range Organics (mg/kg)	Lube Oil Range Organics (mg/kg)
Method Blank	2/10/2016	2/10/2016	105	nd	nd
LCS	2/10/2016	2/10/2016	89	91%	---
B1-15	2/10/2016	2/10/2016	110	nd	nd
B1-15 Duplicate	2/10/2016	2/10/2016	87	nd	nd
B2-15	2/10/2016	2/10/2016	116	nd	nd
B3-5	2/10/2016	2/10/2016	122	nd	nd
B4-10	2/10/2016	2/10/2016	130	nd	nd
B5-10	2/10/2016	2/10/2016	91	nd	nd
Reporting Limits				50	100

"nd" Indicates not detected at the listed detection limits.
"int" Indicates that interference prevents determination.

ACCEPTABLE RECOVERY LIMITS FOR SURROGATE : 50% TO 150%

ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
CHRI-MAR APTS PROJECT
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Analysis of Diesel Range Organics & Lube Oil Range Organics in Water by Method NWTPH-Dx Extended

Sample Number	Date Prepared	Date Analyzed	Surrogate Recovery (%)	Diesel Range Organics (ug/L)	Lube Oil Range Organics (ug/L)
Method Blank	2/8/2016	2/8/2016	147	nd	nd
LCS	2/8/2016	2/8/2016	113	110%	---
B1-Water	2/8/2016	2/8/2016	108	nd	nd
B2-Water	2/8/2016	2/8/2016	108	nd	nd
B3-Water	2/8/2016	2/8/2016	113	nd	nd
B4-Water	2/8/2016	2/8/2016	109	nd	nd
B5-Water	2/8/2016	2/8/2016	113	nd	nd
Reporting Limits				250	500

"nd" Indicates not detected at the listed detection limits.
"int" Indicates that interference prevents determination.

ACCEPTABLE RECOVERY LIMITS FOR SURROGATE : 50% TO 150%

ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
CHRI-MAR APTS PROJECT
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Analysis of Gasoline Range Organics & BTEX in Soil by Method NWTPH-Gx/8260

Sample Number	Date Prepared	Date Analyzed	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Xylenes (mg/kg)	Gasoline Range Organics (mg/kg)	Surrogate Recovery (%)
Method Blank	2/8/2016	2/8/2016	nd	nd	nd	nd	nd	114
LCS	2/8/2016	2/8/2016	120%	115%	126%	118%	110%	110
LCSD	2/8/2016	2/8/2016	100%	100%	100%	97%	---	109
B1-15	2/4/2016	2/8/2016	nd	nd	nd	nd	nd	114
B2-15	2/4/2016	2/9/2016	nd	nd	nd	nd	nd	110
B2-15 Duplicate	2/4/2016	2/9/2016	nd	nd	nd	nd	nd	114
B3-5	2/4/2016	2/9/2016	nd	nd	nd	nd	nd	114
B4-10	2/4/2016	2/9/2016	nd	nd	nd	nd	nd	107
B5-10	2/4/2016	2/9/2016	nd	nd	nd	nd	nd	113
Reporting Limits			0.02	0.05	0.05	0.15	10	

"---" Indicates not tested for component.
"nd" Indicates not detected at the listed detection limits.
"int" Indicates that interference prevents determination.

ACCEPTABLE RECOVERY LIMITS FOR SURROGATE (Bromoflurorbenzene) & LCS : 65% TO 135%

ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
CHRI-MAR APTS PROJECT
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Lynnwood, Washington

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Analysis of Gasoline Range Organics & BTEX in Water by Method NWTPH-Gx/8260

Sample Number	Date Analyzed	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	Xylenes (ug/L)	Gasoline Range Organics (ug/L)	Surrogate Recovery (%)
Method Blank	2/10/2016	nd	nd	nd	nd	nd	99
LCS	2/10/2016	70%	69%	75%	76%	69%	97
LCSD	2/10/2016	81%	85%	91%	92%	---	95
B1-Water	2/10/2016	nd	nd	nd	nd	nd	93
B2-Water	2/10/2016	nd	nd	nd	nd	nd	96
B3-Water	2/10/2016	nd	nd	nd	nd	nd	96
B4-Water	2/10/2016	nd	nd	nd	nd	nd	93
B5-Water	2/10/2016	nd	nd	nd	nd	nd	93
Trip Blank	2/10/2016	nd	nd	nd	nd	nd	94
Reporting Limits		1.0	1.0	1.0	3.0	100	

"nd" Indicates not detected at the listed detection limits.
"int" Indicates that interference prevents determination.

ACCEPTABLE RECOVERY LIMITS FOR SURROGATE (Bromoflurorbenzene) & LCS: 65% TO 135%

ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
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Analysis of Chlorinated Volatile Organic Compounds in Soil by Method 8260C/5035

	RL	MB	LCS	LCSD	B1-15	B2-15	B3-5	B4-10
Date extracted		02/08/16	02/08/16	02/08/16	02/04/16	02/04/16	02/04/16	02/04/16
Date analyzed	(mg/Kg)	02/08/16	02/08/16	02/08/16	02/08/16	02/09/16	02/09/16	02/09/16
% Moisture					9%	16%	12%	10%
Dichlorodifluoromethane	0.05	nd			nd	nd	nd	nd
Chloromethane	0.05	nd			nd	nd	nd	nd
Vinyl chloride	0.02	nd	105%	103%	nd	nd	nd	nd
Chloroethane	0.05	nd			nd	nd	nd	nd
Trichlorofluoromethane	0.05	nd			nd	nd	nd	nd
1,1-Dichloroethene	0.05	nd	77%	82%	nd	nd	nd	nd
Methylene chloride	0.05	nd			nd	nd	nd	nd
trans-1,2-Dichloroethene	0.05	nd			nd	nd	nd	nd
1,1-Dichloroethane	0.05	nd			nd	nd	nd	nd
cis-1,2-Dichloroethene	0.05	nd			nd	nd	nd	nd
2,2-Dichloropropane	0.05	nd			nd	nd	nd	nd
Chloroform	0.05	nd	119%	117%	nd	nd	nd	nd
Bromochloromethane	0.05	nd			nd	nd	nd	nd
1,1,1-Trichloroethane	0.05	nd			nd	nd	nd	nd
1,2-Dichloroethane (EDC)	0.05	nd			nd	nd	nd	nd
1,1-Dichloropropene	0.05	nd			nd	nd	nd	nd
Carbon tetrachloride	0.05	nd			nd	nd	nd	nd
Trichloroethene (TCE)	0.02	nd	111%	117%	nd	nd	nd	nd
1,2-Dichloropropane	0.05	nd	123%	124%	nd	nd	nd	nd
Bromodichloromethane	0.05	nd			nd	nd	nd	nd
cis-1,3-Dichloropropene	0.05	nd			nd	nd	nd	nd
trans-1,3-Dichloropropene	0.05	nd			nd	nd	nd	nd
1,1,2-Trichloroethane	0.05	nd			nd	nd	nd	nd
1,3-Dichloropropane	0.05	nd			nd	nd	nd	nd
Dibromochloromethane	0.05	nd			nd	nd	nd	nd
Tetrachloroethene (PCE)	0.02	nd	92%	96%	nd	**0.095**	**0.031**	nd
Chlorobenzene	0.05	nd	96%	99%	nd	nd	nd	nd
1,1,1,2-Tetrachloroethane	0.05	nd			nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	0.05	nd			nd	nd	nd	nd
1,2,3-Trichloropropane	0.05	nd			nd	nd	nd	nd
2-Chlorotoluene	0.05	nd			nd	nd	nd	nd
4-Chlorotoluene	0.05	nd			nd	nd	nd	nd
1,3-Dichlorobenzene	0.05	nd			nd	nd	nd	nd
1,4-Dichlorobenzene	0.05	nd			nd	nd	nd	nd
1,2-Dichlorobenzene	0.05	nd			nd	nd	nd	nd
1,2-Dibromo-3-Chloropropane	0.05	nd			nd	nd	nd	nd
1,2,4-Trichlorobenzene	0.05	nd			nd	nd	nd	nd
Hexachloro-1,3-butadiene	0.05	nd			nd	nd	nd	nd
1,2,3-Trichlorobenzene	0.05	nd			nd	nd	nd	nd
Surrogate recoveries								
Dibromofluoromethane		104%	107%	101%	104%	106%	107%	105%
Toluene-d8		97%	90%	89%	92%	97%	100%	96%
4-Bromofluorobenzene		114%	110%	109%	114%	110%	114%	107%

Data Qualifiers and Analytical Comments

nd - not detected at listed reporting limits
Acceptable Recovery limits: 65% TO 135%
Acceptable RPD limit: 35%

ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
CHRI-MAR APTS PROJECT
Client Project #36005
Lynnwood, Washington

ESN Northwest
1210 Eastside Street SE Suite 200
Olympia, WA 98501
(360) 459-4670 (360) 459-3432 Fax
lab@esnnw.com

Analysis of Chlorinated Volatile Organic Compounds in Water by Method 8260C/5030C

Analytical Results

	RL	MB	LCS	LCSD	B1-Water	B2-Water	B3-Water	B4-Water
Date analyzed	(ug/L)	02/10/16	02/10/16	02/10/16	02/10/16	02/10/16	02/10/16	02/10/16
Dichlorodifluoromethane	1.0	nd			nd	nd	nd	nd
Chloromethane	1.0	nd			nd	nd	nd	nd
Vinyl chloride	0.2	nd	89%	115%	nd	nd	nd	nd
Chloroethane	1.0	nd			nd	nd	nd	nd
Trichlorofluoromethane	1.0	nd			nd	nd	nd	nd
1,1-Dichloroethene	1.0	nd	84%	105%	nd	nd	nd	nd
Methylene chloride	1.0	nd			nd	nd	nd	nd
trans-1,2-Dichloroethene	1.0	nd			nd	nd	nd	nd
1,1-Dichloroethane	1.0	nd			nd	nd	nd	nd
cis-1,2-Dichloroethene	1.0	nd			nd	nd	**1.0**	nd
2,2-Dichloropropane	1.0	nd			nd	nd	nd	nd
Chloroform	1.0	nd	84%	102%	nd	nd	nd	nd
Bromochloromethane	1.0	nd			nd	nd	nd	nd
1,1,1-Trichloroethane	1.0	nd			nd	nd	nd	nd
1,2-Dichloroethane (EDC)	1.0	nd			nd	nd	nd	nd
1,1-Dichloropropene	1.0	nd			nd	nd	nd	nd
Carbon tetrachloride	1.0	nd			nd	nd	nd	nd
Trichloroethene (TCE)	1.0	nd	81%	98%	nd	nd	**5.3**	nd
1,2-Dichloropropane	1.0	nd			nd	nd	nd	nd
Bromodichloromethane	1.0	nd			nd	nd	nd	nd
cis-1,3-Dichloropropene	1.0	nd			nd	nd	nd	nd
trans-1,3-Dichloropropene	1.0	nd			nd	nd	nd	nd
1,1,2-Trichloroethane	1.0	nd			nd	nd	nd	nd
1,3-Dichloropropane	1.0	nd			nd	nd	nd	nd
Dibromochloromethane	1.0	nd			nd	nd	nd	nd
Tetrachloroethene (PCE)	1.0	nd	83%	103%	nd	**14**	**35**	nd
Chlorobenzene	1.0	nd	77%	92%	nd	nd	nd	nd
1,1,1,2-Tetrachloroethane	1.0	nd			nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	1.0	nd			nd	nd	nd	nd
1,2,3-Trichloropropane	1.0	nd			nd	nd	nd	nd
2-Chlorotoluene	1.0	nd			nd	nd	nd	nd
4-Chlorotoluene	1.0	nd			nd	nd	nd	nd
1,3-Dichlorobenzene	1.0	nd			nd	nd	nd	nd
1,4-Dichlorobenzene	1.0	nd			nd	nd	nd	nd
1,2-Dichlorobenzene	1.0	nd			nd	nd	nd	nd
1,2-Dibromo-3-Chloropropane	1.0	nd			nd	nd	nd	nd
1,2,4-Trichlorobenzene	1.0	nd			nd	nd	nd	nd
Hexachloro-1,3-butadiene	1.0	nd			nd	nd	nd	nd
1,2,3-Trichlorobenzene	1.0	nd			nd	nd	nd	nd

Surrogate recoveries

		MB	LCS	LCSD	B1-Water	B2-Water	B3-Water	B4-Water
Dibromofluoromethane		113%	127%	118%	122%	123%	130%	131%
Toluene-d8		99%	98%	99%	99%	100%	97%	92%
4-Bromofluorobenzene		99%	97%	95%	93%	96%	96%	93%

Data Qualifiers and Analytical Comments

nd - not detected at listed reporting limits
Acceptable Recovery limits: 65% TO 135%
Acceptable RPD limit: 35%

ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
CHRI-MAR APTS PROJECT
Client Project #36005
Lynnwood, Washington

ESN Northwest
1210 Eastside Street SE Suite 200
Olympia, WA 98501
(360) 459-4670 (360) 459-3432 Fax
lab@esnnw.com

Analysis of Chlorinated Volatile Organic Compounds in Water by Method 8260C/5030C

Analytical Results

Date analyzed	RL (ug/L)	B5-Water 02/10/16	Trip Blank 02/10/16
Dichlorodifluoromethane	1.0	nd	nd
Chloromethane	1.0	nd	nd
Vinyl chloride	0.2	nd	nd
Chloroethane	1.0	nd	nd
Trichlorofluoromethane	1.0	nd	nd
1,1-Dichloroethene	1.0	nd	nd
Methylene chloride	1.0	nd	nd
trans-1,2-Dichloroethene	1.0	nd	nd
1,1-Dichloroethane	1.0	nd	nd
cis-1,2-Dichloroethene	1.0	nd	nd
2,2-Dichloropropane	1.0	nd	nd
Chloroform	1.0	nd	nd
Bromochloromethane	1.0	nd	nd
1,1,1-Trichloroethane	1.0	nd	nd
1,2-Dichloroethane (EDC)	1.0	nd	nd
1,1-Dichloropropene	1.0	nd	nd
Carbon tetrachloride	1.0	nd	nd
Trichloroethene (TCE)	1.0	nd	nd
1,2-Dichloropropane	1.0	nd	nd
Bromodichloromethane	1.0	nd	nd
cis-1,3-Dichloropropene	1.0	nd	nd
trans-1,3-Dichloropropene	1.0	nd	nd
1,1,2-Trichloroethane	1.0	nd	nd
1,3-Dichloropropane	1.0	nd	nd
Dibromochloromethane	1.0	nd	nd
Tetrachloroethene (PCE)	1.0	nd	nd
Chlorobenzene	1.0	nd	nd
1,1,1,2-Tetrachloroethane	1.0	nd	nd
1,1,2,2-Tetrachloroethane	1.0	nd	nd
1,2,3-Trichloropropane	1.0	nd	nd
2-Chlorotoluene	1.0	nd	nd
4-Chlorotoluene	1.0	nd	nd
1,3-Dichlorobenzene	1.0	nd	nd
1,4-Dichlorobenzene	1.0	nd	nd
1,2-Dichlorobenzene	1.0	nd	nd
1,2-Dibromo-3-Chloropropane	1.0	nd	nd
1,2,4-Trichlorobenzene	1.0	nd	nd
Hexachloro-1,3-butadiene	1.0	nd	nd
1,2,3-Trichlorobenzene	1.0	nd	nd

Surrogate recoveries			
Dibromofluoromethane		128%	129%
Toluene-d8		100%	93%
4-Bromofluorobenzene		93%	94%

Data Qualifiers and Analytical Comments

nd - not detected at listed reporting limits
Acceptable Recovery limits: 65% TO 135%
Acceptable RPD limit: 35%

ESN NORTHWEST CHEMISTRY LABORATORY

Environmental Associates, Inc
CHRI-MAR APTS PROJECT
Client Project #36005
Lynnwood, Washington

ESN Northwest
1210 Eastside Street SE Suite 200
Olympia, WA 98501
(360) 459-4670 (360) 459-3432 Fax
lab@esnnw.com

Analysis of Chlorinated Volatile Organic Compounds in Soil by Method 8260C/5035

	RL	MB	LCS	LCSD	B3-15
Date extracted		02/08/16	02/08/16	02/08/16	02/04/16
Date analyzed	(mg/Kg)	02/08/16	02/08/16	02/08/16	02/18/16
% Moisture					
Dichlorodifluoromethane	0.05	nd			nd
Chloromethane	0.05	nd			nd
Vinyl chloride	0.02	nd	116%	91%	nd
Chloroethane	0.05	nd			nd
Trichlorofluoromethane	0.05	nd			nd
1,1-Dichloroethene	0.05	nd	82%	66%	nd
Methylene chloride	0.05	nd			nd
trans-1,2-Dichloroethene	0.05	nd			nd
1,1-Dichloroethane	0.05	nd			nd
cis-1,2-Dichloroethene	0.05	nd			nd
2,2-Dichloropropane	0.05	nd			nd
Chloroform	0.05	nd	120%	94%	nd
Bromochloromethane	0.05	nd			nd
1,1,1-Trichloroethane	0.05	nd			nd
1,2-Dichloroethane (EDC)	0.05	nd			nd
1,1-Dichloropropene	0.05	nd			nd
Carbon tetrachloride	0.05	nd			nd
Trichloroethene (TCE)	0.02	nd	124%	103%	nd
1,2-Dichloropropane	0.05	nd	129%	100%	nd
Bromodichloromethane	0.05	nd			nd
cis-1,3-Dichloropropene	0.05	nd			nd
trans-1,3-Dichloropropene	0.05	nd			nd
1,1,2-Trichloroethane	0.05	nd			nd
1,3-Dichloropropane	0.05	nd			nd
Dibromochloromethane	0.05	nd			nd
Tetrachloroethene (PCE)	0.02	nd	128%	106%	**0.10**
Chlorobenzene	0.05	nd	130%	106%	nd
1,1,1,2-Tetrachloroethane	0.05	nd			nd
1,1,2,2-Tetrachloroethane	0.05	nd			nd
1,2,3-Trichloropropane	0.05	nd			nd
2-Chlorotoluene	0.05	nd			nd
4-Chlorotoluene	0.05	nd			nd
1,3-Dichlorobenzene	0.05	nd			nd
1,4-Dichlorobenzene	0.05	nd			nd
1,2-Dichlorobenzene	0.05	nd			nd
1,2-Dibromo-3-Chloropropane	0.05	nd			nd
1,2,4-Trichlorobenzene	0.05	nd			nd
Hexachloro-1,3-butadiene	0.05	nd			nd
1,2,3-Trichlorobenzene	0.05	nd			nd

Surrogate recoveries					
Dibromofluoromethane		98%	98%	95%	96%
Toluene-d8		101%	97%	99%	103%
4-Bromofluorobenzene		104%	98%	99%	103%

Data Qualifiers and Analytical Comments

nd - not detected at listed reporting limits
Acceptable Recovery limits: 65% TO 135%
Acceptable RPD limit: 35%

eurofins | Air Toxics

2/16/2016
Mr. Steve Loague
ESN Northwest
1210 Eastside St
SE Suite 200
Olympia WA 98501

Project Name: Chri-Mar Apts.
Project #: 36005
Workorder #: 1602170A

Dear Mr. Steve Loague

The following report includes the data for the above referenced project for sample(s) received on 2/9/2016 at Air Toxics Ltd.

The data and associated QC analyzed by TO-15 are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Eurofins Air Toxics Inc. for your air analysis needs. Eurofins Air Toxics Inc. is committed to providing accurate data of the highest quality. Please feel free the Project Manager: Kelly Buettner at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Kelly Buettner

Kelly Buettner
Project Manager

WORK ORDER #: 1602170A

Work Order Summary

CLIENT:
Mr. Steve Loague
ESN Northwest
1210 Eastside St
SE Suite 200
Olympia, WA 98501

PHONE: 360-459-4670
FAX: 360-4595-3432
DATE RECEIVED: 02/09/2016
DATE COMPLETED: 02/16/2016

BILL TO:
Mr. Steve Loague
ESN Northwest
1210 Eastside St
SE Suite 200
Olympia, WA 98501

P.O. # 36005
PROJECT # 36005 Chri-Mar Apts.
CONTACT: Kelly Buettner

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	B-1	TO-15	0.8 "Hg	14.6 psi
02A	B-3	TO-15	3.9 "Hg	14.6 psi
03A	Lab Blank	TO-15	NA	NA
04A	CCV	TO-15	NA	NA
05A	LCS	TO-15	NA	NA
05AA	LCSD	TO-15	NA	NA

CERTIFIED BY: Heidi Hayes

Technical Director

DATE: 02/16/16

Certification numbers: AZ Licensure AZ0775, NJ NELAP - CA016, NY NELAP - 11291,
TX NELAP - T104704343-14-7, UT NELAP CA009332014-5, VA NELAP - 460197, WA NELAP - C935
Name of Accreditation Body: NELAP/ORELAP (Oregon Environmental Laboratory Accreditation Program)
Accreditation number: CA300005, Effective date: 10/18/2014, Expiration date: 10/17/2015.
Eurofins Air Toxics Inc.. certifies that the test results contained in this report meet all requirements of the NELAC standards

LABORATORY NARRATIVE
EPA Method TO-15
ESN Northwest
Workorder# 1602170A

Two 1 Liter Summa Canister samples were received on February 09, 2016. The laboratory performed analysis via EPA Method TO-15 using GC/MS in the full scan mode.

This workorder was independently validated prior to submittal using 'USEPA National Functional Guidelines' as generally applied to the analysis of volatile organic compounds in air. A rules-based, logic driven, independent validation engine was employed to assess completeness, evaluate pass/fail of relevant project quality control requirements and verification of all quantified amounts.

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

There were no analytical discrepancies.

Definition of Data Qualifying Flags

Eight qualifiers may have been used on the data analysis sheets and indicates as follows:

B - Compound present in laboratory blank greater than reporting limit (background subtraction not performed).
J - Estimated value.
E - Exceeds instrument calibration range.
S - Saturated peak.
Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the reporting limit, LOD, or MDL value. See data page for project specific U-flag definition.
UJ- Non-detected compound associated with low bias in the CCV
N - The identification is based on presumptive evidence.

File extensions may have been used on the data analysis sheets and indicates as follows:

a-File was requantified
b-File was quantified by a second column and detector
r1-File was requantified for the purpose of reissue

Summary of Detected Compounds
EPA METHOD TO-15 GC/MS FULL SCAN

Client Sample ID: B-1

Lab ID#: 1602170A-01A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
1,3-Butadiene	1.0	27	2.3	59
Ethanol	4.1	19	7.7	36
Acetone	10	100	24	240
Carbon Disulfide	4.1	4.2	13	13
Hexane	1.0	12	3.6	42
2-Butanone (Methyl Ethyl Ketone)	4.1	16	12	47
Tetrahydrofuran	1.0	1.3	3.0	3.9
Cyclohexane	1.0	5.2	3.5	18
Benzene	1.0	15	3.3	48
Heptane	1.0	4.4	4.2	18
Toluene	1.0	13	3.9	48
m,p-Xylene	1.0	2.3	4.4	10

Client Sample ID: B-3

Lab ID#: 1602170A-02A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
1,3-Butadiene	1.1	73	2.5	160
Acetone	11	70	27	170
Carbon Disulfide	4.6	11	14	35
Hexane	1.1	23	4.0	80
2-Butanone (Methyl Ethyl Ketone)	4.6	10	14	30
Tetrahydrofuran	1.1	1.3	3.4	3.9
Cyclohexane	1.1	8.8	3.9	30
2,2,4-Trimethylpentane	1.1	1.7	5.3	8.1
Benzene	1.1	18	3.6	59
Heptane	1.1	5.8	4.7	24
Trichloroethene	1.1	3.7	6.2	20
Toluene	1.1	12	4.3	47
Tetrachloroethene	1.1	5.6	7.8	38
m,p-Xylene	1.1	2.2	5.0	9.4

Client Sample ID: B-1

Lab ID#: 1602170A-01A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021214**	**Date of Collection:**	**2/4/16 9:52:00 AM**
Dil. Factor:	**2.05**	**Date of Analysis:**	**2/12/16 11:01 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Freon 12	1.0	Not Detected	5.1	Not Detected
Freon 114	1.0	Not Detected	7.2	Not Detected
Chloromethane	10	Not Detected	21	Not Detected
Vinyl Chloride	1.0	Not Detected	2.6	Not Detected
1,3-Butadiene	1.0	27	2.3	59
Bromomethane	10	Not Detected	40	Not Detected
Chloroethane	4.1	Not Detected	11	Not Detected
Freon 11	1.0	Not Detected	5.8	Not Detected
Ethanol	4.1	19	7.7	36
Freon 113	1.0	Not Detected	7.8	Not Detected
1,1-Dichloroethene	1.0	Not Detected	4.1	Not Detected
Acetone	10	100	24	240
2-Propanol	4.1	Not Detected	10	Not Detected
Carbon Disulfide	4.1	4.2	13	13
3-Chloropropene	4.1	Not Detected	13	Not Detected
Methylene Chloride	10	Not Detected	36	Not Detected
Methyl tert-butyl ether	1.0	Not Detected	3.7	Not Detected
trans-1,2-Dichloroethene	1.0	Not Detected	4.1	Not Detected
Hexane	1.0	12	3.6	42
1,1-Dichloroethane	1.0	Not Detected	4.1	Not Detected
2-Butanone (Methyl Ethyl Ketone)	4.1	16	12	47
cis-1,2-Dichloroethene	1.0	Not Detected	4.1	Not Detected
Tetrahydrofuran	1.0	1.3	3.0	3.9
Chloroform	1.0	Not Detected	5.0	Not Detected
1,1,1-Trichloroethane	1.0	Not Detected	5.6	Not Detected
Cyclohexane	1.0	5.2	3.5	18
Carbon Tetrachloride	1.0	Not Detected	6.4	Not Detected
2,2,4-Trimethylpentane	1.0	Not Detected	4.8	Not Detected
Benzene	1.0	15	3.3	48
1,2-Dichloroethane	1.0	Not Detected	4.1	Not Detected
Heptane	1.0	4.4	4.2	18
Trichloroethene	1.0	Not Detected	5.5	Not Detected
1,2-Dichloropropane	1.0	Not Detected	4.7	Not Detected
1,4-Dioxane	4.1	Not Detected	15	Not Detected
Bromodichloromethane	1.0	Not Detected	6.9	Not Detected
cis-1,3-Dichloropropene	1.0	Not Detected	4.6	Not Detected
4-Methyl-2-pentanone	1.0	Not Detected	4.2	Not Detected
Toluene	1.0	13	3.9	48
trans-1,3-Dichloropropene	1.0	Not Detected	4.6	Not Detected
1,1,2-Trichloroethane	1.0	Not Detected	5.6	Not Detected
Tetrachloroethene	1.0	Not Detected	7.0	Not Detected
2-Hexanone	4.1	Not Detected	17	Not Detected

Client Sample ID: B-1

Lab ID#: 1602170A-01A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021214**	**Date of Collection:**	**2/4/16 9:52:00 AM**
Dil. Factor:	**2.05**	**Date of Analysis:**	**2/12/16 11:01 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Dibromochloromethane	1.0	Not Detected	8.7	Not Detected
1,2-Dibromoethane (EDB)	1.0	Not Detected	7.9	Not Detected
Chlorobenzene	1.0	Not Detected	4.7	Not Detected
Ethyl Benzene	1.0	Not Detected	4.4	Not Detected
m,p-Xylene	1.0	2.3	4.4	10
o-Xylene	1.0	Not Detected	4.4	Not Detected
Styrene	1.0	Not Detected	4.4	Not Detected
Bromoform	1.0	Not Detected	10	Not Detected
Cumene	1.0	Not Detected	5.0	Not Detected
1,1,2,2-Tetrachloroethane	1.0	Not Detected	7.0	Not Detected
Propylbenzene	1.0	Not Detected	5.0	Not Detected
4-Ethyltoluene	1.0	Not Detected	5.0	Not Detected
1,3,5-Trimethylbenzene	1.0	Not Detected	5.0	Not Detected
1,2,4-Trimethylbenzene	1.0	Not Detected	5.0	Not Detected
1,3-Dichlorobenzene	1.0	Not Detected	6.2	Not Detected
1,4-Dichlorobenzene	1.0	Not Detected	6.2	Not Detected
alpha-Chlorotoluene	1.0	Not Detected	5.3	Not Detected
1,2-Dichlorobenzene	1.0	Not Detected	6.2	Not Detected
1,2,4-Trichlorobenzene	4.1	Not Detected	30	Not Detected
Hexachlorobutadiene	4.1	Not Detected	44	Not Detected

Container Type: 1 Liter Summa Canister

Surrogates	%Recovery	Method Limits
Toluene-d8	106	70-130
1,2-Dichloroethane-d4	105	70-130
4-Bromofluorobenzene	98	70-130

Client Sample ID: B-3

Lab ID#: 1602170A-02A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021215**	**Date of Collection:**	**2/4/16 12:05:00 PM**
Dil. Factor:	**2.29**	**Date of Analysis:**	**2/12/16 11:28 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Freon 12	1.1	Not Detected	5.7	Not Detected
Freon 114	1.1	Not Detected	8.0	Not Detected
Chloromethane	11	Not Detected	24	Not Detected
Vinyl Chloride	1.1	Not Detected	2.9	Not Detected
1,3-Butadiene	1.1	73	2.5	160
Bromomethane	11	Not Detected	44	Not Detected
Chloroethane	4.6	Not Detected	12	Not Detected
Freon 11	1.1	Not Detected	6.4	Not Detected
Ethanol	4.6	Not Detected	8.6	Not Detected
Freon 113	1.1	Not Detected	8.8	Not Detected
1,1-Dichloroethene	1.1	Not Detected	4.5	Not Detected
Acetone	11	70	27	170
2-Propanol	4.6	Not Detected	11	Not Detected
Carbon Disulfide	4.6	11	14	35
3-Chloropropene	4.6	Not Detected	14	Not Detected
Methylene Chloride	11	Not Detected	40	Not Detected
Methyl tert-butyl ether	1.1	Not Detected	4.1	Not Detected
trans-1,2-Dichloroethene	1.1	Not Detected	4.5	Not Detected
Hexane	1.1	23	4.0	80
1,1-Dichloroethane	1.1	Not Detected	4.6	Not Detected
2-Butanone (Methyl Ethyl Ketone)	4.6	10	14	30
cis-1,2-Dichloroethene	1.1	Not Detected	4.5	Not Detected
Tetrahydrofuran	1.1	1.3	3.4	3.9
Chloroform	1.1	Not Detected	5.6	Not Detected
1,1,1-Trichloroethane	1.1	Not Detected	6.2	Not Detected
Cyclohexane	1.1	8.8	3.9	30
Carbon Tetrachloride	1.1	Not Detected	7.2	Not Detected
2,2,4-Trimethylpentane	1.1	1.7	5.3	8.1
Benzene	1.1	18	3.6	59
1,2-Dichloroethane	1.1	Not Detected	4.6	Not Detected
Heptane	1.1	5.8	4.7	24
Trichloroethene	1.1	3.7	6.2	20
1,2-Dichloropropane	1.1	Not Detected	5.3	Not Detected
1,4-Dioxane	4.6	Not Detected	16	Not Detected
Bromodichloromethane	1.1	Not Detected	7.7	Not Detected
cis-1,3-Dichloropropene	1.1	Not Detected	5.2	Not Detected
4-Methyl-2-pentanone	1.1	Not Detected	4.7	Not Detected
Toluene	1.1	12	4.3	47
trans-1,3-Dichloropropene	1.1	Not Detected	5.2	Not Detected
1,1,2-Trichloroethane	1.1	Not Detected	6.2	Not Detected
Tetrachloroethene	1.1	5.6	7.8	38
2-Hexanone	4.6	Not Detected	19	Not Detected

Client Sample ID: B-3

Lab ID#: 1602170A-02A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021215**	**Date of Collection:**	**2/4/16 12:05:00 PM**
Dil. Factor:	**2.29**	**Date of Analysis:**	**2/12/16 11:28 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Dibromochloromethane	1.1	Not Detected	9.8	Not Detected
1,2-Dibromoethane (EDB)	1.1	Not Detected	8.8	Not Detected
Chlorobenzene	1.1	Not Detected	5.3	Not Detected
Ethyl Benzene	1.1	Not Detected	5.0	Not Detected
m,p-Xylene	1.1	2.2	5.0	9.4
o-Xylene	1.1	Not Detected	5.0	Not Detected
Styrene	1.1	Not Detected	4.9	Not Detected
Bromoform	1.1	Not Detected	12	Not Detected
Cumene	1.1	Not Detected	5.6	Not Detected
1,1,2,2-Tetrachloroethane	1.1	Not Detected	7.9	Not Detected
Propylbenzene	1.1	Not Detected	5.6	Not Detected
4-Ethyltoluene	1.1	Not Detected	5.6	Not Detected
1,3,5-Trimethylbenzene	1.1	Not Detected	5.6	Not Detected
1,2,4-Trimethylbenzene	1.1	Not Detected	5.6	Not Detected
1,3-Dichlorobenzene	1.1	Not Detected	6.9	Not Detected
1,4-Dichlorobenzene	1.1	Not Detected	6.9	Not Detected
alpha-Chlorotoluene	1.1	Not Detected	5.9	Not Detected
1,2-Dichlorobenzene	1.1	Not Detected	6.9	Not Detected
1,2,4-Trichlorobenzene	4.6	Not Detected	34	Not Detected
Hexachlorobutadiene	4.6	Not Detected	49	Not Detected

Container Type: 1 Liter Summa Canister

Surrogates	%Recovery	Method Limits
Toluene-d8	110	70-130
1,2-Dichloroethane-d4	114	70-130
4-Bromofluorobenzene	100	70-130

Client Sample ID: Lab Blank

Lab ID#: 1602170A-03A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021206**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**2/12/16 01:41 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Freon 12	0.50	Not Detected	2.5	Not Detected
Freon 114	0.50	Not Detected	3.5	Not Detected
Chloromethane	5.0	Not Detected	10	Not Detected
Vinyl Chloride	0.50	Not Detected	1.3	Not Detected
1,3-Butadiene	0.50	Not Detected	1.1	Not Detected
Bromomethane	5.0	Not Detected	19	Not Detected
Chloroethane	2.0	Not Detected	5.3	Not Detected
Freon 11	0.50	Not Detected	2.8	Not Detected
Ethanol	2.0	Not Detected	3.8	Not Detected
Freon 113	0.50	Not Detected	3.8	Not Detected
1,1-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Acetone	5.0	Not Detected	12	Not Detected
2-Propanol	2.0	Not Detected	4.9	Not Detected
Carbon Disulfide	2.0	Not Detected	6.2	Not Detected
3-Chloropropene	2.0	Not Detected	6.3	Not Detected
Methylene Chloride	5.0	Not Detected	17	Not Detected
Methyl tert-butyl ether	0.50	Not Detected	1.8	Not Detected
trans-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Hexane	0.50	Not Detected	1.8	Not Detected
1,1-Dichloroethane	0.50	Not Detected	2.0	Not Detected
2-Butanone (Methyl Ethyl Ketone)	2.0	Not Detected	5.9	Not Detected
cis-1,2-Dichloroethene	0.50	Not Detected	2.0	Not Detected
Tetrahydrofuran	0.50	Not Detected	1.5	Not Detected
Chloroform	0.50	Not Detected	2.4	Not Detected
1,1,1-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Cyclohexane	0.50	Not Detected	1.7	Not Detected
Carbon Tetrachloride	0.50	Not Detected	3.1	Not Detected
2,2,4-Trimethylpentane	0.50	Not Detected	2.3	Not Detected
Benzene	0.50	Not Detected	1.6	Not Detected
1,2-Dichloroethane	0.50	Not Detected	2.0	Not Detected
Heptane	0.50	Not Detected	2.0	Not Detected
Trichloroethene	0.50	Not Detected	2.7	Not Detected
1,2-Dichloropropane	0.50	Not Detected	2.3	Not Detected
1,4-Dioxane	2.0	Not Detected	7.2	Not Detected
Bromodichloromethane	0.50	Not Detected	3.4	Not Detected
cis-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
4-Methyl-2-pentanone	0.50	Not Detected	2.0	Not Detected
Toluene	0.50	Not Detected	1.9	Not Detected
trans-1,3-Dichloropropene	0.50	Not Detected	2.3	Not Detected
1,1,2-Trichloroethane	0.50	Not Detected	2.7	Not Detected
Tetrachloroethene	0.50	Not Detected	3.4	Not Detected
2-Hexanone	2.0	Not Detected	8.2	Not Detected

Client Sample ID: Lab Blank

Lab ID#: 1602170A-03A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021206**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**2/12/16 01:41 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Dibromochloromethane	0.50	Not Detected	4.2	Not Detected
1,2-Dibromoethane (EDB)	0.50	Not Detected	3.8	Not Detected
Chlorobenzene	0.50	Not Detected	2.3	Not Detected
Ethyl Benzene	0.50	Not Detected	2.2	Not Detected
m,p-Xylene	0.50	Not Detected	2.2	Not Detected
o-Xylene	0.50	Not Detected	2.2	Not Detected
Styrene	0.50	Not Detected	2.1	Not Detected
Bromoform	0.50	Not Detected	5.2	Not Detected
Cumene	0.50	Not Detected	2.4	Not Detected
1,1,2,2-Tetrachloroethane	0.50	Not Detected	3.4	Not Detected
Propylbenzene	0.50	Not Detected	2.4	Not Detected
4-Ethyltoluene	0.50	Not Detected	2.4	Not Detected
1,3,5-Trimethylbenzene	0.50	Not Detected	2.4	Not Detected
1,2,4-Trimethylbenzene	0.50	Not Detected	2.4	Not Detected
1,3-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,4-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
alpha-Chlorotoluene	0.50	Not Detected	2.6	Not Detected
1,2-Dichlorobenzene	0.50	Not Detected	3.0	Not Detected
1,2,4-Trichlorobenzene	2.0	Not Detected	15	Not Detected
Hexachlorobutadiene	2.0	Not Detected	21	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	103	70-130
1,2-Dichloroethane-d4	103	70-130
4-Bromofluorobenzene	102	70-130

Client Sample ID: CCV
Lab ID#: 1602170A-04A
EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021202**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 2/12/16 12:01 PM**

Compound	%Recovery
Freon 12	102
Freon 114	98
Chloromethane	102
Vinyl Chloride	101
1,3-Butadiene	94
Bromomethane	104
Chloroethane	99
Freon 11	99
Ethanol	105
Freon 113	98
1,1-Dichloroethene	100
Acetone	100
2-Propanol	105
Carbon Disulfide	101
3-Chloropropene	100
Methylene Chloride	101
Methyl tert-butyl ether	101
trans-1,2-Dichloroethene	103
Hexane	101
1,1-Dichloroethane	103
2-Butanone (Methyl Ethyl Ketone)	98
cis-1,2-Dichloroethene	99
Tetrahydrofuran	100
Chloroform	100
1,1,1-Trichloroethane	98
Cyclohexane	100
Carbon Tetrachloride	98
2,2,4-Trimethylpentane	101
Benzene	97
1,2-Dichloroethane	101
Heptane	96
Trichloroethene	97
1,2-Dichloropropane	94
1,4-Dioxane	97
Bromodichloromethane	99
cis-1,3-Dichloropropene	100
4-Methyl-2-pentanone	98
Toluene	95
trans-1,3-Dichloropropene	102
1,1,2-Trichloroethane	95
Tetrachloroethene	99
2-Hexanone	99

Client Sample ID: CCV

Lab ID#: 1602170A-04A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021202**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 2/12/16 12:01 PM**

Compound	%Recovery
Dibromochloromethane	99
1,2-Dibromoethane (EDB)	99
Chlorobenzene	97
Ethyl Benzene	100
m,p-Xylene	102
o-Xylene	99
Styrene	102
Bromoform	104
Cumene	100
1,1,2,2-Tetrachloroethane	98
Propylbenzene	98
4-Ethyltoluene	99
1,3,5-Trimethylbenzene	99
1,2,4-Trimethylbenzene	100
1,3-Dichlorobenzene	98
1,4-Dichlorobenzene	96
alpha-Chlorotoluene	101
1,2-Dichlorobenzene	94
1,2,4-Trichlorobenzene	101
Hexachlorobutadiene	100

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	103	70-130
1,2-Dichloroethane-d4	102	70-130
4-Bromofluorobenzene	103	70-130

Client Sample ID: LCS

Lab ID#: 1602170A-05A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name: 3021203		**Date of Collection:** NA
Dil. Factor: 1.00		**Date of Analysis:** 2/12/16 12:25 PM

Compound	%Recovery	Method Limits
Freon 12	107	70-130
Freon 114	104	70-130
Chloromethane	103	70-130
Vinyl Chloride	107	70-130
1,3-Butadiene	97	70-130
Bromomethane	107	70-130
Chloroethane	105	70-130
Freon 11	102	70-130
Ethanol	105	70-130
Freon 113	97	70-130
1,1-Dichloroethene	102	70-130
Acetone	102	70-130
2-Propanol	108	70-130
Carbon Disulfide	91	70-130
3-Chloropropene	99	70-130
Methylene Chloride	104	70-130
Methyl tert-butyl ether	101	70-130
trans-1,2-Dichloroethene	107	70-130
Hexane	103	70-130
1,1-Dichloroethane	106	70-130
2-Butanone (Methyl Ethyl Ketone)	99	70-130
cis-1,2-Dichloroethene	101	70-130
Tetrahydrofuran	100	70-130
Chloroform	102	70-130
1,1,1-Trichloroethane	100	70-130
Cyclohexane	102	70-130
Carbon Tetrachloride	100	70-130
2,2,4-Trimethylpentane	104	70-130
Benzene	98	70-130
1,2-Dichloroethane	102	70-130
Heptane	98	70-130
Trichloroethene	100	70-130
1,2-Dichloropropane	97	70-130
1,4-Dioxane	94	70-130
Bromodichloromethane	103	70-130
cis-1,3-Dichloropropene	96	70-130
4-Methyl-2-pentanone	96	70-130
Toluene	97	70-130
trans-1,3-Dichloropropene	101	70-130
1,1,2-Trichloroethane	95	70-130
Tetrachloroethene	98	70-130
2-Hexanone	97	70-130

Client Sample ID: LCS

Lab ID#: 1602170A-05A

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021203**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 2/12/16 12:25 PM**

Compound	%Recovery	Method Limits
Dibromochloromethane	101	70-130
1,2-Dibromoethane (EDB)	100	70-130
Chlorobenzene	97	70-130
Ethyl Benzene	97	70-130
m,p-Xylene	99	70-130
o-Xylene	100	70-130
Styrene	102	70-130
Bromoform	105	70-130
Cumene	100	70-130
1,1,2,2-Tetrachloroethane	98	70-130
Propylbenzene	99	70-130
4-Ethyltoluene	99	70-130
1,3,5-Trimethylbenzene	98	70-130
1,2,4-Trimethylbenzene	100	70-130
1,3-Dichlorobenzene	98	70-130
1,4-Dichlorobenzene	96	70-130
alpha-Chlorotoluene	105	70-130
1,2-Dichlorobenzene	94	70-130
1,2,4-Trichlorobenzene	102	70-130
Hexachlorobutadiene	104	70-130

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	103	70-130
1,2-Dichloroethane-d4	102	70-130
4-Bromofluorobenzene	102	70-130

Client Sample ID: LCSD

Lab ID#: 1602170A-05AA

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021204**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**2/12/16 12:50 PM**

Compound	%Recovery	Method Limits
Freon 12	104	70-130
Freon 114	102	70-130
Chloromethane	102	70-130
Vinyl Chloride	106	70-130
1,3-Butadiene	95	70-130
Bromomethane	104	70-130
Chloroethane	102	70-130
Freon 11	101	70-130
Ethanol	109	70-130
Freon 113	95	70-130
1,1-Dichloroethene	101	70-130
Acetone	98	70-130
2-Propanol	106	70-130
Carbon Disulfide	90	70-130
3-Chloropropene	95	70-130
Methylene Chloride	101	70-130
Methyl tert-butyl ether	99	70-130
trans-1,2-Dichloroethene	103	70-130
Hexane	102	70-130
1,1-Dichloroethane	103	70-130
2-Butanone (Methyl Ethyl Ketone)	96	70-130
cis-1,2-Dichloroethene	97	70-130
Tetrahydrofuran	99	70-130
Chloroform	101	70-130
1,1,1-Trichloroethane	98	70-130
Cyclohexane	100	70-130
Carbon Tetrachloride	97	70-130
2,2,4-Trimethylpentane	102	70-130
Benzene	98	70-130
1,2-Dichloroethane	100	70-130
Heptane	96	70-130
Trichloroethene	99	70-130
1,2-Dichloropropane	96	70-130
1,4-Dioxane	96	70-130
Bromodichloromethane	101	70-130
cis-1,3-Dichloropropene	95	70-130
4-Methyl-2-pentanone	95	70-130
Toluene	97	70-130
trans-1,3-Dichloropropene	101	70-130
1,1,2-Trichloroethane	95	70-130
Tetrachloroethene	98	70-130
2-Hexanone	96	70-130

Client Sample ID: LCSD
Lab ID#: 1602170A-05AA

EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**3021204**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 2/12/16 12:50 PM**

Compound	%Recovery	Method Limits
Dibromochloromethane	101	70-130
1,2-Dibromoethane (EDB)	99	70-130
Chlorobenzene	97	70-130
Ethyl Benzene	98	70-130
m,p-Xylene	99	70-130
o-Xylene	102	70-130
Styrene	102	70-130
Bromoform	105	70-130
Cumene	99	70-130
1,1,2,2-Tetrachloroethane	98	70-130
Propylbenzene	99	70-130
4-Ethyltoluene	98	70-130
1,3,5-Trimethylbenzene	101	70-130
1,2,4-Trimethylbenzene	100	70-130
1,3-Dichlorobenzene	98	70-130
1,4-Dichlorobenzene	96	70-130
alpha-Chlorotoluene	104	70-130
1,2-Dichlorobenzene	94	70-130
1,2,4-Trichlorobenzene	108	70-130
Hexachlorobutadiene	107	70-130

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
Toluene-d8	101	70-130
1,2-Dichloroethane-d4	96	70-130
4-Bromofluorobenzene	102	70-130

APPENDIX D

Limited Air Sampling and Testing (EAI, 2016b)

LIMITED AIR SAMPLING AND TESTING

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

MILESTONE PROPERTIES

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue Northeast, Suite 300
Bellevue, Washington 98004
(425) 455-9025 Office
(888) 453-5394 Toll Free
(425) 455-2316 Fax

March 22, 2016

JN-36005-1

Ms. Rhoda Altom
Milestone Properties
P.O. Box 18379
Seattle, Washington 98118

Subject: **LIMITED AIR SAMPLING & TESTING**
Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Dear Ms. Altom:

Environmental Associates, Inc. (EAI) has performed limited sampling and testing of indoor and outdoor air at selected localities on the subject property. The purpose of this work was to make an assessment for the potential presence of select volatile organic compounds (VOCs) previously detected in shallow subsurface materials (benzene, 1,3-butadiene, tetrachloroethene (PCE), and trichloroethene (TCE)) in indoor and outdoor air at the subject property and to evaluate whether those compounds (if present) would pose a risk to on-site tenants. This report, prepared in accordance with the terms of our proposal dated March 2, 2016, summarizes our approach to the project along with results and conclusions.

The contents of this report are confidential and are intended solely for your use and the use of your representatives. Two (2) copies of this report are being distributed to you. No other distribution or discussion of this report will take place without your prior approval in writing.

Associate Offices: Oregon / San Francisco Bay Area

We appreciate the opportunity to be of service on this assignment. If you have any questions or if we may be of additional service, please do not hesitate to contact us.

Respectfully submitted,
ENVIRONMENTAL ASSOCIATES, INC.

Don W. Spencer

Don W. Spencer, M.Sc., P.G., R.E.A.
Principal

License: 604	(Washington)
License: 11464	(Oregon)
License: 876	(California)
License: 5195	(Illinois)
License: 0327	(Mississippi)

Hydrogeologist
604
DON W. SPENCER

LIMITED AIR SAMPLING AND TESTING

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Prepared for:

Milestone Properties
P.O. Box 18379
Seattle, Washington 98118

Questions regarding this investigation, the conclusions reached and the recommendations given should be addressed to one of the following undersigned.

Eric Zuern
Environmental Geologist / Project Manager

Don W. Spencer, M.Sc., P.G., R.E.A.
Principal

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State of Washington Licensed Geologist
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DON W. SPENCER

Reference Job Number: JN 36005-1

March 22, 2016

ENVIRONMENTAL ASSOCIATES, INC.

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INTRODUCTION/SCOPE OF WORK

SITE/PROJECT DESCRIPTION

The subject property is comprised of two (2) rectangular-shaped parcels (tax parcel numbers 27042000201000, 27042000200900) covering approximately 1.41 acres of land. The property is currently occupied by four (4) two-story apartment buildings constructed between 1962 and 1963. The approximate location of the site is shown on the Vicinity/Topographic Map, Plate 1, appended herewith.

Background

EAI previously presented Milestone Properties with a report titled Limited Subsurface Sampling and Testing on February 19, 2016. That report documented the results of soil, groundwater, and soil-vapor sampling and testing on the northern portion of the property in relation to a historic off-site dry cleaner and gas station/service shop formerly located on the adjacent northern parcels. That report documented the presence of PCE in soils and PCE and TCE groundwater at concentrations exceeding their applicable MTCA Method-A cleanup limits. Additionally, soil-vapor samples collected from shallow depths adjacent to on-site buildings (address numbers 19618 and 19620) detected concentrations of benzene, 1,3-butadiene, and TCE at concentrations exceeding their MTCA Method-B screening limits.

Current Study

Your expressed interests to conduct a preliminary evaluation of indoor and outdoor air to assess the potential for the presence of benzene, 1,3-butadiene, tetrachloroethene (PCE), and trichloroethene (TCE) as memorialized in EAI's proposal dated March 2, 2016, formed the basis for the following scope of work:

- Collect two (2) indoor air samples from ground level units of buildings 19618 and 19620, as well as one (1) outdoor air sample from the northern exterior of the subject site. Samples were collected over a 24-hour timeframe into laboratory prepared summa canisters.
- Laboratory analysis of the air samples for benzene, 1,3-butadiene, tetrachloroethene (PCE), and trichloroethene (TCE).
- Preparation of this summary report documenting the methodology and results of the investigation.

FINDINGS

AIR SAMPLING PROCEDURE

Three (3) 6-liter summa canisters were deployed at various locations on the property (depicted on Plate 2, Site Plan) on March 8, 2016. The samplers were placed within a ground-level managers office in building 19618, within ground-level apartment #123 in building 19620, and within a fenced exterior area at the north-central portion of the property. The canisters were deployed in locations approximately 4 feet above the ground surface (near the approximate breathing zone). Time, canister number, flow controller number, and initial canister pressure measurements were recorded by the EAI project manager. The summa canisters were then left to collect air for approximately 24-hours.

On March 9, 2016, EAI returned to the site to collect the canisters. The time and final canister pressure measurements were documented by the project manager. The samples were then transported to the project laboratory for analysis.

LABORATORY ANALYSIS

Laboratory analysis of soil and groundwater samples was conducted by Friedman & Bruya, Inc., Seattle, Washington, a WDOE-accredited analytical laboratory. As previously mentioned, air samples were submitted for analysis of benzene, 1,3-butadiene, tetrachloroethene (PCE), and trichloroethene (TCE) by EPA Method TO-15.

As summarized in Table 1, attached to this report, the solvents PCE and TCE were detected either below the WDOE Standard Method-B Air Target Compliance limits or the lower laboratory detection limits. Benzene was detected in all three samples at 0.99 ug/m^3 (Building 19618), 1.10 ug/m^3 (Building 19620), and 0.71 ug/m^3 (outdoor air). Those concentrations are above the WDOE MTCA Method-B Indoor Air Compliance limit of 0.321 ug/m^3 for that compound. Additionally, 1,3-butadiene was detected in all three samples at 0.14 ug/m^3 (Building 19618), 0.27 ug/m^3 (Building 19620), and 0.088 ug/m^3 (outdoor air). Those concentrations are also above the applicable MTCA Method-B compliance limit of 0.0833 ug/m^3 for that analyte.

CONCLUSIONS/ RECOMMENDATIONS

Relying upon the results of limited air sampling and testing conducted to date, benzene and 1,3-butadiene are present in both indoor and outdoor air at the subject property at concentrations exceeding their applicable MTCA Method-B compliance limits.

As noted in previous reports prepared by EAI and others, a release of gasoline, benzene, and other petroleum products has historically occurred on the adjacent property to the northeast. Acknowledging that 1,3-butadiene is a related petroleum compound and can be indicative of petroleum releases, the on-site detections <u>may</u> conceivably be a result from the off-site release to the northeast.

Attempting to add perspective to these discussions, according to data provided by the Centers for Disease Control and Prevention (CDCP), benzene can typically be found at higher concentrations in indoor air compared to outdoor air (as was the case at the subject site) due to off-gassing from products such as glues, paints, furniture wax, detergents, tobacco smoke, etc. Similarly, 1,3-butadiene can be found in cigarette smoke and car exhaust. These potential sources <u>may</u> conceivably contribute to the detections found at the subject.

Additionally, acknowledging the subject site's close proximity to State Highway 524 (196th Street Southwest) approximately 145 feet north of the subject, these compounds may be related to high motor vehicle use in the vicinity of the subject property. This can be a common source for airborne petroleum contaminants in densely populated areas. The Puget Sound Clean Air Agency (PSCAA) has monitored various contaminants of concern including benzene and 1,3-butadiene throughout the greater Seattle metropolitan area. In 2003, the PSCAA published the results of air monitoring at six sites in the metro area conducted between 2000 and 2001 (appended to this report). That study revealed <u>average</u> elevated concentrations of both benzene and 1,3-butadiene <u>above</u> the current MTCA Method-B compliance limits. Based on the results of the PSCAA monitoring, the on-site detections of benzene and 1,3-butadiene may potentially be considered a "background" condition of the area.

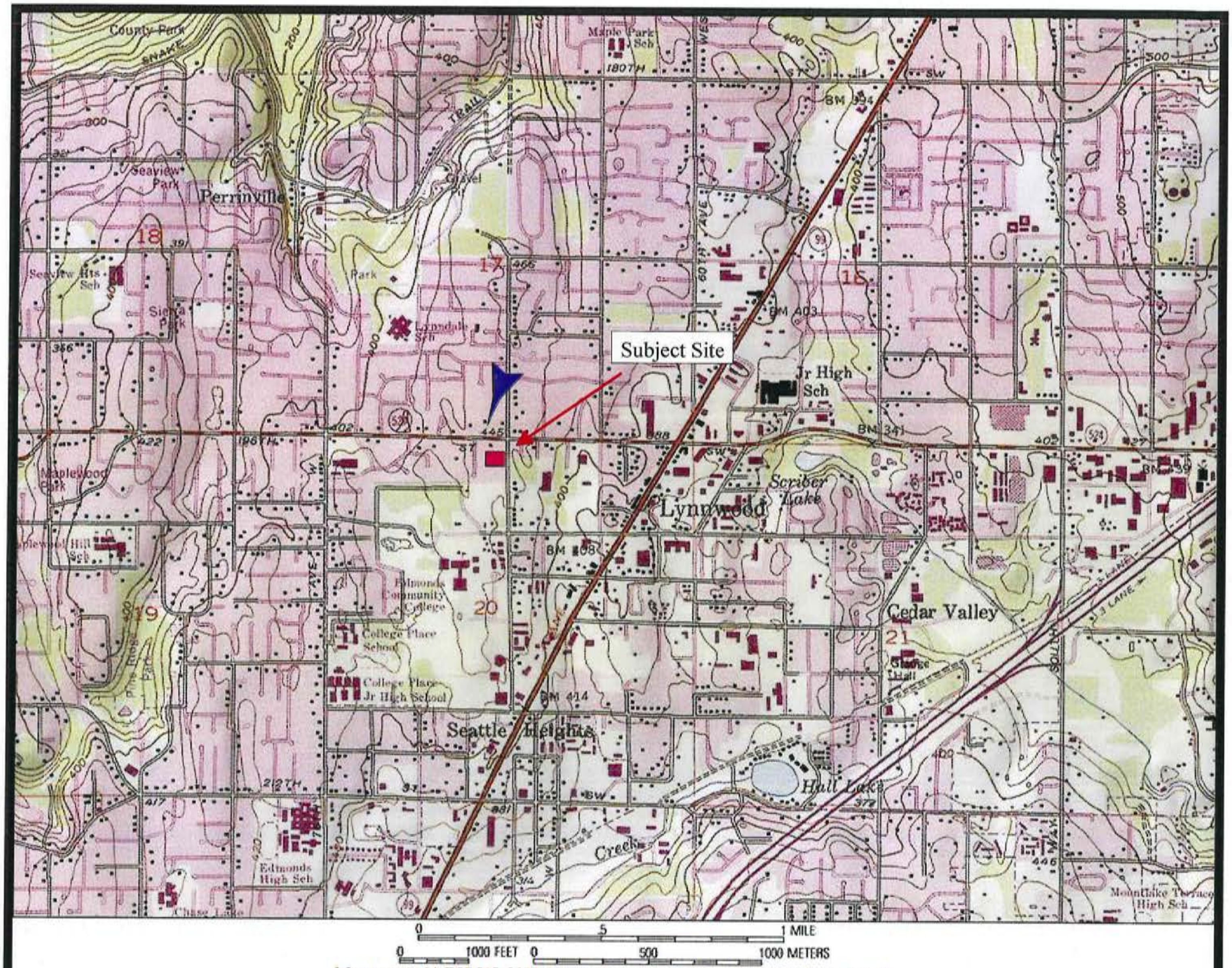
The PSCAA's 2003-dated report also presented potential cancer risks for the six (6) monitored Seattle metro area sites discussed in their report. Based on their average numbers over a 70-year exposure period, the estimated cancer risk for benzene was shown as 10.3 in a million while the estimated cancer risk for 1,3-butadiene was depicted as 3.4 in a million.

The PSCAA 2003 report also presented comparative potential cancer risks for Snohomish County related to benzene and 1,3-butadiene based on an ambient air concentration model developed in 1996 by National-scale Air Toxics Assessment (NATA) and estimating a 70-year exposure period. Based on that particular data, the potential cancer risk from benzene in Snohomish County was approximately 13 in a million while the potential cancer risk from 1,3-butadiene was approximately 1 in a million. Based on this limited comparative data presented by the PSCAA, and assuming a less than 70 year tenant occupancy (exposure period), while <u>some</u> exposure risk is present at the subject site based on the values observed from the current round of testing, the potential cancer risk to on-site tenants may be considered comparatively "low".

In an effort to mitigate potential long term health risk related to airborne benzene and 1,3-butadiene and acknowledging that indoor air concentrations were higher compared to outdoor levels, the client may wish to consider installation of fans or other methods of increasing ventilation to the buildings. New window, door, and floor seals may also prevent seepage of airborne contaminants into the buildings. Additionally, any new structures erected on the site should be constructed with a vapor barrier as part of its foundation design.

LIMITATIONS

This report has been prepared for the exclusive use of Milestone Properties and their several representatives for specific application to this site. Our work for this project was conducted in a manner consistent with that level of care and skill normally exercised by members of the environmental science profession currently practicing under similar conditions in the area, and in accordance with the terms and conditions set forth in our proposal dated March 2, 2016. The findings and conclusions of this study are based upon the results of laboratory testing of selected samples obtained from separated localities and conditions may vary between those localities or at other locations or media or at other times. No other warranty, expressed or implied, is made. If new information is developed in future site work which may include excavations, borings, studies, etc., Environmental Associates, Inc., must be retained to reevaluate the conclusions of this report and to provide amendments as required.



Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

🟥 **Site Location**

➤ **Inferred Approximate Direction of Groundwater Flow at Subject**

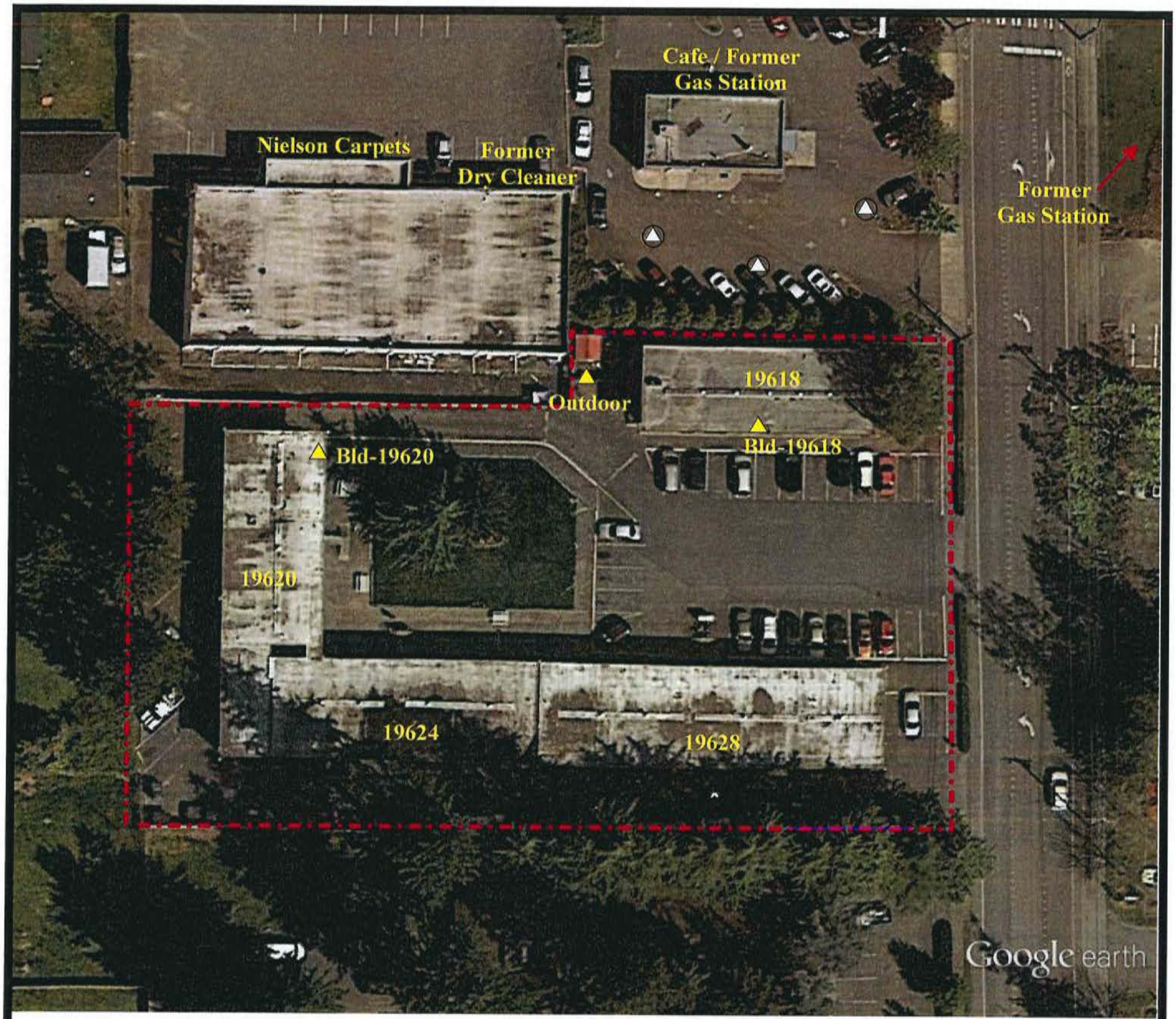
ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

VICINITY/TOPOGRAPHIC MAP

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	*Date:*		*Plate:*
JN 36005-1	March 2016		1



◬ **Approximate Monitoring Well Locations**

▲ **Approximate Air Sample Locations**

⬚ **Approximate Site Boundary**

◤ **Inferred Approximate Direction of Groundwater Flow at Subject**

N

ENVIRONMENTAL
ASSOCIATES, INC.

1380 - 112th Avenue N.E., Ste. 300
Bellevue, Washington 98004

SITE PLAN

Chri-Mar Apartments
19618-19628 68th Avenue West
Lynnwood, Washington

Job Number:	*Date:*		*Plate:*
JN 36005-1	March 2016		2

TABLE 1 - Select VOCs - Air Sampling Results
All results and limits in micro-grams per cubic meter (ug/M^3)

Sample Name	Location	Tetrachloroethene (PCE)	Trichloroethene (TCE)	Benzene	1, 3-Butadiene
Bld-19618	Ground Floor Manager Office	0.260	<0.054	***0.990***	***0.140***
Bld-19620	Ground Floor Unit #123	0.500	0.054	***1.100***	***0.270***
Outdoor	Central/north exterior near property line	0.350	<0.054	***0.710***	***0.088***
WDOE MTCA Method-B Indoor Air Target Compliance levels		9.62	0.37	0.321	0.0833

Bold and Italics indicate concentrations of compounds that exceed the WDOE Standard Method-B Air Target Compliance Levels.

APPENDIX A

Lab Reports

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James E. Bruya, Ph.D.
Yelena Aravkina, M.S.
Michael Erdahl, B.S.
Arina Podnozova, B.S.
Eric Young, B.S.

3012 16th Avenue West
Seattle, WA 98119-2029
(206) 285-8282
fbi@isomedia.com
www.friedmanandbruya.com

March 16, 2016

Eric Zuern, Project Manager
Environmental Associates, Inc.
1380 112th Ave. NE, 300
Bellevue, WA 98004

Dear Mr. Zuern:

Included are the results from the testing of material submitted on March 9, 2016 from the Chri-Mar Apts, PO 36005-1, F&BI 603158 project. There are 7 pages included in this report. Any samples that may remain are currently scheduled for disposal in 30 days. If you would like us to return your samples or arrange for long term storage at our offices, please contact us as soon as possible.

We appreciate this opportunity to be of service to you and hope you will call if you have any questions.

Sincerely,

FRIEDMAN & BRUYA, INC.

Michael Erdahl
Project Manager

Enclosures
EAI0316R.DOC

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

CASE NARRATIVE

This case narrative encompasses samples received on March 9, 2016 by Friedman & Bruya, Inc. from the Environmental Associates Chri-Mar Apts, PO 36005-1, F&BI 603158 project. Samples were logged in under the laboratory ID's listed below.

Laboratory ID	Environmental Associates
603158 -01	Bld-19618
603158 -02	Outdoor
603158 -03	Bld-19620

All quality control requirements were acceptable.

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Bld-19618	Client:	Environmental Associates
Date Received:	03/09/16	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	603158-01
Date Analyzed:	03/09/16	Data File:	030909.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	100	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	0.14	0.062
Benzene	0.99	0.31
Trichloroethene	<0.054	<0.01
Tetrachloroethene	0.26	0.038

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Outdoor	Client:	Environmental Associates
Date Received:	03/09/16	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	603158-02
Date Analyzed:	03/09/16	Data File:	030908.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	99	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	0.088	0.040
Benzene	0.71	0.22
Trichloroethene	<0.054	<0.01
Tetrachloroethene	0.35	0.051

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Bld-19620	Client:	Environmental Associates
Date Received:	03/09/16	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	603158-03
Date Analyzed:	03/09/16	Data File:	030910.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	106	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	0.27	0.12
Benzene	1.1	0.34
Trichloroethene	0.054	0.010
Tetrachloroethene	0.50	0.074

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Method Blank	Client:	Environmental Associates
Date Received:	Not Applicable	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	06-471 mb
Date Analyzed:	03/09/16	Data File:	030907.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	96	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	<0.022	<0.01
Benzene	<0.032	<0.01
Trichloroethene	<0.054	<0.01
Tetrachloroethene	<0.068	<0.01

Date of Report: 03/16/16
Date Received: 03/09/16
Project: Chri-Mar Apts, PO 36005-1, F&BI 603158

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF AIR SAMPLES FOR VOLATILES BY METHOD TO-15 SIM

Laboratory Code: Laboratory Control Sample

Analyte	Reporting Units	Spike Level	Percent Recovery LCS	Acceptance Criteria
1,3-Butadiene	ppbv	1	108	70-130
Benzene	ppbv	1	107	70-130
Trichloroethene	ppbv	1	110	70-130
Tetrachloroethene	ppbv	1	110	70-130

Data Qualifiers & Definitions

a - The analyte was detected at a level less than five times the reporting limit. The RPD results may not provide reliable information on the variability of the analysis.

b - The analyte was spiked at a level that was less than five times that present in the sample. Matrix spike recoveries may not be meaningful.

ca - The calibration results for the analyte were outside of acceptance criteria. The value reported is an estimate.

c - The presence of the analyte may be due to carryover from previous sample injections.

cf - The sample was centrifuged prior to analysis.

d - The sample was diluted. Detection limits were raised and surrogate recoveries may not be meaningful.

dv - Insufficient sample volume was available to achieve normal reporting limits.

f - The sample was laboratory filtered prior to analysis.

fb - The analyte was detected in the method blank.

fc - The compound is a common laboratory and field contaminant.

hr - The sample and duplicate were reextracted and reanalyzed. RPD results were still outside of control limits. Variability is attributed to sample inhomogeneity.

hs - Headspace was present in the container used for analysis.

ht – The analysis was performed outside the method or client-specified holding time requirement.

ip - Recovery fell outside of control limits. Compounds in the sample matrix interfered with the quantitation of the analyte.

j - The analyte concentration is reported below the lowest calibration standard. The value reported is an estimate.

J - The internal standard associated with the analyte is out of control limits. The reported concentration is an estimate.

jl - The laboratory control sample(s) percent recovery and/or RPD were out of control limits. The reported concentration should be considered an estimate.

js - The surrogate associated with the analyte is out of control limits. The reported concentration should be considered an estimate.

lc - The presence of the analyte is likely due to laboratory contamination.

L - The reported concentration was generated from a library search.

nm - The analyte was not detected in one or more of the duplicate analyses. Therefore, calculation of the RPD is not applicable.

pc - The sample was received with incorrect preservation or in a container not approved by the method. The value reported should be considered an estimate.

ve - The analyte response exceeded the valid instrument calibration range. The value reported is an estimate.

vo - The value reported fell outside the control limits established for this analyte.

x - The sample chromatographic pattern does not resemble the fuel standard used for quantitation.

Send report to
Eric Zuern, Environmental Associates, Inc.

SAMPLE CHAIN OF CUSTODY

ME 03/09/16

Report 603158

ill to: Company Milestone Properties

Address PO Box 18379

City, State, Seattle WA

Phone (EAI) 425-455-9025 Email info@environmentalassociatesinc.com

SAMPLERS (signature)

PROJECT NAME Chri-Mar Apts

PO # 36005-1

REMARKS send report to Eric @ EAI

INVOICE TO Milestone Prop

Page # 1 of 1

TURNAROUND TIME
[✓ Standard] 1 week
· RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
[✓ Dispose after 30 days]
· Archive Samples
· Other

ANALYSIS REQUESTED

Sample Name	Lab ID	Canister ID	Flow Contr. ID	Date Sampled	Field Initial Press. (Hg)	Field Initial Time	Field Final Press. (Hg)	Field Final Time	TO-15 Full Scan	TO-15 BTEXN	TO-15 cVOCs	TO-15 [illegible] Benzene, 1,3 Butadiene	Notes
Bld-19618	01	18580	07853	3-8-16 3-9-16	29	8:10	5	8:00				X	
outdoor	02	18574	[illegible]	3-8-16 3-9-16	28	8:20	5	8:10				X	
Bld-19620	03	[illegible]	[illegible]	3-8-16 3-9-16	[illegible]	8:50	7	[illegible]				X	

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282
Fax (206) 283-5044

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Eric Zuern	EAI	3-9-16	9:40
Received by:	Nhan Phan	FeBI	3-9-16	9:40
Relinquished by:				
Received by:				

FORMS\COC\COCTO-15.DOC

Samples received at 19 °C

APPENDIX B

2003 Puget Sound Clean Air Agency Report

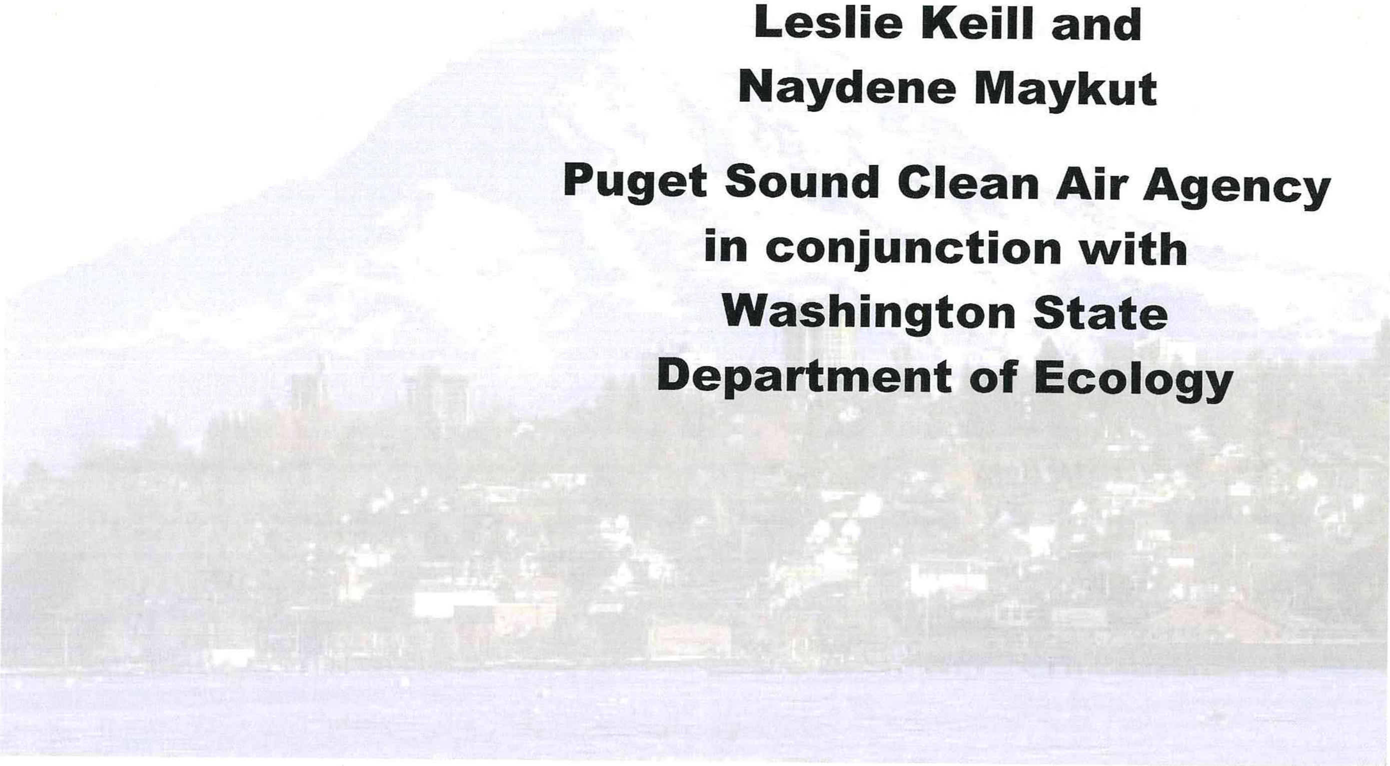
PUGET SOUND
Clean Air Agency

Final Report: Puget Sound Air Toxics Evaluation

October 2003

Leslie Keill and
Naydene Maykut

Puget Sound Clean Air Agency
in conjunction with
Washington State
Department of Ecology



For more information about this report, call Leslie Keill at (206) 689-4022

Puget Sound Clean Air Agency
110 Union Street, Suite 500
Seattle, WA 98101-2038
(206) 343-8800 or
(800) 552-3565
www.pscleanair.org

Printed on recycled paper, October 2003

This report was released as a draft in 2002 and we received comments on the draft from a variety of reviewers. These reviewers include Dr. Sally Liu from the University of Washington, Dr. Jane Koenig from the University of Washington, Dr. David Solet from the Metro King County Public Health Department, Dr. Matt Kadlec from the Washington Department of Ecology, Dr. Harriet Ammann from the Washington Department of Health, Ms. Julie Wroble from the US Environmental Protection Agency, and Dr. Kay Jones from Zephyr Consulting Company. We also received comments from Dr. Houck of Omni Consulting on behalf of the Hearth Products Association.

The authors addressed many of these comments in this final report. We would like to thank our reviewers, and appreciate the time they took to provide valuable feedback on our draft.

Table of Contents

List of Tables

List of Figures

Executive Summary

The Puget Sound Clean Air Agency conducted this screening study to identify chemicals and emission sources that pose the greatest potential health risks to citizens in the Puget Sound region. We also hope to better characterize the potential health risks to our three million residents from a group of air contaminants referred to as air toxics. This study is intended to assist the Agency in focusing resources on those emissions and sources that may pose the highest risks. The results should also help improve air toxics regulations and voluntary programs. The estimates of cancer and non-cancer health effects should not be viewed as actual cancer or non-cancer cases resulting from air pollution but as an estimate of relative impact of the evaluated toxic-air pollutants so the Agency can prioritize its efforts to reduce air pollution.

Defining Air Toxics

Air toxics are different from the 6 traditional air pollutants or "criteria pollutants" that have been regulated by environmental regulatory agencies for a number of years. Our agency defines "air toxics" as a broad category of chemicals that covers over 400 air pollutants along with woodsmoke and diesel particles. Similarly, the United States Environmental Protection Agency (USEPA) commonly refers to "air toxics" as a synonym for the 189 hazardous air pollutants listed in the 1990 amendments to the federal Clean Air Act. Because resources are not available to evaluate every chemical, this study evaluates a short list of 17 to 30 air toxics. We hope to expand the list of toxics when more resources become available.

Persistent, Bioaccumulative Toxics (PBTs)

Some persistent, bioaccumulative toxics (PBTs) such as mercury, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), cadmium, and arsenic were included in our study. However, we evaluate potential health risks only from the inhalation pathway, as the ingestion pathway was considered to be beyond the scope of this study.

Methods

This study uses basic risk assessment concepts and models, such as toxicity and exposure assessment, to provide a general overview of the potential health impacts that could be due to air toxics. Because of limited resources, this report does not perform a comprehensive risk assessment, which would include more detailed analyses and discussion of toxicity and exposure parameters, as well as a more in-depth risk characterization section. More comprehensive information on various details of this study can be found in the technical support documents referenced throughout this report.

Toxicity

The toxicity chapter includes dose-response information on the variety of air toxics evaluated in the Puget Sound region. The majority of this information is based on toxicity analyses performed by USEPA and included in their Integrated Risk Information System (IRIS). For some chemicals and mixtures, such as diesel particulate matter, chromium, and woodsmoke, we depart from recommended USEPA IRIS toxicity values. For example, for diesel particulate matter, we use the California Environmental Protection Agency's toxicity evaluation. Our rationale for this and other departures is described in the toxicity chapter.

Exposure

The toxicity values described above are combined with exposure assessment information to estimate both cancer and non-cancer potential health risks. We use results from three different exposure assessments to characterize air emissions and to estimate potential exposure concentrations for the residents of the Puget Sound area. These three exposure assessments include a monitoring study conducted in the greater Seattle/King County area, and two modeling assessments conducted as part of USEPA National-scale Air Toxics Assessment (NATA) in the four counties in the Puget Sound Clean Air Agency jurisdiction (King, Kitsap, Pierce, and Snohomish counties).

The monitoring study, which was conducted by the Washington State Department of Ecology in partnership with the Puget Sound Clean Air Agency and USEPA, sampled outdoor air at six different locations throughout the greater Seattle/King County area during 2000 and 2001. These six locations include areas near or in Beacon Hill, Georgetown, Lake Sammamish, Lake Forest Park, the Maple Leaf reservoir in north Seattle, and the city of SeaTac.

In addition to the monitoring study, we used exposure estimates from two models used by USEPA in their nationwide air toxics study entitled the National-scale Air Toxics Assessment (NATA). In this study, USEPA predicts outdoor air concentrations using the ASPEN model for 32 air toxics in counties across the country. We obtained the outdoor air concentrations for the four Puget Sound counties, compared them to monitored concentrations, and calculated potential health risks associated with those concentrations.

The third model used to predict exposure concentrations is also part of the NATA study. This model, entitled the Hazardous Air Pollutant Exposure Model4 (HAPEM4), predicts human exposures to the outdoor air pollutants by considering typical human behaviors and micro-environments where these outdoor pollutants might accumulate or dissipate. For example, this model uses average commute time estimates for a variety of individuals to estimate potential exposures to vehicle exhaust while riding in cars or waiting in traffic. Exposures such as these are combined for multiple activities and locations to estimate an average exposure concentration for each of the 32 air toxics for different population groups.

All exposure concentrations are based on annual averages or medians (the 50th percentile), and residents are assumed to be exposed for 70 years, an average lifetime for an individual. We also assumed that these residents are healthy adults. Because of limited resources, we did not include exposure or toxicity adjustments specific to children, such as changes to body weight. Some health-protective assumptions (e.g., assuming a 70-year exposure period) are included in the toxicity estimates to protect sensitive people such as the elderly or diseased individuals. The health risk estimates are based on a combination of average and reasonably conservative or health-protective assumptions. *This is expected to lead to risk estimates that are reasonably high for the chemicals included in the analysis, but not worst case.*

Results

The primary health effect of concern from the chemicals evaluated in this study is cancer. More specifically, lung cancer is associated with both diesel soot and woodsmoke, although it is also associated with 1,3-butadiene, a mobile source-related contaminant. In addition to lung cancer, leukemia, nasal, and liver cancers are associated with chemicals that ranked high (e.g., benzene, formaldehyde) in our study. The majority of the cancer risk estimated in our study is due to diesel soot. On average, diesel soot accounts for somewhere between 70% to 85% of the total cancer risk from air toxics in our area. Of the PBTs, arsenic is the only single compound to appear among the top ranking toxics, however, DPM and woodsmoke include numerous PAHs, so we conclude that these mixtures also contribute PBTs to the air in the Puget Sound region.

Our study found that the significant non-cancer health effects from air toxics in our area are primarily due to acrolein. This chemical is associated with upper respiratory irritation.

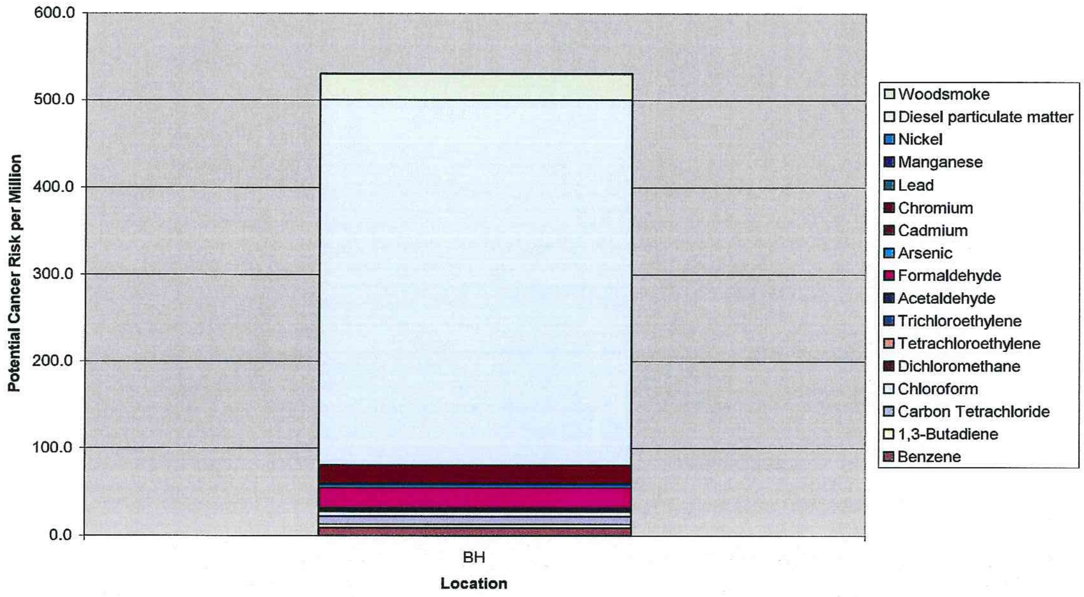
It is important to note, however, that our study does *not* include the serious non-cancer health effects associated with the particle fraction of 2 air toxics: diesel soot and woodsmoke. Non-cancer health effects associated with these particles have been extensively studied and documented in the scientific literature, and a full analysis is beyond the scope of this study.

Potential Cancer Risks

The average cancer risk estimates, even when human and pollutant movement/penetration are considered, are similar among the different methods of calculating exposure concentrations, and across different areas of the Puget Sound region. For example, average cancer risk estimates for King County alone range from approximately 400 to 700 in a million, based on 32 air toxics from the human exposure model and outdoor model data, respectively.

The average cancer risk estimates for the monitored data are approximately 550 in a million for the Beacon Hill area (see Figure ES-1). As described above, the monitoring study only looked at a total of 17 air toxics. The total cancer risks associated with the King County modeled estimates are higher because they include more chemicals, not because the estimates of each chemical are higher.

Figure ES-1: Potential Cancer Risks at Beacon Hill including Diesel Particulate Matter and Woodsmoke



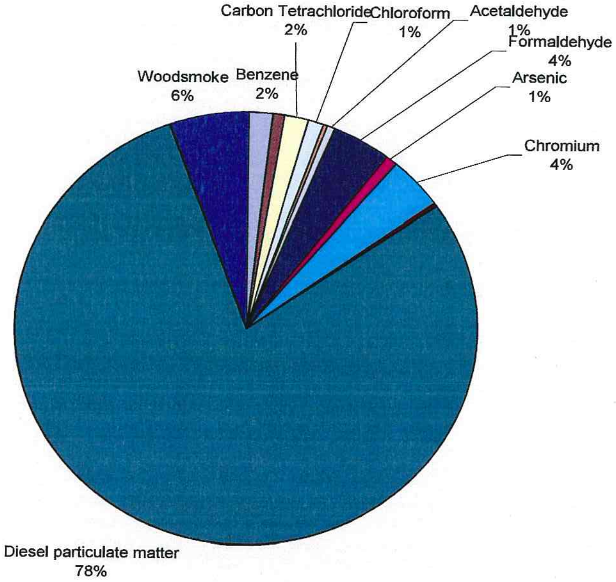
The average cancer risk estimates are also similar in the remaining three counties in the Puget Sound jurisdiction (Kitsap, Pierce, and Snohomish counties), although we do not have monitored information to confirm our findings. The estimated cancer risks range from 400 in a million for all air toxics included in the HAPEM4 model in Snohomish County, including diesel soot, to a high of 600 in a million as an average for 32 ASPEN-modeled ambient concentrations in King County, including diesel soot. All risk estimates reflect a 70-year exposure period. Upper 95th percentile risk estimates based on the modeled ambient concentrations are approximately 980 in a million for King County.

The air toxics that contribute most to the cancer risks are also consistent across the different methods of analysis. **The top toxics for all 3 methods include diesel soot, benzene, formaldehyde, and carbon tetrachloride**. **Woodsmoke** also contributes to the risk estimates based on the monitored data.

In addition, the percent contribution of the top air toxics is also very similar across the different methods of analysis. For example, at Beacon Hill, diesel soot accounts for over 75% of the potential cancer risks (see Figure ES-2) with another 10% or so coming from volatile organic compounds (VOCs) associated with mobile sources. The King County results from the outdoor

NATA model estimate diesel particulate matter at 86%, with other mobile-source-related chemicals at about 8%, and stationary-source-related chemicals at about 6%. Similarly, the NATA human exposure results indicate a diesel soot contribution of 86%, with other mobile-source-related chemicals at 7%, and stationary sources at about 4%. ***This indicates that mobile sources are likely to account for approximately 85% to 95% of the potential cancer risks among outdoor air toxics.***

Figure ES-2: Contributions to Potential Cancer Risk at Beacon Hill (2001)



The only emission source that ranks high in the monitoring data but not in the modeled data is woodsmoke. This is because woodsmoke emissions are estimated differently. The modeled concentrations associated with woodsmoke reflect very few chemicals in the woodsmoke mixture, while the concentrations based on monitored data reflect a greater number of chemicals present in woodsmoke.

Uncertainties

The large number of assumptions necessary in our study reflects the amount of uncertainty and variability associated with the health risk estimates. It is possible that risk is underestimated because (1) not all air toxics are considered in this analysis, and (2) many chemicals have been shown to accumulate in indoor micro-environments, which could increase exposure. In addition, potential cancer estimates will underestimate risk for those individuals living near large point sources or "hot spots". Alternatively, risk may be underestimated or overestimated by assuming that the concentration at the monitor accurately reflects lifetime exposure to ambient pollutants. Obviously, chemical concentrations could increase or decrease throughout the lifetime exposure period.

It is important to note that this analysis does not evaluate indoor sources of air pollution (i.e., from paints, home furnishings, cleaning products, building materials, and other indoor sources). Uncertainties in the toxicity information could also serve to over- or underestimate potential risk estimates. These are only a few of the uncertainties associated with this study. A more detailed discussion can be found in Chapter 5.

In summary, we use screening risk estimates as a tool to focus Clean Air Agency attention on those compounds and mixtures that are likely to present the greatest risk of cancer and some non-cancer effects. Concentrations, and corresponding risks, were relatively consistent among areas measured and modeled throughout the Puget Sound region. Although some differences were apparent, overall it is clear that the sites and the region as a whole have similar emission sources of concern (e.g., diesel particulate matter, mobile-source-related VOCs, and probably woodsmoke).

Diesel soot ranks high in potential contributions to cancer risk, higher than other air toxics measured in this study. However, volatile organics associated with mobile sources, such as benzene and formaldehyde, contribute significantly to the potential cancer risks from air toxics. Diesel soot, benzene, 1,3-butadiene, and formaldehyde are classified as class A or B carcinogens under the USEPA cancer rating system. This indicates that USEPA is relatively confident that these chemicals probably cause cancer in humans. These chemicals should have high priority during development of an air toxics reduction program for the Puget Sound area. Finally, acrolein appears to present a potential non-cancer risk as well. As stated earlier, the non-cancer health effects associated with the particulate-matter-related combustion mixtures (e.g., woodsmoke and diesel soot) are not evaluated here, but present serious non-cancer health risks.

Chapter 1: Introduction

1.1 Purpose

The purpose of this study is to characterize air emissions and to identify those air toxics and sources that may pose the greatest risks to residents of the Puget Sound area. This analysis uses results from a monitoring study conducted in the greater Seattle/King County area and modeling studies conducted in the four counties in the Puget Sound Clean Air Agency jurisdiction (King, Kitsap, Pierce, and Snohomish counties). The United States Environmental Protection Agency (USEPA) performed the modeling in its National-scale Air Toxics Assessment (NATA) project to estimate potential cancer and non-cancer risks associated with the ambient air concentrations of those toxics. In addition, results from a human exposure study provide a general view of the potential exposures and health risks when average or typical human behaviors are considered.

The Puget Sound Clean Air Agency will use the results from this study to evaluate existing air toxics regulations, to focus on compounds of greatest concern, and to identify areas of potential improvement in its air toxics program. These results are intended to provide general direction to planners and managers. These results are *not* intended to provide exact estimates of potential health risk.

The estimates of cancer and non-cancer health effects should not be viewed as actual cancer or non-cancer cases resulting from air pollution, but as an estimate of relative impact of the toxic air pollutants evaluated in order to prioritize Agency efforts at reducing exposures. The estimates are based on a combination of average and reasonably conservative or health-protective assumptions. This is expected to lead to risk estimates that are reasonably high for the chemicals included in the analysis, but not the worst case scenario.

1.2 Methods

Regulatory agencies typically employ risk-based approaches to evaluate potential health impacts from exposures to toxic chemicals. This study uses basic risk assessment concepts and models to provide a general overview of the potential air toxics problems that could be due to air toxics. However, we have not performed a comprehensive risk assessment, which would include more detailed discussions of toxicity and exposure parameters used to calculate risk estimates.

For the purposes of conducting the screening analysis, potential cancer risks are calculated using the following equation:

Cancer Risk = Exposure concentration x Toxicity

where:
Exposure concentration = annual average ($\mu g/m^3$)
Toxicity = unit risk for carcinogens (cancer risk/1 $\mu g/m^3$)

Similarly, non-cancer risks are estimated by calculating a hazard index, using the following equation:

Hazard Index (HI) = Exposure concentration/Toxicity

where:
Exposure concentration = annual average ($\mu g/m^3$)
Toxicity = reference concentration ($\mu g/m^3$)

Exposure concentrations used to calculate potential cancer and non-cancer health risks were obtained through three different methods. These methods are discussed generally below, and in more detail in Chapters 3 and 4 of this report.

Because resources were not available, a complete risk assessment was not conducted. However, the report includes the primary risk assessment components such as a toxicity or dose-response section, an exposure assessment section, and a risk characterization section. It includes a general discussion of the two major types of exposure models (ASPEN and HAPEM4, discussed later) used to calculate exposure concentrations. More comprehensive descriptions of these models were not included for two reasons. First, adequate resources were not available to the Agency, and second, these models are described and discussed extensively in technical support documents that accompany the NATA project.[1] However, general descriptions of the model

---

[1] USEPA. ***National-Scale Air Toxics Assessment for 1996.*** Office of Air Quality Planning and Standards. EPA-453/R-01-003. January 2001.

assumptions are included when appropriate, and the supporting documentation is referenced accordingly throughout this document.

1.3 Exposure

In this evaluation, three separate methods are used to provide exposure estimates. These include:

1. Monitored ambient concentrations
2. Modeled ambient concentrations
3. Modeled "human exposure concentrations" (where human activities and locations are considered in estimating exposures to air pollutants)

Results from each method of predicting exposure are presented and compared with toxicity values and evaluated for potential or relative risk.

1.4 Toxicity

Although several different methods are used to estimate exposures, essentially one method is used to evaluate toxicity associated with airborne toxics. In most cases, USEPA-recommended toxicity factors are used as the basis for quantitative dose-response information. These values are usually obtained from the USEPA Integrated Risk Information System (IRIS) database. However, in some cases neither IRIS values nor USEPA values in the NATA project were available. In these instances, the alternative values were usually chosen from other sources. The basis for each toxicity factor and rationale for any adjustments are included in Chapter 2.

1.5 Conclusions and Recommendations

In the last chapter, the results from the different methods used in the evaluation are compared. Discrepancies and similarities are discussed. In addition, the uncertainties and limitations of the evaluation and the impact on the results are described. Finally, recommendations for Agency priorities are presented.

Chapter 2: Toxicity Estimates

Although several different methods are used to evaluate potential exposures, the same toxicity values are used for each of the analyses. Rather than describe toxicity in each section, toxicity estimates and the details associated with them are described in this section.

2.1 Separating Carcinogenic and Non-carcinogenic Impacts

Toxicity estimates for carcinogens and non-carcinogens are derived through different processes and reflect fundamentally different concepts in toxicity. Toxicity values for non-cancer effects are based on the idea that a threshold exists for these health effects. USEPA believes that carcinogenic effects may not have thresholds, and that any exposure is associated with some corresponding (although very low) risk of disease. Physiological changes leading to cancer may occur over many years or decades.

Carcinogenic health effects are presented as a probability or risk of developing cancer. This can be viewed in two ways. First, the risk concept can be viewed as an additional cancer risk for each exposed individual. For example, a risk of one in a million could be added to the existing lifetime cancer risk of one in two to one in three (this excludes consideration of genetic or other susceptibilities) for most individuals.[2] USEPA also interprets risk estimates as potential cancer cases over the population of potentially exposed individuals. For example, a one in a million risk can also be viewed as one additional cancer case for every million people exposed to that concentration.[3,4]

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[2] Ries LAG, Eisner MP, Kosary CL, Hankey BF, Miller BA, Clegg L, Mariotto A, Fay MP, Feuer EJ, Edwards BK (eds). *SEER Cancer Statistics Review, 1975-2000*, National Cancer Institute. Bethesda, MD, http://seer.cancer.gov/csr/1975_2000, 2003. http://seer.cancer.gov/csr/1975_2000/results_merged/topic_lifetime_risk.pdf

[3] USEPA IRIS Glossary defines the unit risk value as **Unit Risk:** The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/L in water, or 1 $\mu g/m^3$ in air. The interpretation of unit risk would be as follows: if unit risk = 1.5×10^{-6} µg/L, 1.5 excess tumors are expected to develop per 1,000,000 people if exposed daily for a lifetime to 1 µg of the chemical in 1 liter of drinking water.

[4] USEPA also defines "one in a million risk" in the NATA glossary (http://www.epa.gov/ttn/atw/nata/gloss1.html) as follows: **1 in a Million Cancer Risk:** A risk level of 1 in a million implies a likelihood that up to one person, out of one million equally exposed people would contract cancer if exposed continuously (24 hours per day) to the specific concentration over 70 years (an assumed lifetime). This would be in addition to those cancer cases that would normally occur in an unexposed population of one million people. Note that this assessment looks at **lifetime** cancer risks, which should not be confused with or compared to **annual** cancer risk estimates. To compare an annual cancer risk estimate with the results in this assessment, multiply that annual estimate by a factor of 70 or alternatively divide the lifetime risk by a factor of 70. A 1 in a million lifetime risk to the U.S. public in 1996 was 250 cancer cases over a 70-year period.

In contrast to carcinogenic health effect evaluation, non-carcinogenic effects are presented as exceeding (or not exceeding) a particular guideline, referred to as a hazard index. The hazard index is a ratio of the estimated exposure concentration, divided by a concentration deemed to have no adverse effect from a lifetime exposure to that level. This non-carcinogen evaluation does not calculate a probability but instead determines whether a particular exposure is above or below a threshold above which there will be an adverse effect. Levels below the hazard index are deemed to be of no risk. Because of these differences, carcinogenic effects are evaluated separately from non-carcinogenic effects.

2.2 Carcinogenic Effects

Potential carcinogenic effects are measured using unit risk factors. USEPA defines the unit risk factor (URF) as "a measure of the potential cancer risk of exposure to 1 microgram chemical per cubic meter of air over a 70-year period."[5] URFs are typically derived from animal laboratory studies, although human data from epidemiological or clinical studies can sometimes provide appropriate dose-response information. In addition, the URF is considered to be highly conservative or protective of health (it is based on the upper 95th percentile of the potency slope). In other words, if we use URFs, it is unlikely that the potential cancer-risk values underestimate the true cancer risk associated with the specified exposure concentrations, and very likely overestimate the true risk.

In addition to the quantitative evaluation, USEPA also assigns each carcinogen a confidence rating based on the certainty associated with the supporting toxicological and health data. The values in this rating are A through E, with Group A being associated with the greatest certainty of evidence for causing cancer in humans and Group E having evidence that the chemical does not cause cancer in humans.

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[5] See USEPA IRIS definition in footnote #2 above.

URFs used in this report are listed in Table 2-1 below. We used the same values as those in the NATA project. Most of the unit risk factors were obtained from the USEPA IRIS database, however if alternative sources are used, they are noted.[6]

It is important to note that most chemicals lack sufficient information to develop URFs. For example, adequate health information on which to base risk estimates is not available for the majority of chemicals used in commerce.[7] In addition, synergistic and/or antagonistic effects among the chemicals are not considered in these potency estimates. In other words, we do not know how the toxicity of these chemicals changes when administered in a mixture with other chemicals (except for woodsmoke and DPM which are discussed below). Finally, USEPA typically notes that the cancer risks associated with carcinogens could be as low as zero. Uncertainties associated with the risk estimates are discussed more fully in the last chapter of this document.

Specific URFs are available for two complex chemical mixtures, woodsmoke and diesel particulate matter, although they are not endorsed by USEPA. These two mixtures account for 46% of the total PM2.5 measured in Seattle, and could present potential cancer risk.[8] These values and the supporting documentation for each are also discussed below.

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[6] USEPA. ***National-Scale Air Toxics Assessment for 1996***. Office of Air Quality Planning and Standards. EPA-453/R-01-003. January 2001.

[7] National Research Council. ***Toxicity Testing: Strategies to Determine Needs and Priorities***. Steering Committee on Identification of Toxic and Potentially Toxic Chemicals for Consideration by the National Toxicology Program. National Academy Press. Washington DC. 1984.

[8] Maykut N, J Lewtas, E Kim, T Larson. *Source Apportionment of PM2.5 at an urban IMPROVE site in Seattle, WA.* Manuscript accepted to Environmental Science and Technology, August 2003.

Table 2-1: Unit Risk Factors and Cancer Ratings

Chemical	Unit Risk Factor (risk /µg/m^3)	USEPA Cancer Rating	Reference
1) Acrylonitrile	6.8E-05	B1	IRIS
2) Benzene	7.80E-06	A	USEPA IRIS file, downloaded 10/22/01
3) 1,3-Butadiene	3.0E-05	A	USEPA NATA[9]: EPA NCEA[10]
4) Carbon tetrachloride	1.50E-05	B2	USEPA IRIS file, downloaded 10/22/01
5) Chloroform	2.30E-05	B2	USEPA IRIS file, downloaded 10/22/01
6) Dichloromethane	4.70E-07	B2	USEPA IRIS file, downloaded 10/22/01
7) 1,3-Dichloropropene	4.0E-06	B2	USEPA NATA: IRIS
8) Diesel particulate matter (DPM)	3.0E-04	B2	CALEPA/OEHHA
9) Ethylene dibromide	2.2E-04	B2	USEPA NATA: IRIS
10) Ethylene dichloride	2.6E-05	B2	USEPA NATA: IRIS
11) Ethylene oxide	8.8E-05	B1	CalEPA
12) Hexachlorobenzene	4.6E-04	B2	USEPA NATA: IRIS
13) Hydrazine	4.9E-03	B2	USEPA NATA: IRIS
14) 7-PAHs	2.0E-04	B2	USEPA NATA: OAQPS
15) PCBs	1.0E-04	B2	USEPA NATA: IRIS
16) POM	5.5E-04	NA	USEPA NATA: OAQPS
17) Propylene dichloride	1.9E-05	C	USEPA NATA: HEAST
18) Quinoline	3.4E-03	C	USEPA NATA: HEAST
19) 1,1,2,2-Tetrachloroethane	5.8E-05	C	IRIS
20) Tetrachloroethylene	5.6E-06	B2	USEPA NATA: CalEPA
21) Trichloroethylene	2.00E-06	B2	USEPA NATA: CalEPA
22) Acetaldehyde	2.20E-06	B2	USEPA NATA: IRIS
23) Formaldehyde	1.30E-05	B1	IRIS
24) Arsenic	4.30E-03	B1	IRIS
25) Beryllium compounds	2.4E-03	B1	IRIS
26) Cadmium	1.80E-03	B1	IRIS
27) Chromium (VI)	1.2E-02	A	USEPA NATA: IRIS
28) Lead	1.20E-05	B2	USEPA NATA: CalEPA
29) Nickel	4.8E-04	A	USEPA NATA: IRIS
30) Woodsmoke	1.0E-05	NA	Lewtas, 1988

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[9] USEPA. NATA Appendix G: *Health Effects Information Used In Cancer and Noncancer Risk Characterization for the NATA 1996 National-scale Assessment.* http://www.epa.gov/ttn/atw/nata/nettables.pdf

[10] EPA National Center for Environmental Assessment.

2.2.1 Woodsmoke Unit Risk Factor

Woodsmoke is comprised of a variety of chemicals, including but not limited to: particulate matter, nitrogen oxides, carbon monoxide, sulfur oxides, volatile organic compounds, and polycyclic aromatic hydrocarbons (PAHs).[11] Many of the chemicals listed as constituents in woodsmoke have been identified as probable or likely human carcinogens. However, woodsmoke as a mixture has not been thoroughly evaluated for its carcinogenicity by USEPA or other health agencies. Evaluations by the World Health Organization suggest that vegetative burning, primarily woodsmoke, is likely to be carcinogenic, although sufficient data is not yet available.[12,13,14]

The unit risk factor for woodsmoke was developed through a comparative potency method where the mutagenicity and tumor initiating potency from particles emitted from several sources (e.g., diesels, woodsmoke and gasoline-powered automobiles) are systematically evaluated (Lewtas 1988). Lewtas uses bioassay-directed fractionation, a combination of several chemical separation and bioassay techniques, to identify the more toxic elements of several complex mixtures. In the Lewtas study, mutagenicity tests are conducted on different segments of the total mixtures. Segments showing higher mutagenic potencies are further divided into groups and tested until the components or segments with the highest potencies are identified.[15] The unit risk factor calculated for woodsmoke is listed in Table 2-1.

We recognize the Lewtas woodsmoke URF has not undergone the same rigorous evaluation as the other URFs used in our analysis. Although USEPA or CalEPA have not reviewed the

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[11] USEPA. *Emission Inventory Improvement Program, Vol. III, Chapter 2: Residential Wood Combustion.* Revised final. January 2001.

[12] World Health Organization (WHO). *Health Guidelines for Vegetation Fire Events.* Edited by DH Schwela, JG Goldammer, LH Morawska, O Simpson (Findings of the WHO-UNEP-WMO expert task force, Lima, Peru) 1999.

[13] WHO. The *Health Effects of Indoor Air Pollution Exposure in Developing Countries.* N Bruce, R Perez-Padilla, R Albalak. WHO/SDE/OEH/02/05. 2002.

[14] WHO. *Health Impacts of Biomass Air Pollution.* M. Brauer. Health Guidelines for Vegetation Fire Events, Lima Peru. Background papers. 1999.

[15] Lewtas J. *Genotoxicity of Complex Mixtures: Strategies for the Identification and Comparative Assessment of Airborne Mutagens and Carcinogens from Combustion Sources.* Funda and Appl Tox 10, 571-589. 1988.

woodsmoke URF, it is developed through a method recommended by the National Academy of Sciences and is published in a respected peer-reviewed journal.[16]

Also, as one reviewer of the draft of this report noted, vegetative burning could include other materials in addition to wood. Therefore, the woodsmoke unit risk factor may not appropriately estimate cancer risk from vegetative burning. As a result of these uncertainties, we use the woodsmoke unit risk as a general indicator of potency and potential risk.

2.2.2 Diesel Particulate Matter (DPM) Unit Risk Factor

Combustion of diesel fuel results in hundreds and probably thousands of organic and inorganic compounds in the diesel exhaust mixture. This mixture includes gaseous compounds such as carbon dioxide, carbon monoxide, aldehydes, benzene, and a wide range of PAHs. Dioxins have also been found in trace quantities in diesel exhaust.[17]

DPM is a component of diesel exhaust. DPM contains elemental carbon, organic carbon, and small amounts of nitrate, metals, and unidentified compounds. We focus on the particulate component of diesel exhaust because it is thought to contain the majority of the toxicity associated with the mixture. These particles and their adsorbed toxics penetrate deep into the lung during inhalation.

While specific knowledge of the role of the adsorbed chemicals is not known, it is hypothesized that the presence of such substances may influence particle toxicity. However, relatively little is known about the cumulative toxicity of the multiple toxics present in certain combustion mixtures. For example, it is possible that antagonism or synergism occurs among the chemicals and/or particles. In addition, there may be a variety of carcinogenic or toxic chemicals present in the mixture that have not yet been identified.[18] Therefore, we use unit risk factors for the whole

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[16] National Academy of Sciences. ***Complex Mixtures: Methods for In Vivo Toxicity Testing.*** National Academy Press. Washington DC, 1988.

[17] USEPA. ***Health Assessment Document for Diesel Engine Exhaust.*** Office of Research and Development. EPA/600/8-90/057F. Washington DC, May 2002.

[18] National Academy of Sciences, 1988.

mixture to estimate potential risk for diesel particulate and woodsmoke, rather than unit risk factors for individual carcinogens and summing the individual risks.

The carcinogenicity of diesel particulate matter is widely recognized by a number of health agencies including the USEPA,[19] CalEPA,[20] the US Department of Health and Human Services,[21] and the International Agency for Research on Cancer (IARC).[22] Because USEPA has not yet developed a unit risk factor for diesel particulate matter, the CalEPA value is used in this analysis.[23] CalEPA conducted an extensive literature review and analysis to develop the unit risk factor for DPM.[24] This value is listed in Table 2-1.

We recognize that USEPA has not identified a final unit risk factor for diesel particulate matter. However, USEPA states firmly that diesel particulate matter is a B1 or probable human carcinogen. In the absence of a confirmed URF, USEPA provides a range of potential cancer risks associated with environmental exposures (i.e., exposure levels typically experienced by the general population) in Section 8.4, entitled "Perspectives on Cancer Risk" of their Health Assessment Document. USEPA estimates this risk range to be approximately 6E-05 to 8E-04. This range assumes average environmental exposures of 0.8 - 4.0 $\mu g/m^3$ over a lifetime.[25] The annual estimate for Beacon Hill is 1.4 $\mu g/m^3$, within the range identified by USEPA. Therefore, we believe it is important to characterize potential risks associated with DPM in relation to other air pollutants.

The risk range used by EPA is also comparable to the unit risk estimate calculated by CalEPA. For example, assuming an environmental exposure of 1 $\mu g/m^3$, the range recommended by

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[19] USEPA. May 2002.

[20] CalEPA/OEHHA. *For the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant. Part B: Health Risk Assessment for Diesel Exhaust.* May 1998.

[21] National Toxicology Program. Public Health Service, US Department of Health and Human Services. ***9th Report on Carcinogens.*** Revised January 2001.

[22] International Agency for Research on Cancer (IARC). ***IARC Monograph on the Evaluation of Carcinogenic Risks to Humans. Vol. 46: Diesel and Gasoline Engine Exhausts***. 1989.

[23] CalEPA, 1998.

[24] CalEPA, 1998.

[25] USEPA 2002.

USEPA could be approximately 8E-05 to 2E-02.[26] The unit risk factor recommended by CalEPA, 3E-04, is also within USEPA's range if one assumes an exposure of 1 μg/m^3. This suggests that the CalEPA unit risk factor is not as highly conservative as USEPA's high-end estimates. The potential risk could also be zero.

One reviewer suggested that the cancer risks from DPM could be adequately evaluated by using the unit risk factors for individual carcinogenic PAHs and 6 metals. Unfortunately, this approach would only account for a small percentage of the potentially toxic chemicals found in DPM. USEPA and CalEPA state that the mechanism of action for DPM carcinogenesis has not yet been established.[27] In fact, both USEPA and CalEPA suggest that Diesel Particulate Matter (DPM) toxicity is related to a complex combination of factors such as:

- The physical characteristics of fine particles. USEPA states "The carcinogenicity of diesel particles…appears to be related, as least to some extent, to their small size and convoluted shape, which results in a large specific particle surface area."[28] It is possible that this large surface area may act as a carrier for many chemicals.
- Diesel particles may enhance PAH toxicity, suggesting a possible synergistic relationship between PAHs and particles.[29] If so, carcinogenic potency would be underestimated by using PAHs alone to evaluate cancer risk.
- Exposure to both DPM-related organics and carbon particles (i.e., DPM without organics such as PAHs) may produce reactive oxygen species that could result in a cascade of events leading to DNA damage.

In summary, it is simply not clear how DPM causes cancer or what the causative agents might be. Therefore, reliance on the toxicity of a limited number of PAHs to estimate potential cancer risk for a complex mixture such as DPM could dramatically underestimate potential risk.

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[26] Assuming an environmental exposure of 1 μg/m^3, an EM ratio of 1 to 252 can be calculated using the "broad concentration range" for occupational exposures described in Section 8.4 of the USEPA 2002 report. Multiplying these values by the 2% excess risk due to diesel particulate matter exposures, results in 8E-05 to 2E-02.

[27] USEPA, 2002.

[28] USEPA, 2002.

[29] USEPA, 2002.

The Clean Air Agency uses a more appropriate approach based on accepted California risk numbers that have been widely cited and are the basis for a diesel retrofit program in place for several years in California. This approach evaluates 100% of the highly toxic diesel particulates as a complete and complex mixture. This method is more likely to account for potential interactions (i.e., synergism and antagonism) among the hundreds and/or thousands of chemicals in DPM.

2.3 Non-carcinogenic Effects

Many chemicals also have non-cancer health effects. Non-carcinogenic effects are presumed to have a threshold of exposure below which no effect occurs, although this is not always the case (e.g., fine particulate matter). Non-carcinogenic effects from air exposures are evaluated using reference concentrations. Reference concentrations (RfCs), like unit risk factors, are based on animal or human studies. RfCs are derived by examining the literature to find a critical study, which is defined as a well-designed chronic exposure study that has identified the non-carcinogenic adverse effect that occurs at the lowest level of inhalation exposure. The no-observable-effect-level (NOEL) or a lowest-observable-adverse-effect-level (LOAEL) from animal or human studies is determined. Adjustments for exposure times are made to extrapolate exposures to 24 hours, 7 days per week, and conversion to units of mg/m^3 are made. A human equivalent concentration is calculated by considering the nature of the contaminant and its behavior in inhaled air; the region of the respiratory system impacted; and the surface area and respiratory rate of the test organism, relative to the same parameters in humans. This concentration is then divided by factors of 10 to account for uncertainties such as extrapolating from animals to humans, from healthy adult individuals to sensitive individuals, or from sub-chronic to chronic exposures. The RfCs also include confidence statements that speak to the extent and quality of the database, and the certainty of the RfC, based on supporting literature aside from the critical study.

As a result of these types of derivations, the RfC is also considered to be highly conservative or protective of human health. Similar to the unit risk factors used for carcinogens, USEPA considers the RfC to be unlikely to underestimate potential risks to humans. It is important to recognize that many chemicals can have a variety of effects that occur at different levels of exposure. The RfC only looks at the effect that occurs at the lowest level of exposure. The assumption is made that protection at this level also provides protection at the higher doses as well.

To determine a hazard index for these chemicals, the RfC is compared to the annual average or median concentration for each of the three exposure data sets (e.g., the monitoring results, the ambient modeling results, and the human exposure modeling results). We compare the RfC to the median concentration for the human exposure modeling estimates because they are the only estimate of central tendency available. For the Seattle monitoring data and the ambient exposure modeling exercise, we compare the RfC to the annual average. We also compare the RfC to an upper-bound concentration for the ambient modeling exercise as it was available. However, this value may overestimate exposures over the lifetime of the exposed individual. RfCs used in this evaluation are listed in Table 2-2 below. The name of the chemical is listed with the RfC value, the uncertainty factors and modifying factors used in calculating the RfC, the critical effect, and the source for the information. The information used in the analysis and listed in the table was taken from the USEPA NATA report.

The non-cancer health effects associated with diesel particulate matter and woodsmoke, and the fine particulate fraction of these mixtures specifically are not included in this evaluation. Non-cancer health effects associated with fine particles, such as morbidity related effects such as increased asthma attacks, upper respiratory irritation, and increased mortality are analyzed elsewhere.

Table 2-2: Reference Concentrations for Air Toxics[30]

Chemical	RfC (mg/m^3)	UF x MF	Target Organ for Critical Effect	Source
1) Acetaldehyde	9.0E-03	1000	Nasal epithelium	IRIS
2) Acrolein	2.0E-05	1000	Nasal epithelium	IRIS
3) Acrylonitrile	2.0E-03	100	Nasal epithelium	IRIS
4) Arsenic and compounds	3.0E-05	1000	Teratogenic effects	Cal EPA
5) Benzene	8.0E-02	100	Blood, bone marrow	IRIS
6) Beryllium compounds	2.0E-05	10	Lung	IRIS
7) 1,3-Butadiene	2.0E-03	300	Reproductive system	IRIS
8) Cadmium compounds	2.0E-05	30	Kidney	Cal EPA
9) Carbon tetrachloride	4.0E-02	300	Liver	Cal EPA
10) Chloroform	9.8E-02	100	Liver, kidney	ATSDR
11) Chromium compounds	1.0E-04	90	Respiratory tract	IRIS
12) 1,3-Dichloropropene	2.0E-02	30	Nasal epithelium	IRIS
13) Ethylene dibromide	8.0E-04	100	Reproductive system	Cal EPA
14) Ethylene dichloride	2.4E-00	90	Kidney	ATSDR
15) Ethylene oxide	3.0E-02	100	Blood	Cal EPA
16) Formaldehyde	9.8E-03	30	Respiratory tract	ATSDR
17) Hexachlorobenzene	3.0E-03	100	Teratogenic effects	Cal EPA
18) Hydrazine	2.0E-04	300	Liver, thyroid	Cal EPA
19) Lead compounds	1.5E-03	1	Central nervous system	NAAQS
20) Manganese compounds	5.0E-05	1000	Central nervous system	IRIS
21) Mercury compounds	3.0E-04	30	Central nervous system	IRIS
22) Methylene chloride	1.0E+00	30	Liver	ATSDR
23) Nickel compounds	2.0E-04	30	Respiratory tract	ATSDR
24) Propylene dichloride	4.0E-03	300	Nasal epithelium	IRIS
25) Tetrachloroethylene (perc)	2.7E-01	100	Central nervous system	ATSDR
26) Trichloroethylene	6.0E-01	100	Central nervous system	Cal EPA

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[30] USEPA. *Health Effects Information Used in Cancer and Noncancer risk Characterization for the NATA 1996 National Scale Assessment.* http://www.epa.gov/ttn/atw/nata/nettables.pdf.

Chapter 3: Health Risks Based on Air Toxics Monitoring Information

After we identified the toxicity values, we obtained exposure concentrations from three separate studies. The first study provides air monitoring concentrations in the Seattle area for 15 air toxics (Seattle Air Toxics Monitoring Study). The second study models ambient concentrations of woodsmoke and DPM from $PM_{2.5}$ monitored concentrations (Source Apportionment at an Urban IMPROVE Site). The third study provides modeled concentrations for 32 air toxics and DPM in the four counties in our jurisdiction (USEPA NATA study). The first two studies are discussed below, while the third study is discussed in Chapter 4.

3.1 Seattle Air Toxics Monitoring Study

The *Seattle Air Toxics Monitoring Study* was conducted during 2000 and 2001 as a collaborative effort by three agencies: USEPA, the Washington State Department of Ecology, and the Puget Sound Clean Air Agency. The purposes of this study were to provide information on the spatial and temporal variability of ambient air toxics, to evaluate modeling results obtained from the NATA project, and compare results to other urban areas in the United States. The objective of this study was to quantify the urban air toxics such as VOCs, carbonyl, and metal species on a regular basis at several surface sites in Seattle.

USEPA originally selected Seattle for this monitoring study as one of four cities nationwide to take part in the air toxics monitoring component of its overall National-scale Air Toxics Program (NATA).[31] The federal Clean Air Act mandates USEPA to determine a subset of the 189 urban hazardous air pollutants (HAPs) that potentially pose the greatest risks in urban areas. USEPA identified a total of 33 urban HAPs in their 1995 ranking analysis,[32] and developed concurrent monitoring and modeling programs (e.g., NATA) to evaluate potential exposures to these top-ranked 33 HAPs.[33] These 33 are discussed more fully in Chapter 4. Of the 33 HAPs identified

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[31] USEPA. Peer Review Draft for the Science Advisory Committee: *Air Toxics Monitoring Concept Paper*. Office of Air Quality Planning and Standards. February 2000.

[32] USEPA. *Ranking and Selection of Hazardous Air Pollutants for Listing Under Section 112(j) of the Clean Air Act Amendments of 1990, Technical Support Document*, July 28, 1999.

[33] USEPA. *National Air Toxics Program: The Integrated Urban Strategy Report to Congress.* Office of Air Quality Planning and Standards. EPA-453/R-99-007. July 2000.

by USEPA, a total of 17 HAPs (see Table 3-1) were monitored at two sites in the Seattle area during calendar year 2000 and at six sites during 2001.

Table 3-1: Monitored Urban Air Toxic Pollutants (17 total)

CAS No.	VOCs
1) 71432	Benzene
2) 7440439	1,3-Butadiene
3) 56235	Carbon tetrachloride
4) 67663	Chloroform
5) 75092	Dichloromethane
6) 78875	1,2-Dichloropropane
7) 127184	Tetrachloroethene
8) 79016	Trichloroethene
9) 7440382	Arsenic
10) Total compounds	Beryllium
11) Total compounds	Cadmium
12) Total compounds	Chromium
13) 7439921	Lead
14) Total compounds	Manganese
15) 7440020	Nickel
16) 75070	Acetaldehyde
17) 50000	Formaldehyde

The remaining 16 HAPs were not monitored because they were considered less stable or lacked approved collection and/or analytical techniques. Every six days at each site, 24-hour integrated air samples were collected.[34] Such collection schedules ensure that every day of the week is sampled over the year. Average concentrations for each monitored chemical were provided by the Washington State Department of Ecology, and are presented in Table 3-2. Because no data were provided for 1,2-dichloropropane and beryllium, these chemicals were removed from further consideration in this analysis.

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[34] Washington Department of Ecology. *Urban Air Toxic Measurements in Seattle*. Conducted by the Laboratory for Atmospheric Research, Washington State University, Pullman, WA. Contract #C0000060. Project Officer: John Williamson, Bellevue, WA., May 2001.

Table 3-2: Monitored Ambient Concentrations at 6 Sites in Greater Seattle, 2000 and 2001 (averages)

Chemical	Beacon Hill ($\mu g/m^3$)	George-town ($\mu g/m^3$)	Lake Forest Park ($\mu g/m^3$)	Lake Sam-mamish ($\mu g/m^3$)	Maple Leaf Reservoir ($\mu g/m^3$)	SeaTac ($\mu g/m^3$)	6-Site Average ($\mu g/m^3$)
Benzene	1.18E+00	1.80E+00	1.64E+00	1.15E+00	1.13E+00	1.02E+00	1.32E+00
1,3-Butadiene	1.37E-01	1.35E-01	1.24E-01	1.06E-01	8.39E-02	9.94E-02	1.14E-01
Carbon tetrachloride	6.10E-01	6.54E-01	6.42E-01	6.23E-01	6.10E-01	6.23E-01	6.27E-01
Chloroform	2.30E-01	1.42E-01	1.47E-01	1.27E-01	2.30E-01	1.27E-01	1.67E-01
Dichloromethane	4.55E-01	9.13E-01	6.53E-01	6.98E-01	5.49E-01	4.69E-01	6.23E-01
Tetrachloroethylene	1.56E-01	3.66E-01	2.44E-01	1.76E-01	2.10E-01	1.42E-01	2.16E-01
Trichloroethylene	1.88E-01	3.82E-01	1.67E-01	1.40E-01	2.10E-01	1.72E-01	2.10E-01
Acetaldehyde	1.26E+00	1.26E+00	1.26E+00	1.26E+00	1.08E+00	1.26E+00	1.23E+00
Formaldehyde	1.72E+00	1.47E+00	1.10E+00	9.82E-01	1.23E+00	1.35E+00	1.31E+00
Arsenic	9.70E-04	1.40E-03	1.63E-03	8.63E-04	8.67E-04	9.69E-04	1.12E-03
Cadmium	5.90E-04	9.00E-04	1.69E-04	1.20E-04	1.10E-04	8.10E-05	3.28E-04
Chromium	1.67E-03	3.20E-03	1.09E-03	9.07E-04	9.27E-04	1.47E-03	1.54E-03
Lead	3.49E-03	9.30E-03	5.27E-03	3.26E-03	4.28E-03	3.24E-03	4.81E-03
Manganese	3.61E-03	1.08E-02	5.15E-03	6.99E-03	5.57E-03	6.54E-03	6.44E-03
Nickel	2.39E-03	3.40E-03	1.16E-03	9.21E-04	3.60E-04	1.42E-03	1.61E-03
Diesel particulate matter*	1.40E+00						
Vegetative burning*	3.00E+00						

**calculated using monitoring results and PMF source apportionment model. See discussion below.*

Site Locations and Selected Pollutants

A total of six sites were selected to represent the Seattle urban area based on a comprehensive site selection study.[35] Two sites were monitored during calendar year 2000, and four more sites (for a total of six sites) were monitored during calendar year 2001 (see Figure 3-1).

The two sites monitored during 2000 were Beacon Hill and Georgetown. The first site represents a typical urban residential area. Beacon Hill (Fig. 3-1: ❸) was selected to represent this type of area because it has a relatively high population density and is impacted by a mix of urban source categories. For example, it is located near the Interstate 90 and Interstate 5 interchange, and is also impacted by local sources. However, it is more significantly impacted by urban residential sources such as mobile exhaust and woodsmoke. A spatial variation study conducted by UW also verified that Beacon Hill is representative of population exposure.[36]

The second area was selected to represent potentially maximum concentrations near an industrial area. This site is located in the Georgetown neighborhood (Fig. 3-1: ❹). It is impacted by several large industrial sources, as well as an airport. Mobile sources from Highway 99, nearby roadways, and residential wood combustion are also expected to impact this site. This neighborhood is located in the Duwamish industrial valley.

Four more sites were added for the 2001 calendar year. These sites include: Lake Sammamish (Fig. 3-1: ❻) for an urban background site, Maple Leaf (Fig.3-1: ❷) for a typical urban residential site, SeaTac (Fig. 3-1: ❺) for a site that is highly impacted by mobile sources, and Lake Forest Park (Fig.3-1: ❶) for an area affected by woodsmoke and mobile sources.

Two of the six sites are located near airports. The SeaTac monitor is located north of the Seattle-Tacoma International Airport, a major airport that serves the Puget Sound area. The Georgetown site is also located near an airport that serves a number of commercial industries including

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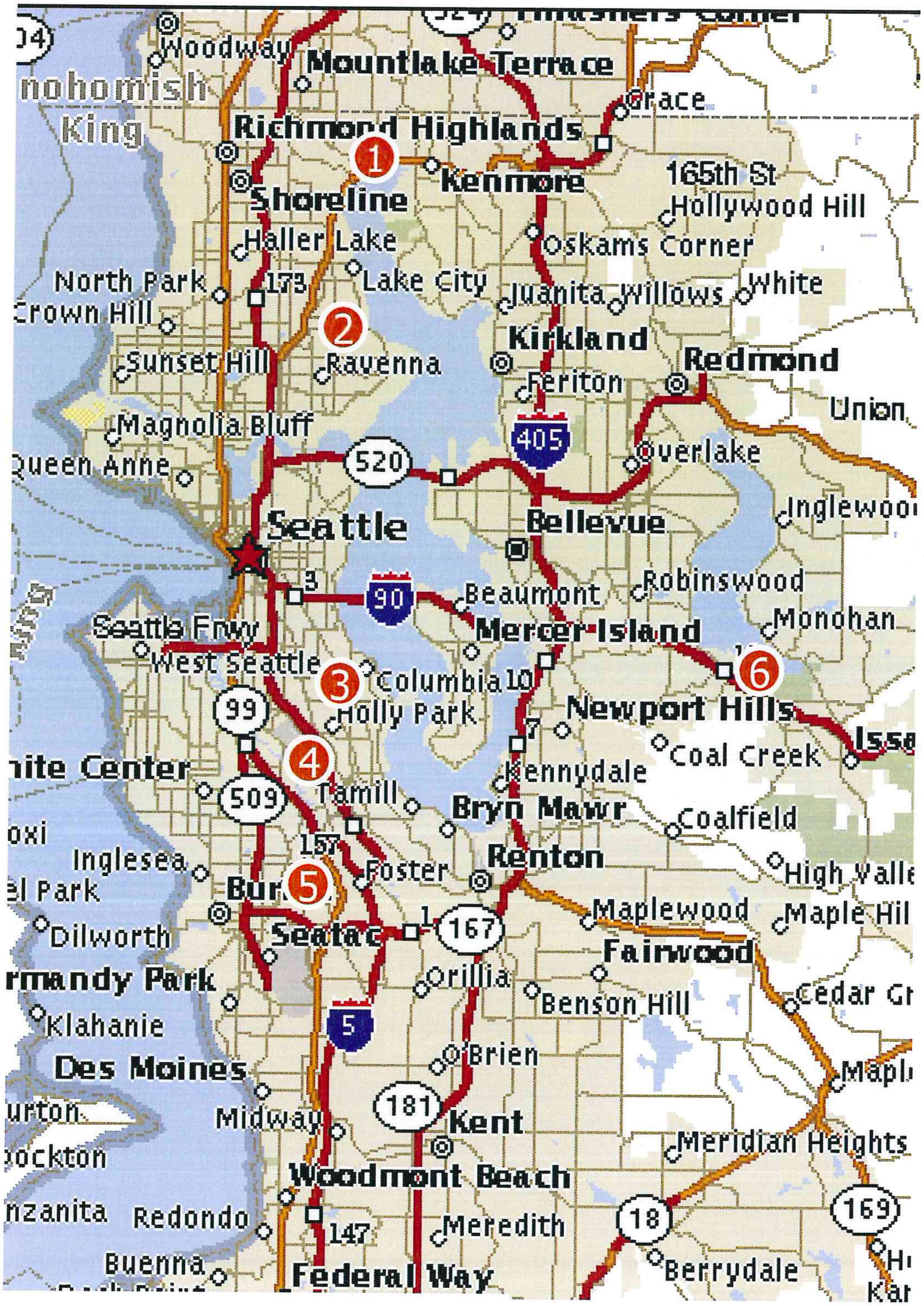
[35] Goswami E, T Larson, T Lumley, S Liu. *Spatial Characteristics of Fine Particulate Matter. Identifying Representative Monitoring Locations in Seattle, Washington.* Journal of Air and Waste Management Association. Vol. 52, March 2002.

[36] Goswami et al., 2002.

Figure 3-1: Air Toxics Monitor Locations



The Boeing Company, a major aerospace manufacturing site. The potential impact of these airport emissions on the monitored concentrations are discussed in the latter sections of this chapter.

3.2 Woodsmoke and Diesel Particulate Concentrations

In addition to risks from ambient air toxics, ambient concentrations of woodsmoke and DPM have long been recognized as potentially carcinogenic and contribute substantially to ambient particulate matter concentrations in the Puget Sound area.[37,38] To quantify potential risks from these mixtures, ambient concentrations are multiplied by a unit risk factor (see methods in Chapters 1 and 2). We use woodsmoke and diesel particulate concentrations for the Beacon Hill monitoring site as estimated in a recent study conducted by Maykut, Larson, Lewtas, and Kim entitled *Source Apportionment of PM2.5 at an urban IMPROVE site in Seattle, WA.*[39]

Source Apportionment of PM2.5 at an Urban IMPROVE site in Seattle, WA

Speciated data from Seattle's Beacon Hill PM2.5 monitoring site were analyzed using two multivariate receptor models, the Positive Matrix Factorization (PMF) and the UNMIX model. EPA's Chemical Mass Balance model was also used to identify the major sources of PM2.5 and organic carbon in Seattle's air. A total of 289 filter samples were obtained with an IMPROVE sampler from 1996 through 1999. These samples were analyzed for 31 particulate "elements" including various fractions of the particulate organic and elemental carbon. All three models predicted the major sources of PM2.5 were wood-burning, mobile sources, and secondary particle formation.

The sources identified by the PMF model are (in descending order of importance): vegetative burning such as wood-burning fireplaces and yard waste (indoor and outdoor), motor vehicles (gasoline and diesel), secondary sulfate, secondary nitrate, soil, and marine sea salt (Fig. 3-2)..

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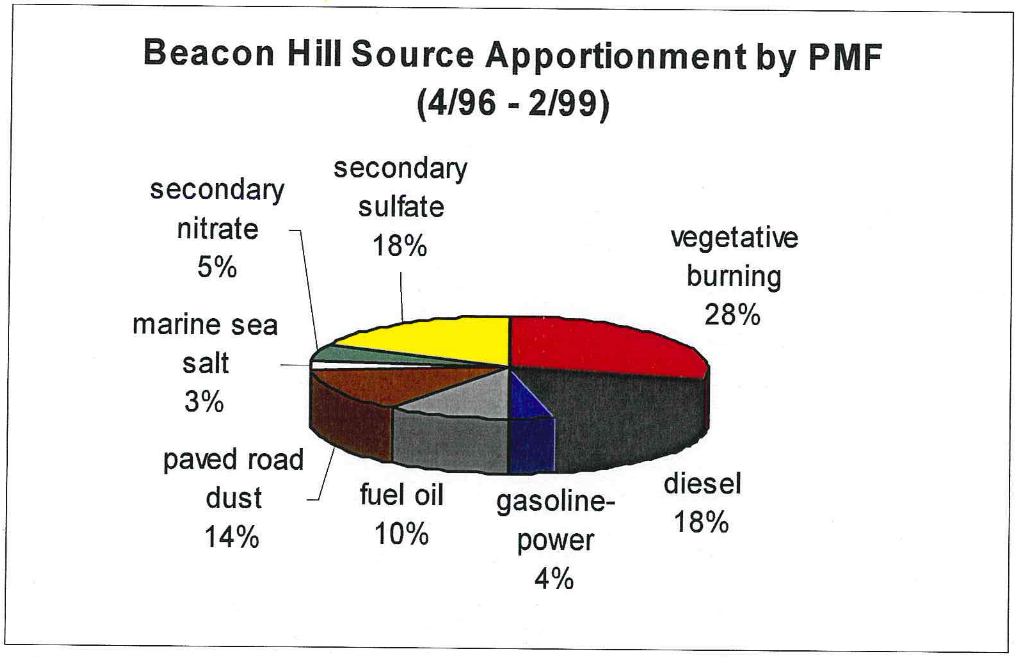
[37] Lewtas J. *Genotoxicity of Complex Mixtures: Strategies for the Identification and Comparative Assessment of Airborne Mutagens and Carcinogens from Combustion Sources.* Fundamental and Applied Toxicology 10, 571-589. 1988.

[38] Yuen and Larson, 1993.

[39] Maykut N, et al. 2003.

Figure 3-2: Beacon Hill Source Apportionment from Maykut, et al. (2003)[40]



The average concentration of PM2.5 at Beacon Hill from April 1996 through February 1999 was 9 μg/m³. This translates to average annual concentrations of approximately 3 μg/m³ for vegetative burning and 1.4 μg/m³ of diesel particulate. It is important to note that our analysis considers only 46% of the PM2.5 present in ambient air (vegetative burning + diesel), while the remaining 54% could contribute to overall cancer risk from particulate matter.[41] Thus our estimates could significantly underestimate potential cancer risk from fine particles.

Diesel particulate matter was estimated from the PM2.5 monitor located at the Beacon Hill site for three years using the Positive Matrix Factorization (PMF model).[42] The ambient annual concentration of diesel particulate matter at the Beacon Hill site is estimated to be 1.4 μg/m³. Some reviewers noted that this value could be high due to the proximity of the monitor to Interstate 5 and Interstate 90.

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[40] Maykut N et al., 2003

[41] Pope CA, RT Burnett, MJ Thun, EE Calle, D Krewski, K Ito, GD Thurston. *Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution*. JAMA, March 6, 2002, vol. 287, No. 9.

[42] Maykut N et al., 2003.

3.3 Estimated Potential Cancer Risks from Six Monitoring Sites

Potential cancer risk estimates for each chemical at each of the six sites of the Seattle Air Toxics Monitoring Study are presented in Table 3-3 and Figure 3-3. Cancer risks for the average concentrations across all 6 sites are also presented. These values are presented as individual cancer risk per million (over a 70-year lifetime) and potential cancer cases per million people exposed over a 70-year exposure period.

It is important to recognize that these cancer risk estimates are based on the assumption that adults (either one or many in an exposed population) are exposed to this average concentration for their entire lifetime or an exposure period of 70 years. The ambient concentrations may or may not represent actual annual average exposures for individuals throughout the Seattle population. For example, it is highly unlikely that an individual would spend an entire 70-year period outside near a particular monitor. Alternatively, both VOCs and semi-volatile compounds can penetrate indoors. Therefore, it is highly likely that people spending time inside homes or other buildings are exposed to ambient air toxics while indoors.

As indicated on the table and figure, the cumulative cancer risks for the 17 chemicals are similar among the six Seattle sites, ranging from a low of approximately 57 in a million in Lake Sammamish to a high of 100 in a million in Georgetown. Preliminary analyses from the University of Washington indicate that the differences in measured concentrations at various sites are statistically significant.[43] However, from a practical standpoint, these differences are still quite small, particularly when compared with potential risks from DPM and woodsmoke later in this section. We also note that the Beacon Hill risk estimates are similar to the 6-site average (again, 80 to 73 in a million), supporting UW findings that this site is a good indicator for the area.[44]

Georgetown appears to have the highest monitored concentrations, and therefore a higher risk than the other five monitor locations. This appears to be due to higher concentrations of chromium, possibly due to industrial activities near the monitoring site.

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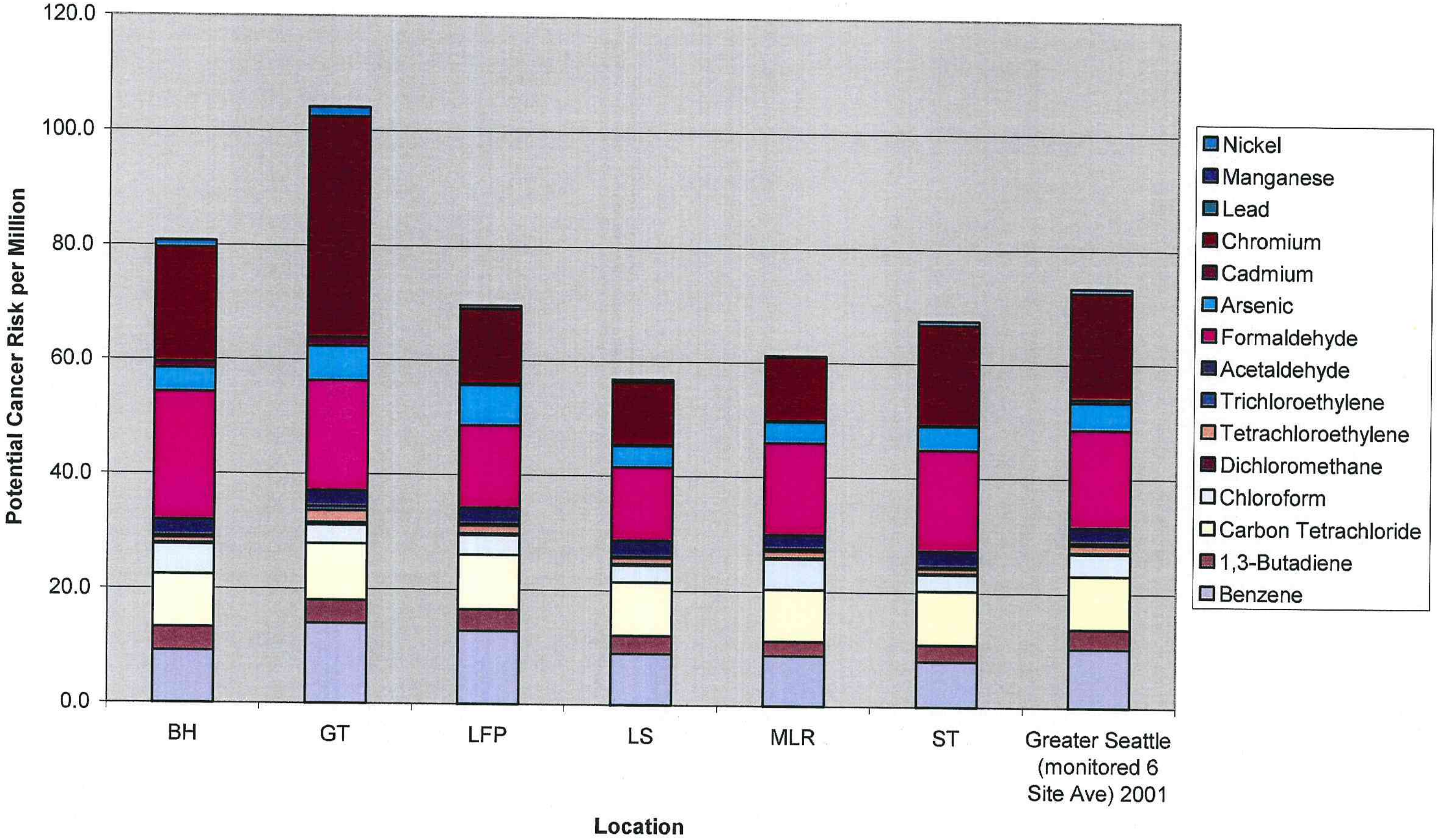
[43] Lui LS, C Wu, A Cullen. *Investigation of Spatial and Temporal Variation in Air Toxics in the Seattle area.* Powerpoint presentation, February 26, 2003.

[44] Goswami et al. 2002.

Table 3-3: **Estimated Cancer Risks Per 1,000,000 Associated with Seattle Air Toxics Monitoring Study Results in 2001 (and 1996-1999 for DPM and Vegetative Burning)**

Chemical	BH	GT	LFP	LS	MLR	ST	Greater Seattle (monitored 6-site avg.) 2001
Benzene	9.2	14.1	12.8	9.0	8.8	8.0	10.3
1,3-Butadiene	4.1	4.0	3.7	3.2	2.5	3.0	3.4
Carbon tetrachloride	9.2	9.8	9.6	9.3	9.2	9.3	9.4
Chloroform	5.3	3.3	3.4	2.9	5.3	2.9	3.8
Dichloromethane	0.2	0.4	0.3	0.3	0.3	0.2	0.3
Tetrachloroethylene	0.9	2.1	1.4	1.0	1.2	0.8	1.2
Trichloroethylene	0.4	0.8	0.3	0.3	0.4	0.3	0.4
Acetaldehyde	2.8	2.8	2.8	2.8	2.4	2.8	2.7
Formaldehyde	22.3	19.1	14.4	12.8	16.0	17.5	17.0
Arsenic	4.2	6.0	7.0	3.7	3.7	4.2	4.8
Cadmium	1.1	1.6	0.3	0.2	0.2	0.1	0.6
Chromium	20.0	38.4	13.1	10.9	11.1	17.6	18.5
Lead	0.0	0.1	0.1	0.0	0.1	0.0	0.1
Manganese	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nickel	1.1	1.6	0.6	0.4	0.2	0.7	0.8
Diesel particulate matter	420.0	0.0	0.0	0.0	0.0	0.0	0.0
Woodsmoke	30.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	530.8	104.1	69.7	56.9	61.2	67.5	73.4

Figure 3-3: Potential Cancer Risk Estimates per 1,000,000 for 6 Monitoring Sites in Greater Seattle in 2001



Although carbon tetrachloride is a significant contributor to the cancer risk estimates, it is important to note that this chemical has been banned in the Puget Sound area for some time. These monitored concentrations may reflect emissions that are not currently reported or previous contamination that is extremely persistent.

We also compared risk estimates calculated using modeled and monitored air concentrations. In Figure 3-4, the cancer risks from the 6-site average for Greater Seattle from the air monitoring study are compared to the cancer risks using the USEPA NATA results for King County. Even though the NATA estimates are for 1996 and the monitored estimates are 2001, the cancer risks compare surprisingly well, with cumulative cancer risks of 73 and 78 per million, respectively.

Since Beacon Hill is considered to represent the area, we also compared Beacon Hill estimates to the USEPA NATA estimates and included DPM (see Figure 3-5 and Table 3-4). It is interesting to note that even though the time periods are different for the studies, the modeled estimates compare reasonably well to the monitored estimates.

The cumulative cancer risk for only the chemicals monitored in the 2000 and 2001 studies ranges from approximately 57 to 100 per million over a 70-year exposure period for these chemicals. The total risk for the Seattle average is approximately 73 per million over a 70-year exposure period. These risk estimates are based on the assumption that concentrations observed in this monitoring study will be constant for the assumed 70-year exposure period and that exposures to ambient air reflect the types of exposures that are occurring over the duration.

Emissions from the two airports could impact the SeaTac and Georgetown monitors. However, the results do not reflect significantly higher pollutant levels at these locations when compared with other sites. In fact, SeaTac potential risks appear slightly lower than Beacon Hill. It is possible that the airport emissions do not significantly impact the monitors because the emissions are diluted over the area. It is also possible that the pollutants of concern at the airport are not those included in the monitoring study.

Figure 3-4: Comparing Cancer Risk between Monitored and Modeled Estimates

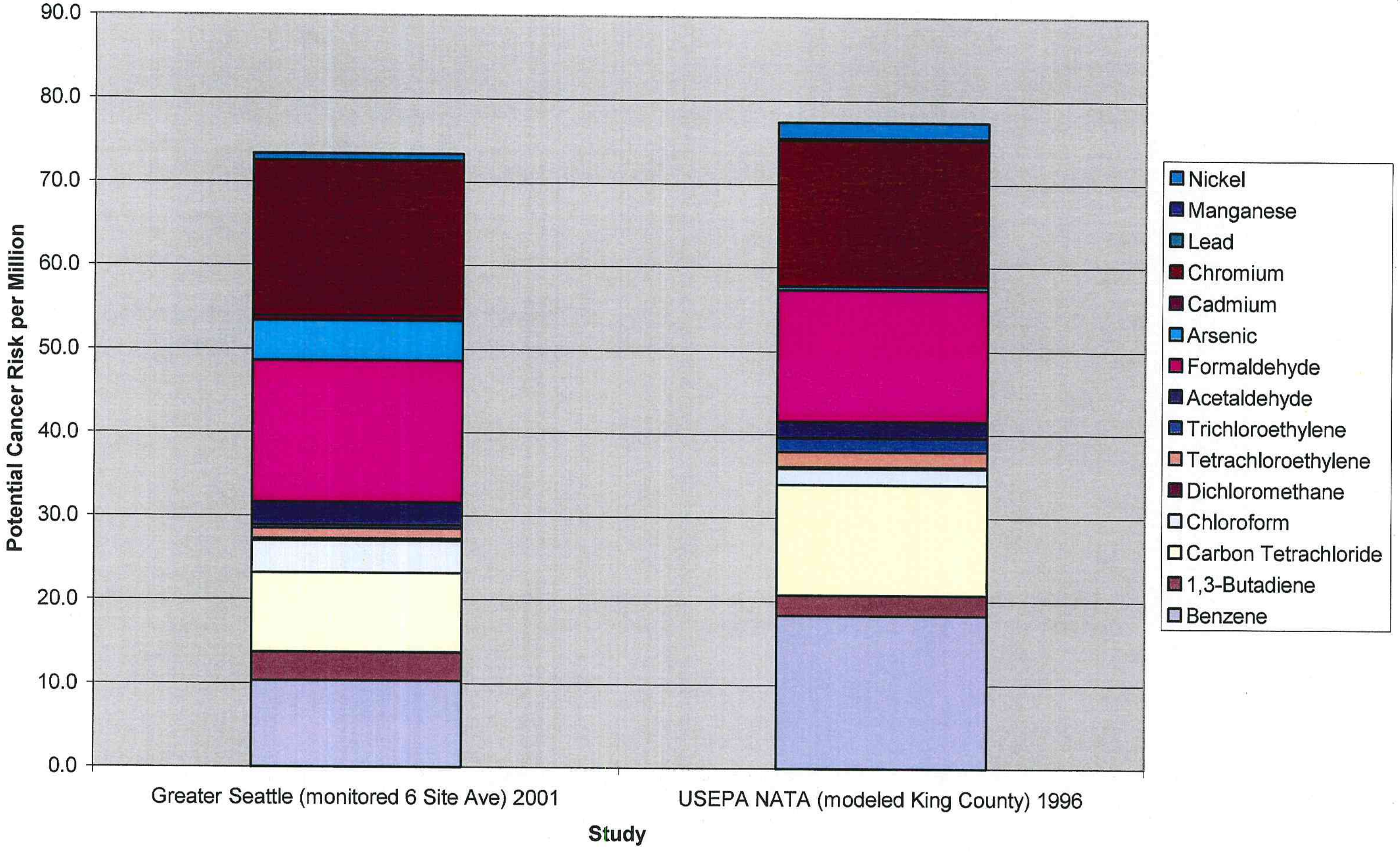


Figure 3-5: Comparing Beacon Hill (monitored) with NATA (modeled) Cancer Risk Estimates

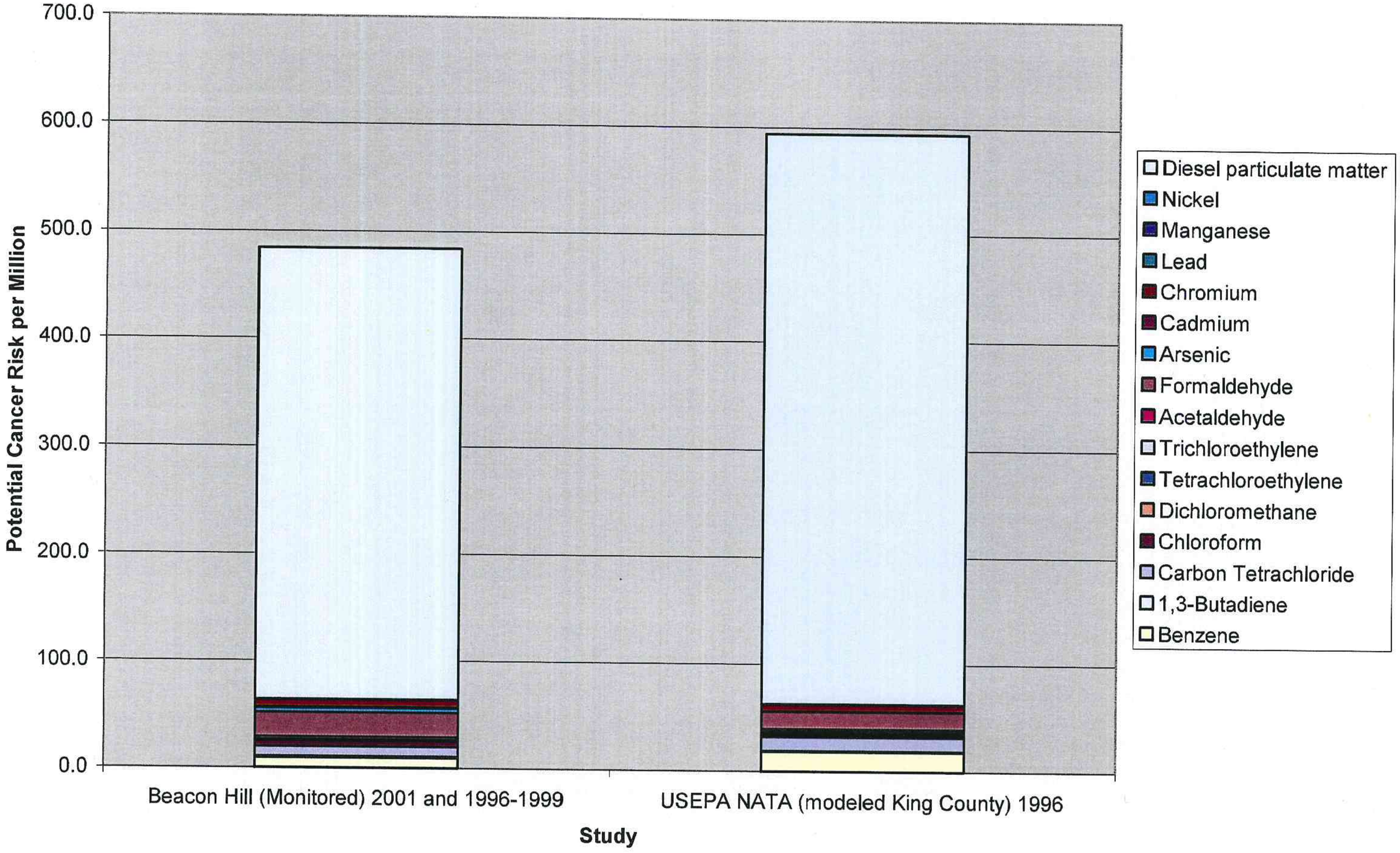


Table 3-4: Comparing Potential Cancer Risks at Beacon Hill (monitoring data) and King County (modeled data)

Chemical	Beacon Hill 2001 Potential Risk (cancer cases per million)	USEPA NATA 1996 Potential Risk (cancer cases per million)
Benzene	9.2	18.3
1,3-Butadiene	4.1	2.5
Carbon tetrachloride	9.2	13.2
Chloroform	5.3	1.9
Dichloromethane	0.2	0.3
Tetrachloroethylene	0.9	1.8
Trichloroethylene	0.4	1.7
Acetaldehyde	2.8	2.0
Formaldehyde	22.3	15.7
Arsenic	4.2	0.5
Cadmium	1.1	0.1
Chromium	20.0	17.4
Lead	0.0	0.2
Manganese	0.0	0.0
Nickel	1.1	1.9
Diesel particulate matter	420.0	531.0
Woodsmoke	30.0	0.0
Total Cancer Risk	530.8	608.4

Chemicals that pose the greatest risks are primarily associated with mobile sources. Similar to Beacon Hill, the Georgetown risks are dominated by the mobile source chemicals benzene, formaldehyde, and 1,3-butadiene. However, the individual risk estimates from these chemicals are somewhat higher than those estimated at the Beacon Hill site. This may reflect the fact that the Georgetown monitor is located in an industrial area or the Duwamish Valley where contaminants may readily accumulate during winter inversion conditions.

It is important to note that these monitors are placed in areas that are not expected to be heavily impacted by a large industrial source or "hotspot" – except for possibly the Georgetown site, which is located in the Duwamish industrial area. The annual average from the selected monitor locations are expected to reflect general urban settings such as an urban residential area, or an urban industrial area. A few chemicals that are associated with industrial point sources, such as chromium and trichloroethylene, are higher in the Georgetown area. These chemicals probably reflect more general industrial uses of paints, solvents, and chrome plating rather than one specific industrial source.

Woodsmoke and DPM

In addition to the air toxics measured in the 2000 and 2001 studies, toxics concentrations in many Seattle neighborhoods are heavily impacted by vegetative smoke from residential indoor burning and DPM. We used the vegetative burning and DPM estimates from the Beacon Hill PMF modeling exercise performed by Maykut et. al. (2003)[45]. The annual average vegetative burning and DPM concentrations for the Beacon Hill site are multiplied by a "residential heating wood" and DPM unit risk factor (see Chapter 2 for more discussion on unit risk estimates), respectively, to estimate the potential cancer risk. These estimates are added to the overall estimated cancer risks from the other monitored air toxics to compare the potential impacts. The cumulative cancer risk from air pollution measured at Beacon Hill is shown in Figure 3-6.

One reviewer noted that because vegetative burning and DPM are complex mixtures that include other chemicals already measured (i.e., metals), our methods overestimate risk from these two sources. We recognize that some portion of ambient metals is due to DPM, and may be "double-counted". However, we do not know exactly how much of the ambient metals concentrations are due to DPM. We also know DPM is not the only source of metals in our region. Therefore, we elect to combine metals and DPM estimates, recognizing the results will slightly overestimate risk. We expect the potential impact of "double counting" overall to be quite low since metals are not among the primary risk drivers. Even if the potential risks from metals were reduced to account for DPM, the overall findings would not change. DPM would still rank highest among contributors, with other mobile sources and vegetative burning also among the top sources. Cumulative cancer risks would still approach 500 in a million on average, and could be higher (see Chapter 4).

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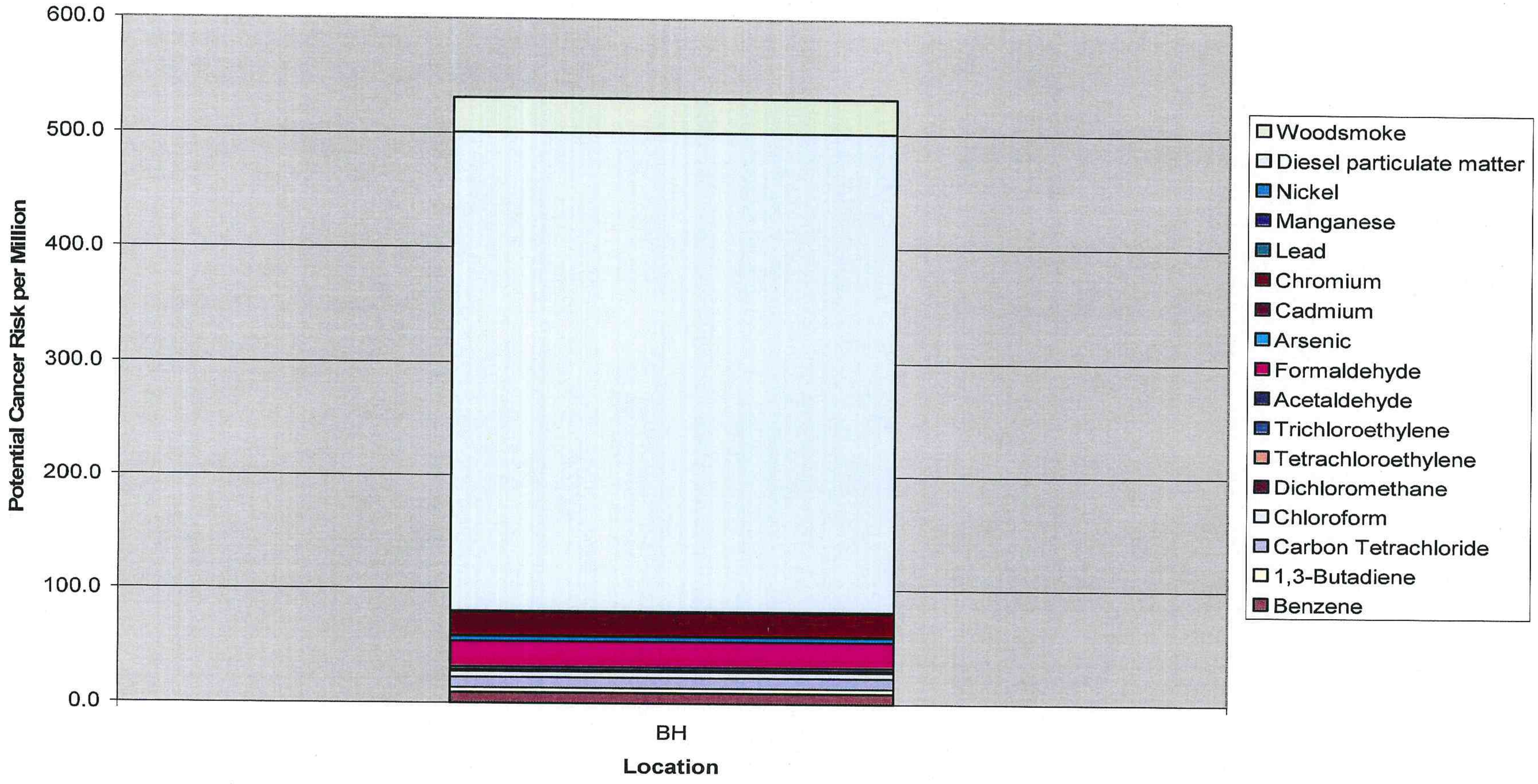
[45] Maykut N et al. 2003.

Figure 3-6: Potential Cancer Risks at Beacon Hill including Diesel Particulate Matter and Woodsmoke



Another reviewer noted that vegetative burning is not synonymous with woodsmoke. We recognize that the unit risk factor for woodsmoke (referred to as "residential heating wood" in the Lewtas study) is uncertain, and could over- or underestimate the toxicity of all vegetative burning included in the Maykut et al (2003) study. However, we believe the limited available data provides a general indication of where vegetative burning might rank in comparison with other air pollution sources in our region.

As indicated in Figure 3-6, DPM is the greatest contributor to potential cancer risk at Beacon Hill. Vegetative burning also contributes significantly to the overall estimated cancer risks from ambient pollution. Although Beacon Hill is considered to represent the area within 20 km,[46] it may underestimate risks in "hot spots" or areas affected by local wood-burning. For example, there are a number of areas, such as Lake Forest Park, Puyallup, and Marysville, where the woodsmoke concentrations may be significantly higher than those measured at Beacon Hill.[47,48] Overall, potential cumulative cancer risks from monitored chemicals approach 500 in a million.

3.4 Potential Non-cancer Effects from Six Monitoring Sites

We evaluated monitored concentrations of toxics for potential non-cancer health effects such as upper respiratory irritation, blood and bone marrow effects, and central nervous system effects. For this exercise, the annual average values from the 6-site average and each individual site were compared to RfCs through ratios referred to as hazard indices (HI).

The HI is a very simple method that compares potential exposure concentrations with health-based guidelines (see Chapter 2 for a discussion of the reference concentrations used in this analysis). HIs for the annual averages (the annual average of the Seattle/King County area) are shown in Table 3-5 and Figure 3-7 below. These results may not be reasonable maximum estimates because upper-bound percentiles were not available for the monitored results.

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[46] Goswami et al., 2002.

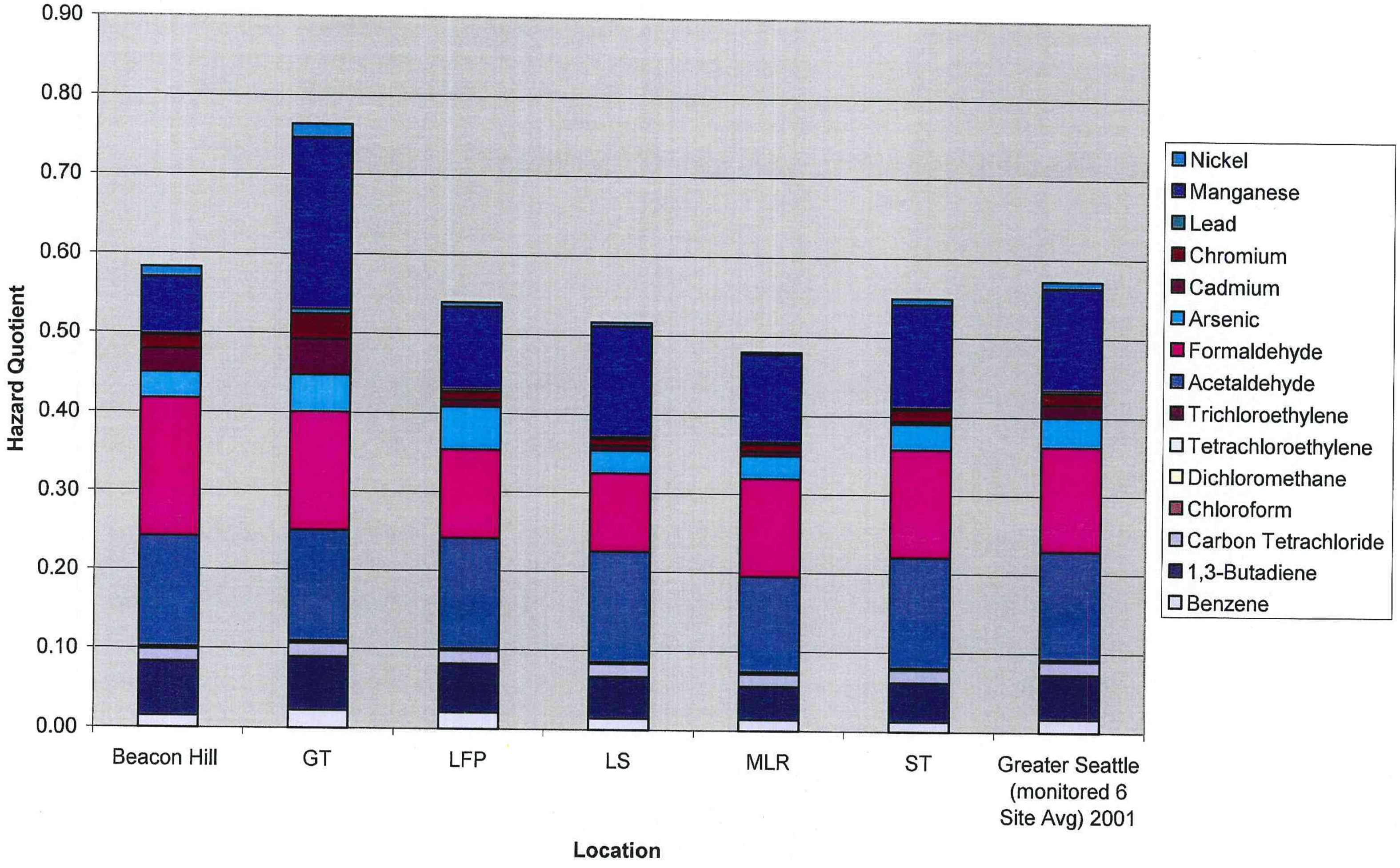
[47] Personal communication, N. Maykut with L. Keill at Puget Sound Clean Air Agency, June 30, 2003.

[48] Yuen and Larson, 1993.

Table 3-5: Hazard Indices for Monitored Air Toxics in Seattle, 2001

	BH	**GT**	**LFP**	**LS**	**MLR**	**ST**	**Greater Seattle (monitored 6-Site Average) 2001**
Benzene	0.01	0.02	0.02	0.01	0.01	0.01	0.02
1,3-Butadiene	0.07	0.07	0.06	0.05	0.04	0.05	0.06
Carbon tetrachloride	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dichloromethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetrachloroethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichloroethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acetaldehyde	0.14	0.14	0.14	0.14	0.12	0.14	0.14
Formaldehyde	0.18	0.15	0.11	0.10	0.13	0.14	0.13
Arsenic	0.03	0.05	0.05	0.03	0.03	0.03	0.04
Cadmium	0.03	0.05	0.01	0.01	0.01	0.00	0.02
Chromium	0.02	0.03	0.01	0.01	0.01	0.01	0.02
Lead	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Manganese	0.07	0.22	0.10	0.14	0.11	0.13	0.13
Nickel	0.01	0.02	0.01	0.00	0.00	0.01	0.01
Sum	***0.58***	***0.76***	***0.54***	***0.52***	***0.48***	***0.55***	***0.57***

Figure 3-7: Non-cancer Evaluation (Hazard Quotients) for 6 Monitoring Sites (2001)



As shown, none of the monitored concentrations exceed a hazard index or hazard quotient of one. Because some chemicals have the same or similar target organ, some hazard indices can be added together. However, even if all chemicals had the same target organ, the resulting hazard index, referred to as a hazard quotient, is approximately 0.76 at the highest location, Georgetown. These results suggest that potential non-cancer health effects associated with the monitored chemicals (with exception of DPM and vegetative burning) alone are not likely to result in significant non-cancer health impacts.

However, these results need to be viewed with caution. The particle-related combustion mixtures, woodsmoke and diesel particulate matter, add a significant amount of $PM_{2.5}$ into the ambient air. The non-cancer health effects associated with fine particles include a wide range of respiratory health effects in humans, and are extensively evaluated elsewhere.[49] More information on non-cancer health impacts are presented in the following chapter on the USEPA NATA project.

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[49] USEPA ***Third External Review Draft of Air Quality Criteria for Particulate Matter***. EPA/600/P-99/002ac. Office of Research and Development. Research Triangle Park, NC. April 2002.

Chapter 4: Air Toxics Modeling: USEPA NATA Project

4.1 Overview

Risks from airborne toxics can also be evaluated and ranked using emission estimates for the primary source categories and dispersion models. USEPA recently completed this type of assessment in their nationwide project entitled the National-scale Air Toxics Assessment (NATA). We use the results from this analysis for King County to evaluate and rank potential risks from airborne toxics. We compare these King County results to those based on the two monitoring studies (see Chapter 3). We also use the results from NATA to evaluate potential cancer risks from the other three counties in the Puget Sound region (Pierce, Kitsap, and Snohomish).

USEPA NATA Project

The NATA project consists of four phases. In Phase I, USEPA uses emission factors to calculate emissions for mobile, area, and point source categories for a total of 33 pollutants and DPM. In Phase II, USEPA predicts ambient air concentrations for these pollutants using an air dispersion model (ASPEN, which is explained in more detail later). In Phase III, USEPA predicts human exposure concentrations through the HAPEM4 model, based on the ambient concentrations calculated in Phase II. The HAPEM4 model accounts for individual movements through various micro-environments such as traveling in a vehicle on the highway, living nearer to significant point sources, and remaining indoors for a portion of each day. Finally, in Phase IV, these human exposure concentrations are used to calculate potential cancer risks and non-cancer risks. Details on the methods and results for each of these phases can be found in the USEPA technical support documents for the NATA project. The general approach used in each of the four phases is briefly described below.

4.2 Phase I: Emission Inventories

In Phase I, USEPA calculates emission estimates for each of the 33 pollutants from mobile, area, and point sources. The 33 pollutants are a subset of the 189 hazardous air pollutants (HAPs) listed in the federal Clean Air Act. This subset was determined by an emission inventory ranking developed by USEPA.[50] This ranking identified 33 chemicals that were expected to contribute the highest risks from airborne toxics. USEPA also added diesel particulate matter to complete the list of 34. Dioxins were originally included in the 33 chemicals, but USEPA recently removed this suite of chemicals. Although coke oven emissions are included in the NATA project, King County does not have any source of this pollutant. Therefore, it is removed from the list. The final list of 32 chemicals used in this analysis is presented in Table 4-1 below:

Table 4-1: Pollutants Included in the NATA Project

Pollutant	CAS Number
1) Acetaldehyde	75070
2) Acrolein	107028
3) Acrylonitrile	107131
4) Arsenic compounds	NA
5) Benzene	71432
6) Beryllium compounds	NA
7) 1,3-Butadiene	106990
8) Cadmium compounds	NA
9) Carbon tetrachloride	56235
10) Chloroform	67663
11) Chromium compounds	NA
12) 1,3-Dichloropropene	542756
13) Diesel particulate matter (DPM)	NA
14) Ethylene dibromide (1,2-dibromoethane)	106934
15) Ethylene dichloride (1,2-dichloroethane)	107062
16) Ethylene oxide	75218
17) Formaldehyde	50000
18) Hexachlorobenzene	118741
19) Hydrazine, hydrazine sulfate	302012
20) Lead compounds	NA
21) Manganese	NA
22) Mercury compounds	NA
23) Methylene chloride	75092
24) Nickel compounds	NA
25) Polychlorinated biphenyls (PCBs)	1336363
26) Polycyclic organic matter (POM)	NA
27) Propylene dichloride (1,2-dichloropropane)	78875
28) Quinoline	91225
29) 1,1,2,2-Tetrachloroethane	79345
30) Tetrachloroethylene (perchloroethylene)	127184
31) Trichloroethylene (TCE)	79016
32) Vinyl chloride	75014

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[50] USEPA, July 1999.

In Phase I, USEPA used emission estimates from 1996 inventory reporting and estimates, as listed on the USEPA database referred to as the National Toxic Inventory (NTI). USEPA also used information from the National Emission Trends inventory to supplement information for chemicals that may be formed from pre-cursors in the atmosphere.

In addition, USEPA took several steps to perform quality assurance on the emission estimates. For example, USEPA filled in missing or erroneous information for sources that were missing or poorly reported in the NTI. Emission estimates in NTI are primarily obtained from state and local inventories, USEPA Maximum Achievable Control Technology information, the Toxics Release Inventory, and emissions from USEPA's Office of Transportation and Air Quality. USEPA also requested that individual state and local agencies review emission estimates calculated for the NATA project and submit changes to USEPA before the dispersion-modeling phase was conducted.

USEPA also grouped similar compounds together for more complete evaluation. For example, some chemicals such as various lead or chromium compounds are evaluated together as groups of compounds. In addition, these groups are subdivided according to particle size for more accurate dispersion modeling. Finally, pollutants are assigned to reactivity classes to account for atmospheric decay.

Source Categories

Total pollutant emissions are calculated from point sources, mobile sources, and area sources. Major point sources are large stationary sources that emit more than 10 tons per year of any HAP or a cumulative total of 25 tons per year of any combination of the 189 HAPs. Area sources are smaller stationary sources. Some smaller facilities do submit emission inventory reports but the majority of the calculations for area sources are estimated as a ratio to countywide population estimates. USEPA also included other types of area sources such as forest fires and prescribed burning. On-road mobile sources include cars, trucks, buses, etc., while off-road mobile sources include all remaining mobile sources such as trains, boats, lawnmowers, construction vehicles, and aircraft.

4.3 Phase II: Predicting Ambient Air Concentrations

ASPEN Model

After the emission estimates are calculated, the information is entered into the USEPA model referred to as the Assessment System for Population Exposure Nationwide (ASPEN) air model. This model essentially combines a Gaussian dispersion model with climatological information for each census tract across the United States. ASPEN considers the rate of release of each chemical, the location of the release, the release height, wind speed, and direction from the nearest meteorological station, weather (e.g., wet and dry deposition), pollutant decay, atmospheric transformation, and general settling.

Background Concentrations

USEPA also added a "background concentration" for 13 of the 33 pollutants. These concentrations account for toxics that are due to natural sources (e.g., windblown soils, volcanic eruptions, etc.), sources not included in the emission estimates, and long-range transport. The values included in the analysis as background are typically monitored concentrations in areas that are not heavily impacted by other sources. USEPA refers to these remote areas as "clean air locations." If background concentrations were not available in the literature, the concentrations were assumed to be zero. DPM background concentrations were adopted from modeling exercises. This is described more fully in Appendix F of the NATA Science Advisory report.[51]

4.4 Phase III: Predicting Human Exposures

HAPEM4 Model

Predicted ambient concentrations are then entered into another model to account for personal exposures and variation among the population in terms of activities. The model used by USEPA is referred to as the Hazardous Air Pollutant Exposure Model, version 4 (HAPEM4). This model evaluates the long-term inhalation exposures by tracking individuals who are considered to be representative of various demographic groups as they move through different locations. These smaller locations are referred to as "micro-environments." USEPA defines a micro-environment as:

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[51] USEPA, 2001. Appendix F.

> *A small space in which human contact with a pollutant takes place, and which can be treated as a well-characterized, relatively homogenous location with respect to pollutant concentrations for a specified time period. MEs include indoors at home, school, work, inside an automobile or bus, outdoors, etc.*

A complete list and more detailed descriptions of each micro-environment are included in the technical support documentation for this model.[52]

The model predicts concentrations in these micro-environments and calculates a time-weighted average depending on the amount of time spent in each micro-location. A total of 37 micro-environments were used in predicting the human exposure concentrations for the NATA project.

The HAPEM4 model includes both population activity pattern data and commuting pattern data. Activity patterns include the amount of time people spend at home, work, or in an automobile along with the activities during that time (e.g., sleeping, eating, etc.). HAPEM4 estimates exposures by activity pattern for various demographic groups as defined by age, gender, or race, etc. The commuting pattern data is based on a 1990 U.S. census tract database that reports the number of individuals who work within the census tract where they live.[53]

Pollutant concentrations within each micro-environment are estimated using ambient concentrations multiplied by a penetration factor, which is a ratio of the indoor to the outdoor concentration. A time-weighted average exposure concentration can be predicted using these factors and the ambient concentration data for a specified amount of time.

In calculating an annual average estimate for the NATA project, USEPA selected 40 demographic groups based on different combinations of characteristics (e.g., age, race, gender). For each of these groups, 365 activity patterns were randomly selected. The amount of time spent in each micro-environment (for eight separate time blocks for a 24-hour day) for each demographic group was then averaged for the entire set of 365. This process was repeated 100

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[52] USEPA. ***Development of Microenvironmental Factors for the HAPEM4 in Support of the National-scale Air Toxics Assessment (NATA).*** External Review Draft. Prepared for the Office of Air Quality Planning and Standards. Prepared by ICF Consulting and TRJ Environmental Inc., Research Triangle Park, NC, May 8, 2000.

[53] USEPA, January 2001.

times for each demographic group so that 100 annual activity patterns were available for each of the 40 groups. For each census tract, 30 of these 100 patterns were randomly selected to represent a typical annual time allocation in each micro-environment for demographic groups in that tract. USEPA notes that this process leads to an annual activity that estimates the average exposure in each group, as opposed to highly sensitive or highly exposed individuals.

4.5 Potential Cancer Risks

Potential cancer risk estimates are presented based on the ASPEN modeling results in Tables 4-2 and 4-3, and Figure 4-1 below. Tables 4-2 and 4-3 present potential cancer risks based on the average concentration and the upper 95th concentration, respectively. We include Figure 4-1 to compare the results more easily. This figure shows the cumulative risks based on the median, average, and upper-bound risk in each county. As shown in Figure 4-1, the median and average risk estimates are very similar, while the upper-bound risk estimates appear greater than the medians and the means. In addition, Kitsap County has the lowest risks, while King County has the highest risks.

In Tables 4-4 and 4-5 we present the exposure concentrations from HAPEM4 and the resulting potential cancer risks, respectively. As noted earlier in this section, the HAPEM4 results only include medians, so we cannot present the range of risks for each chemical. In Figure 4-2, we compare the cumulative potential cancer risks for each county based on the HAPEM4 exposure concentrations. Similar to the results for the ASPEN-based estimates, the potential cancer risks are similar among the four counties, with Kitsap being the lowest and King being the highest.

Finally, in Table 4-6 and Figure 4-3, we compare risks based on the median estimates from ASPEN and HAPEM4 for King County. The cumulative risks for both ASPEN and HAPEM4 are 580 in a million and 419 in a million, respectively. As expected, the risks are reduced when movement among various micro-environments is taken into account, although not dramatically. The only chemicals that appear to present significantly different cancer risks for ASPEN versus HAPEM4 are tetrachloroethylene or perchloroethylene, and PCBs.

Table 4-2: Average Potential Cancer Risks for Puget Sound Region based on ASPEN (ambient air concentration model) NATA (1996)

Chemical	King County	Kitsap County	Pierce County	Snohomish County
1) 1,1,2,2-Tetrachloroethane	2.35E-09	1.26E-08	7.13E-09	1.21E-08
2) 1,3-Butadiene	2.46E-06	9.84E-07	1.63E-06	1.31E-06
3) 1,3-Dichloropropene	4.16E-07	2.37E-07	3.46E-07	2.81E-07
4) 7-PAH	1.09E-06	5.88E-07	9.78E-07	6.48E-07
5) Acetaldehyde	1.96E-06	1.27E-06	1.70E-06	1.16E-06
6) Acrylonitrile	6.94E-09	3.20E-08	1.86E-08	2.75E-08
7) Arsenic Compounds	4.56E-07	1.84E-07	4.07E-07	1.83E-07
8) Benzene	1.83E-05	1.15E-05	1.58E-05	1.34E-05
9) Beryllium Compounds	3.05E-08	1.45E-08	2.42E-08	1.73E-08
10) Cadmium Compounds	5.81E-08	4.14E-08	6.59E-08	3.78E-08
11) Carbon Tetrachloride	1.32E-05	1.32E-05	1.32E-05	1.32E-05
12) Chloroform	1.92E-06	1.95E-06	1.94E-06	1.93E-06
13) Chromium Compounds	1.74E-05	3.92E-05	7.04E-06	1.10E-05
14) DPM	5.31E-04	3.54E-04	4.62E-04	3.84E-04
15) Ethylene Dibromide	1.69E-06	1.69E-06	1.69E-06	1.69E-06
16) Ethylene Dichloride	1.59E-06	1.59E-06	1.59E-06	1.59E-06
17) Ethylene Oxide	1.84E-07	7.36E-08	2.07E-07	7.14E-08
18) Formaldehyde	1.57E-05	1.08E-05	1.35E-05	1.08E-05
19) Hexachlorobenzene	4.28E-08	4.28E-08	4.28E-08	4.28E-08
20) Hydrazine	2.64E-10	2.61E-11	1.82E-10	6.91E-11
21) Lead Compounds	1.99E-07	4.90E-08	4.16E-08	3.23E-08
22) Methylene Chloride	2.53E-07	1.41E-07	2.00E-07	1.73E-07
23) Nickel Compounds	1.93E-06	3.16E-06	6.67E-07	6.14E-07
24) Perchloroethylene	1.80E-06	1.14E-06	1.34E-06	1.29E-06
25) Polychlorinated Biphenyls	3.88E-08	3.86E-08	3.81E-08	3.82E-08
26) Polycyclic Organic Matter	8.64E-06	4.15E-06	7.15E-06	2.97E-06
27) Propylene Dichloride	1.36E-10	5.09E-10	3.10E-10	4.62E-10
28) Quinoline	7.99E-10	1.63E-10	5.00E-10	2.50E-10
29) Trichloroethylene	1.71E-06	4.34E-07	7.16E-07	1.33E-06
30) Vinyl Chloride	1.58E-09	4.91E-09	3.73E-09	4.76E-09
Total	6.22E-04	4.47E-04	5.32E-04	4.48E-04

Table 4-3: 95th Percentile Upper-bound Potential Cancer Risk Estimates based on ASPEN NATA (1996)

Chemical	King County	Kitsap County	Pierce County	Snohomish County
1) 1,1,2,2-Tetrachloroethane	3.74E-09	1.94E-08	1.47E-08	2.49E-08
2) 1,3-Butadiene	4.74E-06	1.69E-06	2.66E-06	2.04E-06
3) 1,3-Dichloropropene	7.80E-07	4.72E-07	6.12E-07	4.92E-07
4) 7-PAH	1.85E-06	1.01E-06	1.55E-06	1.00E-06
5) Acetaldehyde	2.93E-06	1.56E-06	2.31E-06	1.50E-06
6) Acrolein	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7) Acrylonitrile	1.02E-08	4.92E-08	3.73E-08	5.66E-08
8) Arsenic Compounds	8.86E-07	2.71E-07	1.06E-06	3.71E-07
9) Benzene	2.64E-05	1.58E-05	2.25E-05	1.83E-05
10) Beryllium Compounds	5.50E-08	2.81E-08	4.80E-08	2.93E-08
11) Cadmium Compounds	1.08E-07	6.62E-08	1.42E-07	7.04E-08
12) Carbon Tetrachloride	1.32E-05	1.32E-05	1.32E-05	1.32E-05
13) Chloroform	1.93E-06	1.97E-06	1.96E-06	1.94E-06
14) Chromium Compounds	3.62E-05	1.26E-04	1.36E-05	3.64E-05
15) Coke Oven Emissions	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16) DPM	8.40E-04	4.20E-04	8.37E-04	6.84E-04
17) Ethylene Dibromide	1.69E-06	1.69E-06	1.69E-06	1.69E-06
18) Ethylene Dichloride	1.59E-06	1.59E-06	1.59E-06	1.59E-06
19) Ethylene Oxide	3.90E-07	1.64E-07	5.22E-07	1.28E-07
20) Formaldehyde	2.39E-05	1.24E-05	1.72E-05	1.24E-05
21) Hexachlorobenzene	4.28E-08	4.28E-08	4.28E-08	4.28E-08
22) Hydrazine	8.04E-10	3.90E-11	8.58E-10	3.18E-10
23) Lead Compounds	6.19E-07	7.45E-08	7.21E-08	7.85E-08
24) Manganese Compounds	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25) Mercury Compounds	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26) Methylene Chloride	4.07E-07	1.96E-07	4.31E-07	2.51E-07
27) Nickel Compounds	4.18E-06	9.89E-06	1.57E-06	1.32E-06
28) Perchloroethylene	2.59E-06	1.43E-06	2.00E-06	1.70E-06
29) Polychlorinated Biphenyls	3.95E-08	3.92E-08	3.82E-08	3.84E-08
30) Polycyclic Organic Matter	1.50E-05	6.77E-06	1.40E-05	5.02E-06
31) Propylene Dichloride	2.20E-10	7.77E-10	5.91E-10	9.69E-10
32) Quinoline	1.84E-09	2.47E-10	1.92E-09	6.66E-10
33) Trichloroethylene	3.70E-06	5.36E-07	2.04E-06	4.70E-06
34) Vinyl Chloride	2.70E-09	7.46E-09	8.98E-09	1.00E-08
Total	9.83E-04	6.17E-04	9.38E-04	7.88E-04

Figure 4-1: Comparing Ranges of Potential Cancer Risks for Puget Sound based on ASPEN NATA (1996)

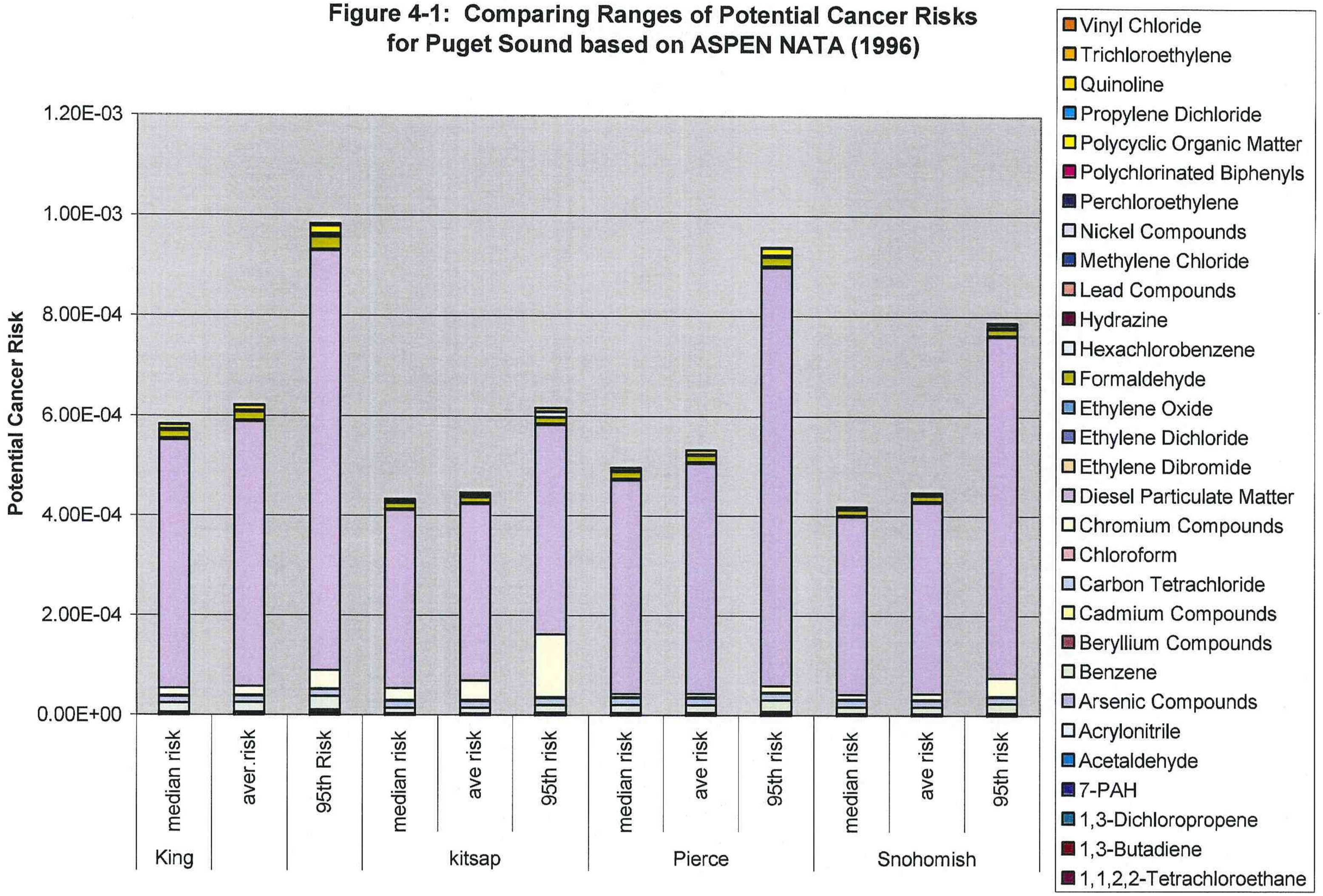


Table 4-4: Human Median Exposure Concentrations (μg/m^3) from HAPEM4

Chemical	King County	Kitsap County	Pierce County	Snohomish County
1) 1,1,2,2-Tetrachloroethane	3.0E-05	1.8E-04	4.6E-05	1.4E-04
2) 1,3-Butadiene	6.4E-02	2.8E-02	4.7E-02	4.1E-02
3) 1,3-Dichloropropene	8.0E-02	4.6E-02	6.9E-02	6.1E-02
4) Acetaldehyde	7.6E-01	5.2E-01	6.9E-01	4.9E-01
5) Acrolein	9.4E-02	5.8E-02	9.2E-02	6.9E-02
6) Acrylonitrile	7.3E-05	3.7E-04	9.6E-05	2.5E-04
7) Arsenic	7.7E-05	3.5E-05	5.8E-05	3.4E-05
8) Benzene	2.3E+00	1.4E+00	2.0E+00	1.8E+00
9) Beryllium	9.4E-06	4.3E-06	7.3E-06	5.9E-06
10) Cadmium	2.3E-05	1.9E-05	2.7E-05	1.7E-05
11) Carbon Tetrachloride	6.4E-01	6.4E-01	6.4E-01	6.4E-01
12) Chloroform	6.8E-02	6.9E-02	6.9E-02	6.8E-02
13) Chromium	8.4E-04	1.4E-03	3.7E-04	5.3E-04
14) Diesel PM	1.2E+00	8.4E-01	1.0E+00	8.7E-01
15) Ethylene Dibromide	6.1E-03	6.1E-03	6.1E-03	6.1E-03
16) Ethylene Dichloride	5.3E-02	5.2E-02	5.3E-02	5.2E-02
17) Ethylene Oxide	1.4E-03	5.6E-04	1.5E-03	6.4E-04
18) Formaldehyde	8.9E-01	6.7E-01	8.2E-01	6.7E-01
19) Hexachlorobenzene	7.5E-05	7.5E-05	7.5E-05	7.5E-05
20) Hydrazine	3.0E-08	3.5E-09	1.7E-08	8.4E-09
21) Lead	8.5E-03	3.4E-03	3.0E-03	1.3E-03
22) Manganese	9.6E-04	4.4E-04	7.4E-04	7.6E-04
23) Mercury	1.3E-03	1.4E-03	1.3E-03	1.3E-03
24) Methylene Chloride	4.0E-01	2.3E-01	3.0E-01	3.0E-01
25) Nickel	2.7E-03	3.4E-03	9.3E-04	1.0E-03
26) PCBS	3.1E-04	3.0E-04	3.0E-04	3.0E-04
27) Perchloroethylene	2.3E-01	1.5E-01	1.8E-01	1.8E-01
28) POM (total)	1.0E-01	6.2E-02	7.4E-02	4.3E-02
29) Propylene Dichloride	5.2E-06	2.2E-05	6.7E-06	1.6E-05
30) Quinoline	1.5E-07	3.2E-08	7.8E-08	5.0E-08
31) Trichloroethylene	5.9E-01	1.8E-01	2.5E-01	4.6E-01
32) Vinyl Chloride	1.2E-04	4.4E-04	1.9E-04	3.4E-04

Table 4-5: Potential Cancer Risks for Puget Sound Clean Air Counties based on HAPEM4 Exposure Estimates (based on median concentrations)

Chemical	King County	Kitsap County	Pierce County	Snohomish County
1) 1,1,2,2-Tetrachloroethane	1.7E-09	1.0E-08	2.7E-09	8.0E-09
2) 1,3-Butadiene	1.9E-06	8.3E-07	1.4E-06	1.2E-06
3) 1,3-Dichloropropene	3.2E-07	1.8E-07	2.8E-07	2.4E-07
4) Acetaldehyde	1.7E-06	1.2E-06	1.5E-06	1.1E-06
5) Acrylonitrile	5.0E-09	2.5E-08	6.6E-09	1.7E-08
6) Arsenic	3.3E-07	1.5E-07	2.5E-07	1.5E-07
7) Benzene	1.8E-05	1.1E-05	1.6E-05	1.4E-05
8) Beryllium	2.2E-08	1.0E-08	1.8E-08	1.4E-08
9) Cadmium	4.2E-08	3.3E-08	4.8E-08	3.1E-08
10) Carbon Tetrachloride	9.6E-06	9.6E-06	9.6E-06	9.6E-06
11) Chloroform	1.6E-06	1.6E-06	1.6E-06	1.6E-06
12) Chromium	1.0E-05	1.7E-05	4.5E-06	6.3E-06
13) Diesel PM	3.6E-04	2.5E-04	3.1E-04	2.6E-04
14) Ethylene Dibromide	1.3E-06	1.3E-06	1.3E-06	1.3E-06
15) Ethylene Dichloride	1.4E-06	1.4E-06	1.4E-06	1.4E-06
16) Ethylene Oxide	1.2E-07	5.0E-08	1.3E-07	5.6E-08
17) Formaldehyde	1.2E-05	8.6E-06	1.1E-05	8.7E-06
18) Hexachlorobenzene	3.4E-08	3.4E-08	3.5E-08	3.4E-08
19) Hydrazine	1.4E-10	1.7E-11	8.4E-11	4.1E-11
20) Lead	1.0E-07	4.1E-08	3.6E-08	1.6E-08
21) Methylene Chloride	1.9E-07	1.1E-07	1.4E-07	1.4E-07
22) Nickel	1.3E-06	1.6E-06	4.4E-07	4.9E-07
23) PCBS	3.1E-08	3.0E-08	3.0E-08	3.0E-08
24) Perchloroethylene	1.4E-06	8.9E-07	1.1E-06	1.1E-06
25) POM (total)	5.7E-06	3.4E-06	4.1E-06	2.3E-06
26) Propylene Dichloride	9.8E-11	4.2E-10	1.3E-10	3.0E-10
27) Quinoline	5.0E-10	1.1E-10	2.7E-10	1.7E-10
28) Trichloroethylene	1.2E-06	3.6E-07	4.9E-07	9.2E-07
29) Vinyl Chloride	1.1E-09	3.9E-09	1.7E-09	3.0E-09
Total	***4.3E-04***	***3.1E-04***	***3.6E-04***	***3.1E-04***

Figure 4-2: Potential Cancer Risks in the Puget Sound Region based on HAPEM4 (medians) 1996

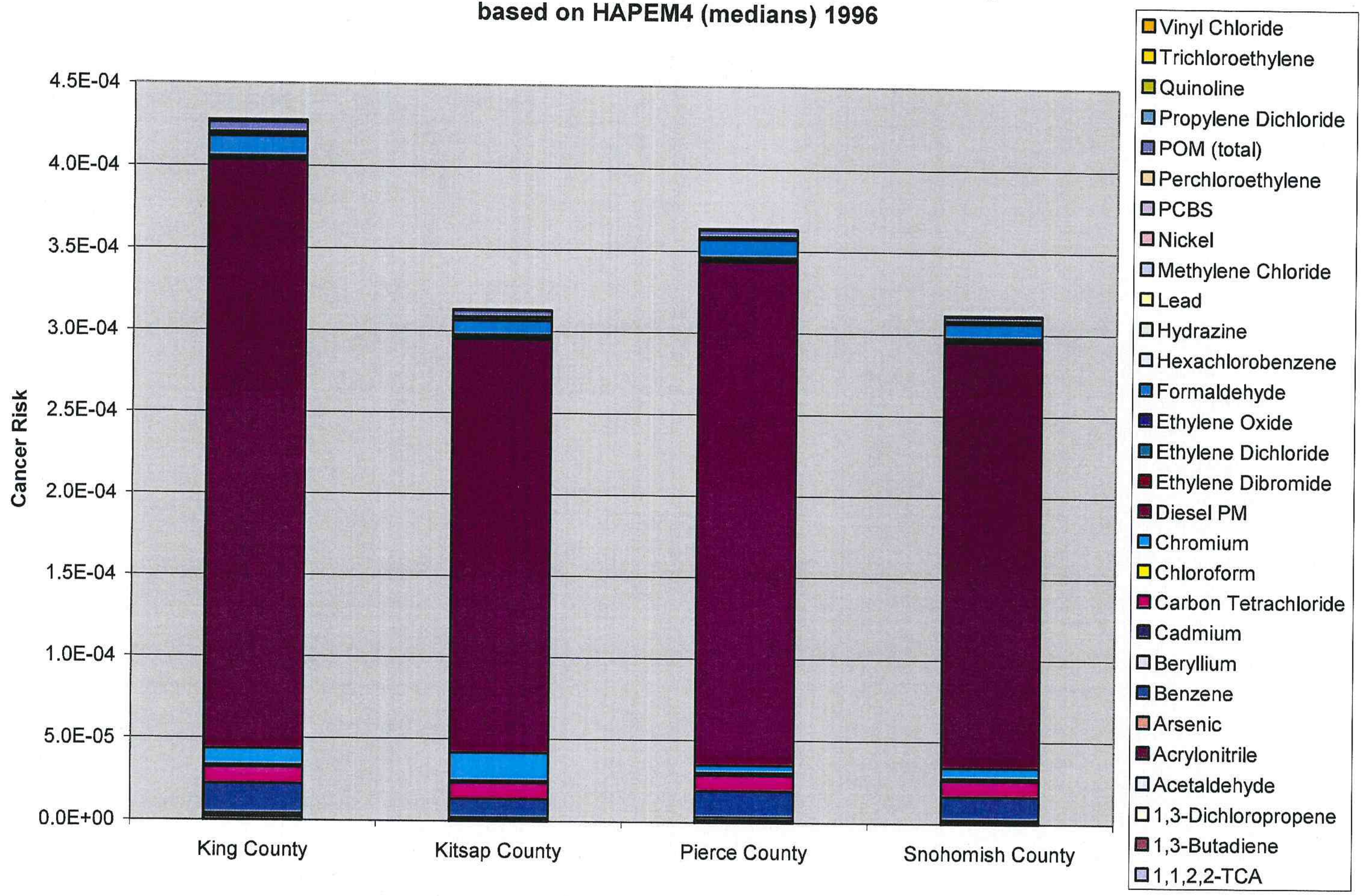
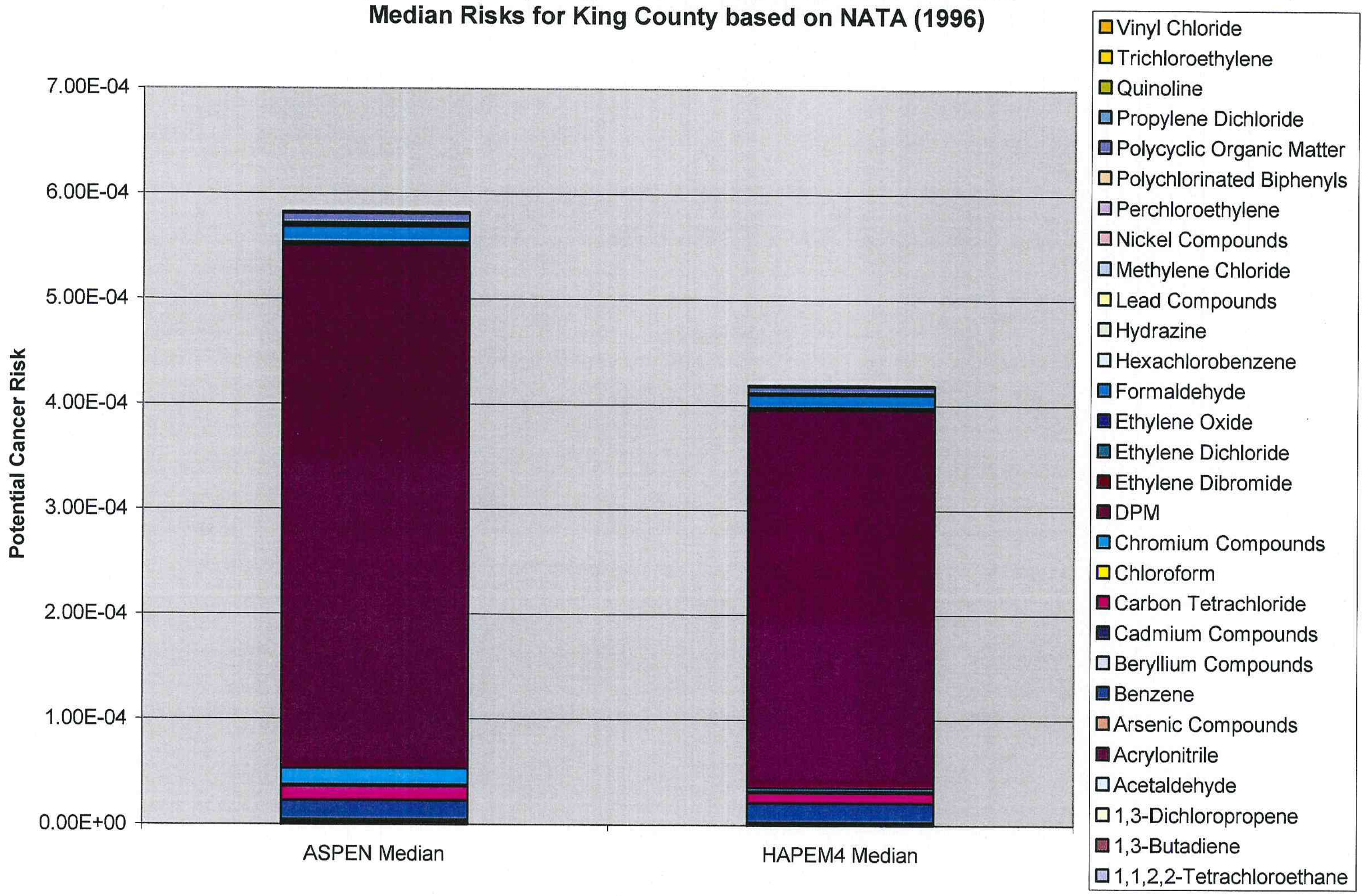


Table 4-6: Comparing Risks between ASPEN (ambient air) and HAPEM4 (micro-environments) for King County

Chemical	ASPEN Median	HAPEM4 Median
1) 1,1,2,2-Tetrachloroethane	2.24E-09	1.74E-09
2) 1,3-Butadiene	2.15E-06	6.42E-07
3) 1,3-Dichloropropene	3.94E-07	3.2E-07
4) Acetaldehyde	1.91E-06	1.67E-06
5) Acrylonitrile	6.69E-09	4.97E-09
6) Arsenic Compounds	4.20E-07	3.31E-07
7) Benzene	1.79E-05	1.82E-05
8) Beryllium Compounds	2.83E-08	2.24E-08
9) Cadmium Compounds	5.38E-08	4.22E-08
10) Carbon Tetrachloride	1.32E-05	9.6E-06
11) Chloroform	1.92E-06	1.57E-06
12) Chromium Compounds	1.49E-05	3.43E-06
13) DPM	4.98E-04	0.00036
14) Ethylene Dibromide	1.69E-06	1.34E-06
15) Ethylene Dichloride	1.59E-06	1.37E-06
16) Ethylene Oxide	1.53E-07	1.22E-07
17) Formaldehyde	1.46E-05	1.15E-05
18) Hexachlorobenzene	4.28E-08	3.45E-08
19) Hydrazine	1.70E-10	1.45E-10
20) Lead Compounds	1.20E-07	1.02E-07
21) Methylene Chloride	2.32E-07	1.9E-07
22) Nickel Compounds	1.65E-06	3.22E-07
23) Perchloroethylene	1.72E-06	3.06E-08
24) Polychlorinated Biphenyls	3.87E-08	1.37E-06
25) Polycyclic Organic Matter	8.42E-06	5.7E-06
26) Propylene Dichloride	1.26E-10	9.81E-11
27) Quinoline	6.66E-10	4.99E-10
28) Trichloroethylene	1.39E-06	1.18E-06
29) Vinyl Chloride	1.43E-09	1.07E-09
Total	5.82E-04	4.19E-04

Figure 4-3: Comparing ASPEN Median Risks with HAPEM4 Median Risks for King County based on NATA (1996)



4.6 Potential Non-cancer Risks

Table 4-7 presents hazard indices for the range of ambient concentrations predicted by ASPEN. These values are presented not only for the average ambient concentration but for the 75th, 90th, and 95th percentile concentrations as well. The HI associated with the upper percentile concentrations are presented to show the range of potential non-cancer risks. Since we do not have 24-hour average concentrations that are typically compared to the RfC, a conservative or health protective estimate can be derived using the upper-bound concentration. These concentration ranges are not available for the monitored concentrations or the HAPEM4 (human exposure model) results, so they are not presented in those corresponding sections.

As shown in this table, the hazard indices for most of the 32 chemicals are less than 1.0 for the range of concentrations predicted across King County using the ASPEN model. The only chemical that appears to present a potential non-cancer health risk is acrolein, which has an average hazard index of 6 but could be as high as 12 or higher. Ambient concentrations of acrolein could not be verified through monitoring results, so these estimates are considered uncertain. The RfC for this chemical is based on irritation effects in the nasal epithelium, although exposure is also associated with irritation of the larynx, trachea, and lungs.[54]

Although this type of analysis indicates that acrolein is the only chemical of those modeled that should be of concern from a non-cancer perspective, it is important to note that the non-cancer health effects associated with particulate matter (e.g., woodsmoke and diesel particulate matter) have not been adequately evaluated using this method. The association between human health effects, such as increased respiratory effects and increased mortality, and ambient exposures to particulate matter are well documented in the literature.[55] As a result, the hazard index for diesel particulate matter should be viewed as only part of the more complex particulate matter non-cancer risk.

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[54] USEPA IRIS file for acrolein. Downloaded February 2002.

[55] USEPA *Air Quality Criteria for Particulate Matter (Second External Review Draft)* EPA 600/P-99/002aB, bB, March 2001.

Hazard indices based on the range of exposure concentrations predicted using the HAPEM4 model could not be calculated at this time. USEPA has indicated that they will provide the range of exposure concentrations from the HAPEM4 model results at a later date. We expect to evaluate these concentrations by calculating hazard indices when this information becomes available.

Table 4-7: Hazard Indices for ASPEN ambient estimates in King County

Pollutant	**HI for average**	**HI for 75th**	**HI for 90th**	**HI for 95th**
1) Acetaldehyde	0.1	0.1	0.1	0.1
2) *Acrolein*	*6.0*	*6.5*	*8.2*	*11.7*
3) Acrylonitrile	0.0	0.0	0.0	0.0
4) Arsenic Compounds	0.0	0.0	0.0	0.0
5) Benzene	0.0	0.0	0.1	0.1
6) Beryllium Compounds	0.0	0.0	0.0	0.0
7) 1,3-Butadiene	0.0	0.0	0.0	0.0
8) Cadmium Compounds	0.0	0.0	0.0	0.0
9) Carbon Tetrachloride	0.0	0.0	0.0	0.0
10) Chloroform	0.0	0.0	0.0	0.0
11) Chromium Compounds	0.0	0.0	0.0	0.0
12) 1,3-Dichloropropene	0.0	0.0	0.0	0.0
13) Ethylene Dibromide	0.0	0.0	0.0	0.0
14) Ethylene Dichloride	0.0	0.0	0.0	0.0
15) Ethylene Oxide	0.0	0.0	0.0	0.0
16) Formaldehyde	0.1	0.1	0.2	0.2
17) Hexachlorobenzene	0.0	0.0	0.0	0.0
18) Hydrazine	0.0	0.0	0.0	0.0
19) Lead Compounds	0.0	0.0	0.0	0.0
20) Manganese Compounds	0.0	0.1	0.1	0.1
21) Mercury Compounds	0.0	0.0	0.0	0.0
22) Methylene Chloride	0.0	0.0	0.0	0.0
23) Nickel Compounds	0.0	0.0	0.0	0.0
24) Perchloroethylene	0.0	0.0	0.0	0.0
25) Polychlorinated Biphenyls	0.0	0.0	0.0	0.0
26) Polycyclic Organic Matter	0.0	0.0	0.0	0.0
27) 7-PAH	0.0	0.0	0.0	0.0
28) Propylene Dichloride	0.0	0.0	0.0	0.0
29) Quinoline	0.0	0.0	0.0	0.0
30) 1,1,2,2-Tetrachloroethane	0.0	0.0	0.0	0.0
31) Trichloroethylene	0.0	0.0	0.0	0.0
32) Vinyl Chloride	0.0	0.0	0.0	0.0
Total Hazard Quotient	***6.2***	***6.8***	***8.7***	***12.2***

Chapter 5: Summary and Conclusions

We evaluated cancer and non-cancer risks using three different methods of estimating potential exposures.

Greater Seattle Monitored Ambient Concentrations, and Modeled DPM and Woodsmoke

Although this method includes the fewest number of compounds, it shows some of the highest potential cancer risks. The average risks range from a low of 57 in a million in Lake Sammamish to a high of 620 in a million at Beacon Hill. The high values at Beacon Hill reflect the fact that we include DPM and woodsmoke in these risk estimates. Excluding DPM and woodsmoke, Lake Sammamish shows the lowest potential cancer risk at 59 in a million and Georgetown the highest at 104 in a million for the greater Seattle area. Although Georgetown is almost twice as high as Lake Sammamish, these differences become less compelling when compared with potential cancer risks that include DPM and woodsmoke, which approach 500 in a million (at Beacon Hill).

Average cancer risks from all monitored sites combined (approximately 73 in a million are comparable to those at Beacon Hill (approximately 80 in a million). Similarly, Beacon Hill average cancer risks including DPM (approximately 500 in a million), are less but within an order of magnitude of cancer risks (approximately 600 in a million) based on NATA ASPEN results for King County. This suggests that the modeled values are reasonable estimates of risk, and could be used when monitored values are not available.

In addition, none of the hazard indices for any of the chemicals monitored in the Seattle Monitoring Study exceed one. However, these results should be viewed with caution because they do not evaluate non-cancer health effects associated with DPM or woodsmoke.

Modeled ambient concentrations from USEPA NATA

USEPA presented a range of modeled ambient concentrations from NATA. Similarly, our assessment presents a range of potential cancer risks from air toxics in all four counties in the Puget Sound region. For all toxics combined, average cumulative cancer risks based on ambient concentrations range from approximately 400 in a million for Kitsap and Snohomish Counties to approximately 600 in a million for King County. Pierce County is approximately 500 in a million. These values include DPM as a whole mixture but only include a small subset of chemicals in the woodsmoke mixture. Although more populated counties such as King and Pierce have somewhat higher potential cancer risks, all four counties are well above the one in a million risk goal for Superfund, and the one-in-a-million to one-in-ten-thousand risk range commonly used by USEPA.[56]

Modeled human exposure concentrations from USEPA NATA

The results from the HAPEM4 modeling exercise in NATA show cumulative risks of approximately 400 in a million. Because the NATA project only provides median exposure concentrations from HAPEM4, we can only calculate risks associated with the median values. However, the median values for the ASPEN modeling are approximately 580 in a million. The greatest difference in individual chemical risk estimates between the two appears to be due to DPM. This may be due to the fact that DPM is a particle rather than a gas, and may not penetrate as easily from ambient air to micro-environments.

For all methods, the cumulative cancer risks that include DPM range from a low of 400 in a million (NATA HAPEM4) to a high of 600 in a million for King County (NATA ASPEN). All risk estimates reflect a 70-year exposure period.

5.1 Priority Chemicals

The air toxics that contribute most to the cancer risks are very consistent across the different methods of analysis. The top toxics for all three methods include DPM, benzene, formaldehyde, carbon tetrachloride, and chromium compounds. Woodsmoke also contributed to the cumulative risk estimates based on the monitored data.

In addition, the percent contribution of the top air toxics is also very similar across the different methods of analysis. For example, at Beacon Hill, diesel particulate matter accounts for 79% of the potential cancer risk. ASPEN and HAPEM4 results also show DPM as the top toxic

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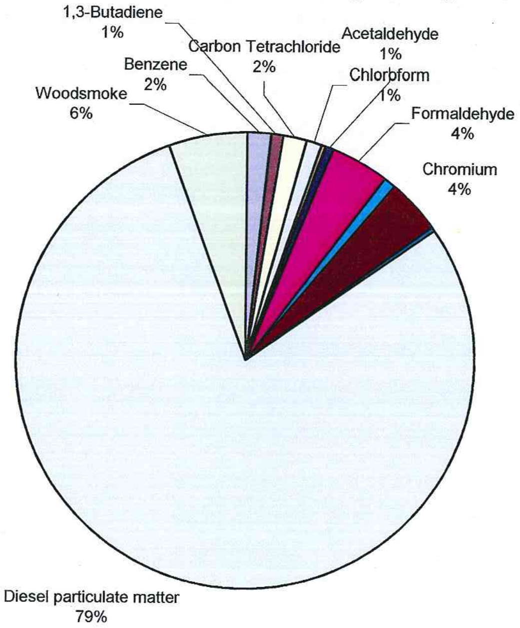
[56] USEPA. ***Residual Risk Report to Congress.*** Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA – 453/R-99-001. March 1999.

comprising approximately 85% of the total risk. The remaining air toxics are primarily formaldehyde, benzene, acetaldehyde, and 1,3-butadiene in all three methods, which are all related to mobile sources. Chromium and carbon tetrachloride also contribute, but appear to be due to area and major sources.[57] Woodsmoke contributes approximately 6% of the risk from Beacon Hill, although it is difficult to say how much it contributes to the NATA estimates because it is not specifically noted. If woodsmoke is included in the POM estimate, NATA results could indicate this category contributes approximately 1% of the total.

Persistent Bioaccumulative Toxics

We examined a limited number of PBTs through the inhalation pathway, and only arsenic and cadmium appear to be possible priority chemicals. However, both DPM and woodsmoke contain numerous PAHs, and should be considered potential sources of PBTs in our region. In addition, the Agency may wish to consider further study into possible air emission sources for PBTs and resulting potential risks through the ingestion pathway.

Figure 5-1: Potential Cancer Risks based on Monitoring/modeling at Beacon Hill (2001)



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[57] USEPA NATA printout for King County, Snohomish County, Pierce County and Kitsap County. See NATA website. http://www.epa.gov/ttn/atw/nata/.

Figure 5-2: Potential Cancer Risks based on NATA ASPEN results for King County (1996)

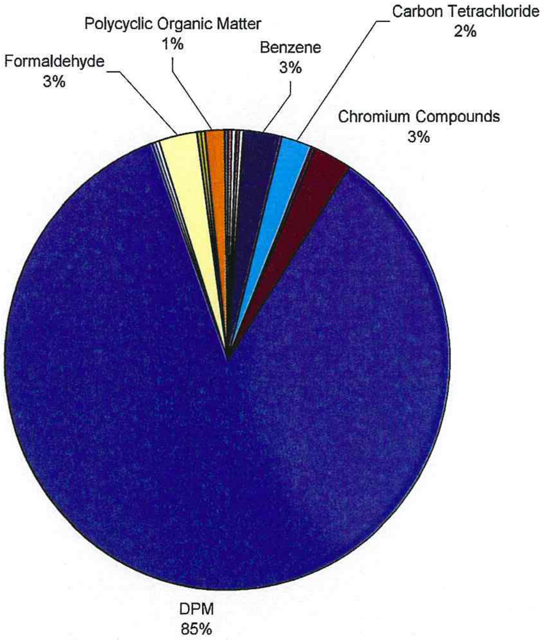
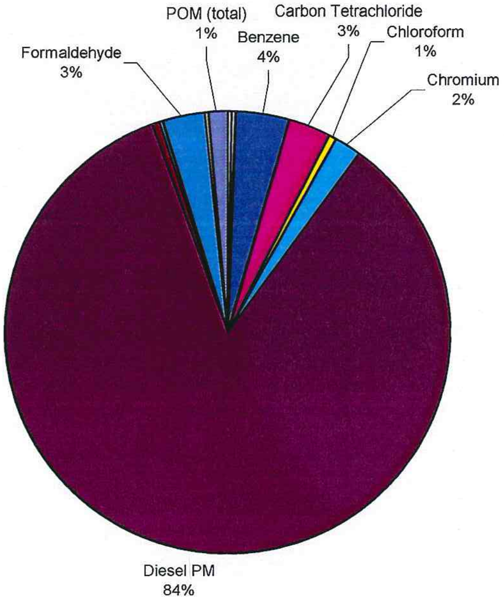


Figure 5-3: Potential Cancer Risks based on NATA HAPEM4 for Kitsap County (1996)



5.2 Uncertainties

Although the modeled concentrations provide the highest cancer risk estimates, these values are likely to underestimate the risks from air toxics. The ASPEN model appears to underestimate ambient concentrations in the King County area because the modeling reflects ambient concentrations across the entire county, which includes less impacted areas. In addition, the emissions inventory does not include all sources and may underestimate emissions for those sources that are represented. Finally, the model may not adequately consider production of HAPs from atmospheric transformation reactions. However, the NATA ambient concentrations (ASPEN) result in larger cancer risk estimates than the monitored estimates because they include a larger number of air toxics than the monitoring studies. This suggests that if the list of air toxics were more comprehensive, the overall estimated cancer risks could increase, although it is difficult to say by how much.

Because all the risk values in this assessment are based on annual average or median exposure concentrations, which are combined with conservative toxicity estimates, they are expected to be reasonable high-end risk estimates but not maximum risk estimates. For some chemicals, the values may underestimate potential cancer risks for some individuals. The concentrations used in the risk calculations are county-wide averages that may not reflect local hotspots. For example, individuals who spend more of their time near large point sources may experience higher risks due to those emissions.

Alternatively, much of the air monitoring and human behavioral information suggests that potential cancer risks may not vary dramatically across the county. For example, the monitoring results suggest that average ambient concentrations for a variety of toxics do not appear to vary significantly among different areas of the county.

Finally, the cancer risk estimates for diesel particulate matter also have some uncertainties associated with them. Although USEPA has not recommended a final unit risk factor for evaluating potential cancer risks associated with environmental exposures to diesel particulate matter, they state strongly that diesel particulate matter is a probable human carcinogen. In addition, USEPA encourages states to consider further the possible range of potential cancer risks associated with those levels predicted using the NATA results. In the NATA document, USEPA states[58]

> *Even the lower end of the risk range (presented in the risk perspectives section of the Diesel Exhaust HAD) is above the level that has historically warranted regulatory concern at USEPA for air toxics. The Agency believes that areas of the U.S. that have relatively higher annual exposure levels for diesel exhaust, certainly those counties and States with annual exposure levels above 2 micrograms per cubic meter, should consider the scientific judgments that the Agency has made in the risk perspectives section of the HAD while considering the important limitations in their efforts to compare air toxics risks and set priorities for their programs. At the higher exposure levels found in a number of urban areas in NATA, there is an overlap between what the occupational levels were in the epidemiological studies that EPA considered and the environmentally equivalent exposures.*

Overall, this information suggests that ambient air toxics could contribute significantly to cancer and non-cancer risks in the Puget Sound region. It is possible that these risks are underestimated because (1) not all air toxics are considered in this analysis, and (2) many chemicals have been shown to accumulate in indoor micro-environments, which could increase exposure. Alternatively, risk may be overestimated by assuming that the concentration at the monitor accurately reflects lifetime exposure to ambient pollutants. It is important to note that this analysis does not evaluate indoor sources of air pollution (i.e., from paints, home furnishings, cleaning products, building materials, and other indoor sources). Uncertainties in the toxicity information could also serve to over- or underestimate potential risk estimates.

5.3 Conclusion

The information presented in this report uses screening risk estimates to focus Agency attention on those compounds and mixtures that are likely to present the greatest risk of cancer and some non-cancer effects. DPM ranks high in potential contributions to cancer risk, higher than other air toxics measured in this study. In addition, volatile organics associated with mobile sources such as benzene, formaldehyde, and 1,3-butadiene contribute significantly to the potential cancer risks from air toxics. Woodsmoke could also contribute to the overall potential cancer risk from air toxics in the Puget Sound region.

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[58] USEPA 2001 pg 102.

DPM, benzene, 1,3-butadiene, and formaldehyde are all classified as class A or B carcinogens under the USEPA cancer rating system. This indicates that USEPA is relatively confident that these chemicals probably cause cancer in humans. These chemicals should have high priority during development of an air toxics reduction program for the Puget Sound area.

Finally, acrolein appears to present a potential non-cancer risk as well. As stated earlier, the non-cancer health effects associated with the particulate-matter combustion mixtures (e.g., woodsmoke and diesel particulate matter) are not adequately evaluated here, and are extensively evaluated in other analyses.

In addition, these analyses suggest that the ambient concentration estimates from mobile sources are predicted with reasonable accuracy, and that they can be used in the absence of more accurate monitoring data, particularly in urban areas. This conclusion may not apply to model results for more rural areas, particularly if outdoor or agricultural burning could contribute substantially to ambient PM or air toxics concentrations. We also recommend additional review of the HAPEM4 results in future NATA analyses, and further research for exposure models that may more accurately predict potential exposures to air toxics.

APPENDIX A

Lab Reports

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James E. Bruya, Ph.D.
Yelena Aravkina, M.S.
Michael Erdahl, B.S.
Arina Podnozova, B.S.
Eric Young, B.S.

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(206) 285-8282
fbi@isomedia.com
www.friedmanandbruya.com

March 16, 2016

Eric Zuern, Project Manager
Environmental Associates, Inc.
1380 112th Ave. NE, 300
Bellevue, WA 98004

Dear Mr. Zuern:

Included are the results from the testing of material submitted on March 9, 2016 from the Chri-Mar Apts, PO 36005-1, F&BI 603158 project. There are 7 pages included in this report. Any samples that may remain are currently scheduled for disposal in 30 days. If you would like us to return your samples or arrange for long term storage at our offices, please contact us as soon as possible.

We appreciate this opportunity to be of service to you and hope you will call if you have any questions.

Sincerely,

FRIEDMAN & BRUYA, INC.

Michael Erdahl
Project Manager

Enclosures
EAI0316R.DOC

CASE NARRATIVE

This case narrative encompasses samples received on March 9, 2016 by Friedman & Bruya, Inc. from the Environmental Associates Chri-Mar Apts, PO 36005-1, F&BI 603158 project. Samples were logged in under the laboratory ID's listed below.

Laboratory ID	Environmental Associates
603158 -01	Bld-19618
603158 -02	Outdoor
603158 -03	Bld-19620

All quality control requirements were acceptable.

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Bld-19618	Client:	Environmental Associates
Date Received:	03/09/16	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	603158-01
Date Analyzed:	03/09/16	Data File:	030909.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	100	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	0.14	0.062
Benzene	0.99	0.31
Trichloroethene	<0.054	<0.01
Tetrachloroethene	0.26	0.038

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Outdoor	Client:	Environmental Associates
Date Received:	03/09/16	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	603158-02
Date Analyzed:	03/09/16	Data File:	030908.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	99	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	0.088	0.040
Benzene	0.71	0.22
Trichloroethene	<0.054	<0.01
Tetrachloroethene	0.35	0.051

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Bld-19620	Client:	Environmental Associates
Date Received:	03/09/16	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	603158-03
Date Analyzed:	03/09/16	Data File:	030910.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	106	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	0.27	0.12
Benzene	1.1	0.34
Trichloroethene	0.054	0.010
Tetrachloroethene	0.50	0.074

Analysis For Volatile Compounds By Method TO-15

Client Sample ID:	Method Blank	Client:	Environmental Associates
Date Received:	Not Applicable	Project:	Chri-Mar Apts, PO 36005-1, F&BI 603158
Date Collected:	03/09/16	Lab ID:	06-471 mb
Date Analyzed:	03/09/16	Data File:	030907.D
Matrix:	Air	Instrument:	GCMS7
Units:	ug/m3	Operator:	MP

Surrogates:	% Recovery:	Lower Limit:	Upper Limit:
4-Bromofluorobenzene	96	70	130

Compounds:	Concentration ug/m3	ppbv
1,3-Butadiene	<0.022	<0.01
Benzene	<0.032	<0.01
Trichloroethene	<0.054	<0.01
Tetrachloroethene	<0.068	<0.01

Date of Report: 03/16/16
Date Received: 03/09/16
Project: Chri-Mar Apts, PO 36005-1, F&BI 603158

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF AIR SAMPLES FOR VOLATILES BY METHOD TO-15 SIM

Laboratory Code: Laboratory Control Sample

Analyte	Reporting Units	Spike Level	Percent Recovery LCS	Acceptance Criteria
1,3-Butadiene	ppbv	1	108	70-130
Benzene	ppbv	1	107	70-130
Trichloroethene	ppbv	1	110	70-130
Tetrachloroethene	ppbv	1	110	70-130

Data Qualifiers & Definitions

a - The analyte was detected at a level less than five times the reporting limit. The RPD results may not provide reliable information on the variability of the analysis.

b - The analyte was spiked at a level that was less than five times that present in the sample. Matrix spike recoveries may not be meaningful.

ca - The calibration results for the analyte were outside of acceptance criteria. The value reported is an estimate.

c - The presence of the analyte may be due to carryover from previous sample injections.

cf - The sample was centrifuged prior to analysis.

d - The sample was diluted. Detection limits were raised and surrogate recoveries may not be meaningful.

dv - Insufficient sample volume was available to achieve normal reporting limits.

f - The sample was laboratory filtered prior to analysis.

fb - The analyte was detected in the method blank.

fc - The compound is a common laboratory and field contaminant.

hr - The sample and duplicate were reextracted and reanalyzed. RPD results were still outside of control limits. Variability is attributed to sample inhomogeneity.

hs - Headspace was present in the container used for analysis.

ht – The analysis was performed outside the method or client-specified holding time requirement.

ip - Recovery fell outside of control limits. Compounds in the sample matrix interfered with the quantitation of the analyte.

j - The analyte concentration is reported below the lowest calibration standard. The value reported is an estimate.

J - The internal standard associated with the analyte is out of control limits. The reported concentration is an estimate.

jl - The laboratory control sample(s) percent recovery and/or RPD were out of control limits. The reported concentration should be considered an estimate.

js - The surrogate associated with the analyte is out of control limits. The reported concentration should be considered an estimate.

lc - The presence of the analyte is likely due to laboratory contamination.

L - The reported concentration was generated from a library search.

nm - The analyte was not detected in one or more of the duplicate analyses. Therefore, calculation of the RPD is not applicable.

pc - The sample was received with incorrect preservation or in a container not approved by the method. The value reported should be considered an estimate.

ve - The analyte response exceeded the valid instrument calibration range. The value reported is an estimate.

vo - The value reported fell outside the control limits established for this analyte.

x - The sample chromatographic pattern does not resemble the fuel standard used for quantitation.

Send report to
Eric Zuern, Environmental Associates, Inc.

SAMPLE CHAIN OF CUSTODY

ME 03/09/16

Page # 1 of 1

Report 603158

Bill to: Company Milestone Properties

Address PO Box 18379

City, State, Seattle WA

Phone (EAI) 425-455-9025 Email info@environmentalassociatesinc.com

SAMPLERS (*signature*) Eric Zuern	
PROJECT NAME Chri-Mar Apts	PO # 36005-1
REMARKS send report to Eric @ EAI	INVOICE TO Milestone Prop

TURNAROUND TIME
[✓ Standard] 1 week
· RUSH
Rush charges authorized by:
SAMPLE DISPOSAL
[✓ · Dispose after 30 days]
· Archive Samples
· Other

ANALYSIS REQUESTED

Sample Name	Lab ID	Canister ID	Flow Contr. ID	Date Sampled	Field Initial Press. (Hg)	Field Initial Time	Field Final Press. (Hg)	Field Final Time	TO-15 Full Scan	TO-15 BTEXN	TO-15 cVOCs	TO-15 PCE TCE Benzene, 1,3 Butadiene	Notes
Bld-19618	01	18580	07853	3-8-16 3-9-16	29	8:10	5	8:00				X	
outdoor	02	18574	07545	3-8-16 3-9-16	28	8:20	5	8:10				X	
Bld-19620	03	25715	[illegible]	3-8-16 3-9-16	28.0	8:50	7	7:[illegible]				X	

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282
Fax (206) 283-5044

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Eric Zuern	EAI	3-9-16	9:40
Received by:	Nhan Phan	FeBI	3-9-16	9:40
Relinquished by:				
Received by:				

FORMS\COC\COCTO-15.DOC

Samples received at 19 °C

APPENDIX B

2003 Puget Sound Clean Air Agency Report

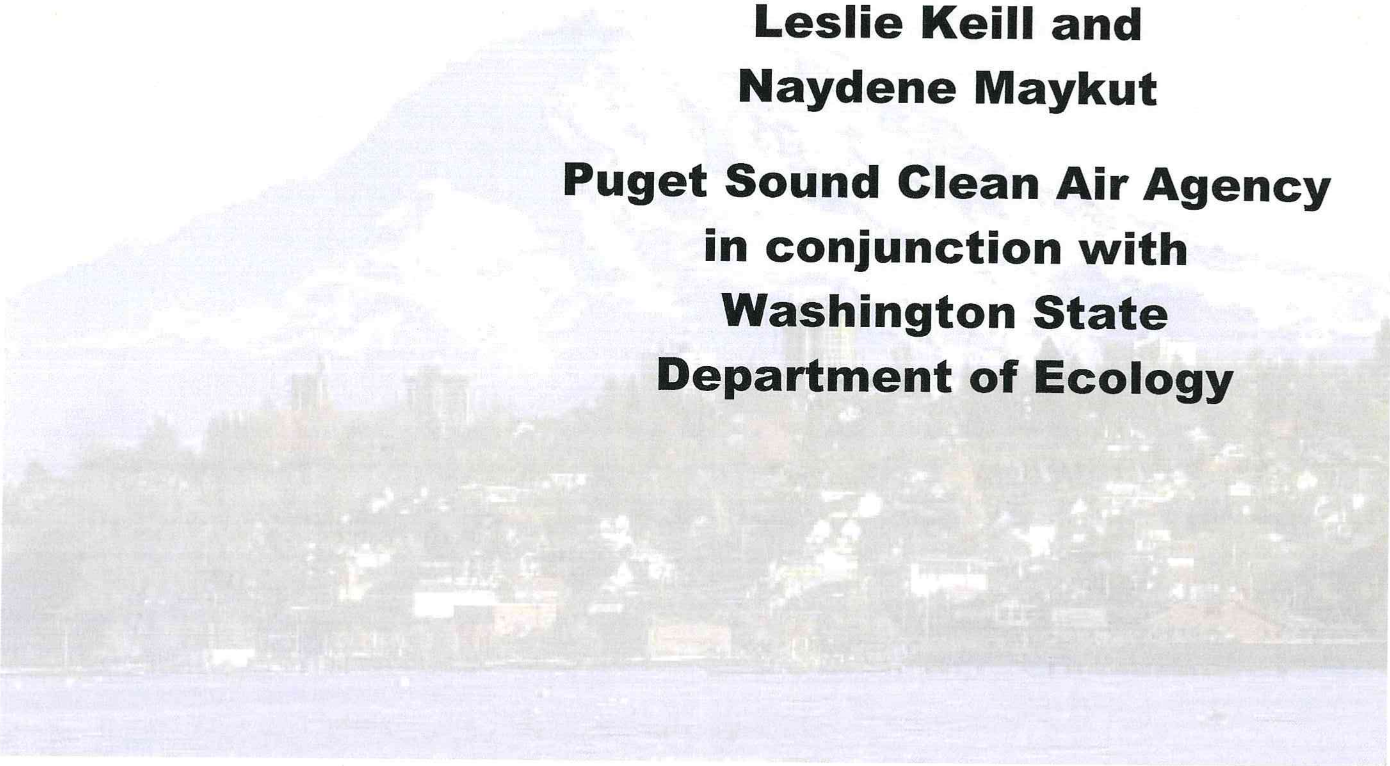
PUGET SOUND
Clean Air Agency

Final Report: Puget Sound Air Toxics Evaluation

October 2003

Leslie Keill and
Naydene Maykut

Puget Sound Clean Air Agency
in conjunction with
Washington State
Department of Ecology



For more information about this report, call Leslie Keill at (206) 689-4022

Puget Sound Clean Air Agency
110 Union Street, Suite 500
Seattle, WA 98101-2038
(206) 343-8800 or
(800) 552-3565
www.pscleanair.org

Printed on recycled paper, October 2003

This report was released as a draft in 2002 and we received comments on the draft from a variety of reviewers. These reviewers include Dr. Sally Liu from the University of Washington, Dr. Jane Koenig from the University of Washington, Dr. David Solet from the Metro King County Public Health Department, Dr. Matt Kadlec from the Washington Department of Ecology, Dr. Harriet Ammann from the Washington Department of Health, Ms. Julie Wroble from the US Environmental Protection Agency, and Dr. Kay Jones from Zephyr Consulting Company. We also received comments from Dr. Houck of Omni Consulting on behalf of the Hearth Products Association.

The authors addressed many of these comments in this final report. We would like to thank our reviewers, and appreciate the time they took to provide valuable feedback on our draft.

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Executive Summary

The Puget Sound Clean Air Agency conducted this screening study to identify chemicals and emission sources that pose the greatest potential health risks to citizens in the Puget Sound region. We also hope to better characterize the potential health risks to our three million residents from a group of air contaminants referred to as air toxics. This study is intended to assist the Agency in focusing resources on those emissions and sources that may pose the highest risks. The results should also help improve air toxics regulations and voluntary programs. The estimates of cancer and non-cancer health effects should not be viewed as actual cancer or non-cancer cases resulting from air pollution but as an estimate of relative impact of the evaluated toxic-air pollutants so the Agency can prioritize its efforts to reduce air pollution.

Defining Air Toxics

Air toxics are different from the 6 traditional air pollutants or "criteria pollutants" that have been regulated by environmental regulatory agencies for a number of years. Our agency defines "air toxics" as a broad category of chemicals that covers over 400 air pollutants along with woodsmoke and diesel particles. Similarly, the United States Environmental Protection Agency (USEPA) commonly refers to "air toxics" as a synonym for the 189 hazardous air pollutants listed in the 1990 amendments to the federal Clean Air Act. Because resources are not available to evaluate every chemical, this study evaluates a short list of 17 to 30 air toxics. We hope to expand the list of toxics when more resources become available.

Persistent, Bioaccumulative Toxics (PBTs)

Some persistent, bioaccumulative toxics (PBTs) such as mercury, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), cadmium, and arsenic were included in our study. However, we evaluate potential health risks only from the inhalation pathway, as the ingestion pathway was considered to be beyond the scope of this study.

Methods

This study uses basic risk assessment concepts and models, such as toxicity and exposure assessment, to provide a general overview of the potential health impacts that could be due to air toxics. Because of limited resources, this report does not perform a comprehensive risk assessment, which would include more detailed analyses and discussion of toxicity and exposure parameters, as well as a more in-depth risk characterization section. More comprehensive information on various details of this study can be found in the technical support documents referenced throughout this report.

Toxicity

The toxicity chapter includes dose-response information on the variety of air toxics evaluated in the Puget Sound region. The majority of this information is based on toxicity analyses performed by USEPA and included in their Integrated Risk Information System (IRIS). For some chemicals and mixtures, such as diesel particulate matter, chromium, and woodsmoke, we depart from recommended USEPA IRIS toxicity values. For example, for diesel particulate matter, we use the California Environmental Protection Agency's toxicity evaluation. Our rationale for this and other departures is described in the toxicity chapter.

Exposure

The toxicity values described above are combined with exposure assessment information to estimate both cancer and non-cancer potential health risks. We use results from three different exposure assessments to characterize air emissions and to estimate potential exposure concentrations for the residents of the Puget Sound area. These three exposure assessments include a monitoring study conducted in the greater Seattle/King County area, and two modeling assessments conducted as part of USEPA National-scale Air Toxics Assessment (NATA) in the four counties in the Puget Sound Clean Air Agency jurisdiction (King, Kitsap, Pierce, and Snohomish counties).

The monitoring study, which was conducted by the Washington State Department of Ecology in partnership with the Puget Sound Clean Air Agency and USEPA, sampled outdoor air at six different locations throughout the greater Seattle/King County area during 2000 and 2001. These six locations include areas near or in Beacon Hill, Georgetown, Lake Sammamish, Lake Forest Park, the Maple Leaf reservoir in north Seattle, and the city of SeaTac.

In addition to the monitoring study, we used exposure estimates from two models used by USEPA in their nationwide air toxics study entitled the National-scale Air Toxics Assessment (NATA). In this study, USEPA predicts outdoor air concentrations using the ASPEN model for 32 air toxics in counties across the country. We obtained the outdoor air concentrations for the four Puget Sound counties, compared them to monitored concentrations, and calculated potential health risks associated with those concentrations.

The third model used to predict exposure concentrations is also part of the NATA study. This model, entitled the Hazardous Air Pollutant Exposure Model4 (HAPEM4), predicts human exposures to the outdoor air pollutants by considering typical human behaviors and micro-environments where these outdoor pollutants might accumulate or dissipate. For example, this model uses average commute time estimates for a variety of individuals to estimate potential exposures to vehicle exhaust while riding in cars or waiting in traffic. Exposures such as these are combined for multiple activities and locations to estimate an average exposure concentration for each of the 32 air toxics for different population groups.

All exposure concentrations are based on annual averages or medians (the 50th percentile), and residents are assumed to be exposed for 70 years, an average lifetime for an individual. We also assumed that these residents are healthy adults. Because of limited resources, we did not include exposure or toxicity adjustments specific to children, such as changes to body weight. Some health-protective assumptions (e.g., assuming a 70-year exposure period) are included in the toxicity estimates to protect sensitive people such as the elderly or diseased individuals. The health risk estimates are based on a combination of average and reasonably conservative or health-protective assumptions. *This is expected to lead to risk estimates that are reasonably high for the chemicals included in the analysis, but not worst case.*

Results

The primary health effect of concern from the chemicals evaluated in this study is cancer. More specifically, lung cancer is associated with both diesel soot and woodsmoke, although it is also associated with 1,3-butadiene, a mobile source-related contaminant. In addition to lung cancer, leukemia, nasal, and liver cancers are associated with chemicals that ranked high (e.g., benzene, formaldehyde) in our study. The majority of the cancer risk estimated in our study is due to diesel soot. On average, diesel soot accounts for somewhere between 70% to 85% of the total cancer risk from air toxics in our area. Of the PBTs, arsenic is the only single compound to appear among the top ranking toxics, however, DPM and woodsmoke include numerous PAHs, so we conclude that these mixtures also contribute PBTs to the air in the Puget Sound region.

Our study found that the significant non-cancer health effects from air toxics in our area are primarily due to acrolein. This chemical is associated with upper respiratory irritation.

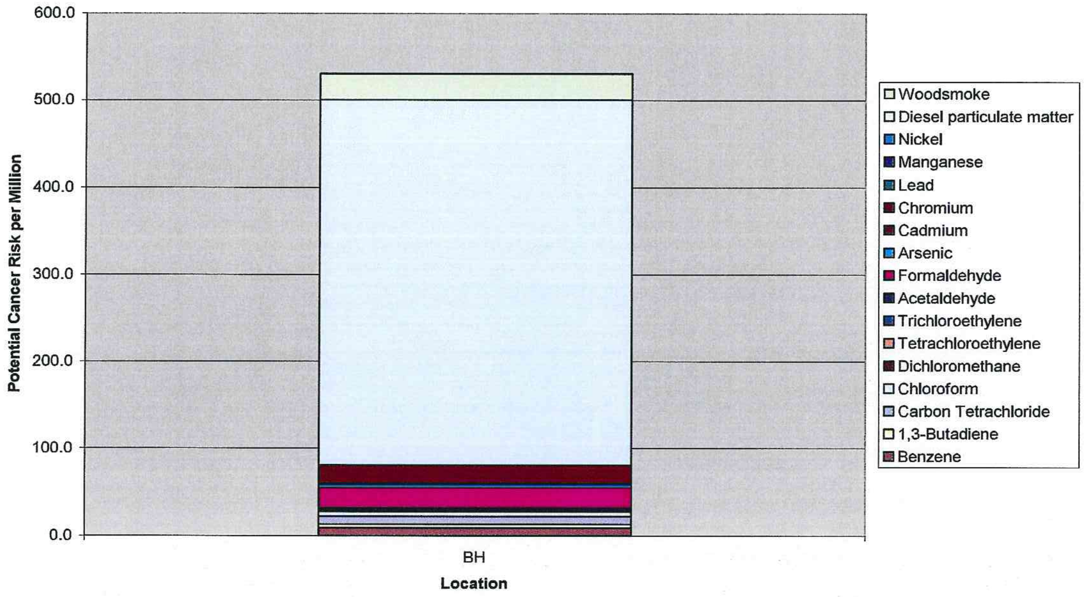
It is important to note, however, that our study does *not* include the serious non-cancer health effects associated with the particle fraction of 2 air toxics: diesel soot and woodsmoke. Non-cancer health effects associated with these particles have been extensively studied and documented in the scientific literature, and a full analysis is beyond the scope of this study.

Potential Cancer Risks

The average cancer risk estimates, even when human and pollutant movement/penetration are considered, are similar among the different methods of calculating exposure concentrations, and across different areas of the Puget Sound region. For example, average cancer risk estimates for King County alone range from approximately 400 to 700 in a million, based on 32 air toxics from the human exposure model and outdoor model data, respectively.

The average cancer risk estimates for the monitored data are approximately 550 in a million for the Beacon Hill area (see Figure ES-1). As described above, the monitoring study only looked at a total of 17 air toxics. The total cancer risks associated with the King County modeled estimates are higher because they include more chemicals, not because the estimates of each chemical are higher.

Figure ES-1: Potential Cancer Risks at Beacon Hill including Diesel Particulate Matter and Woodsmoke



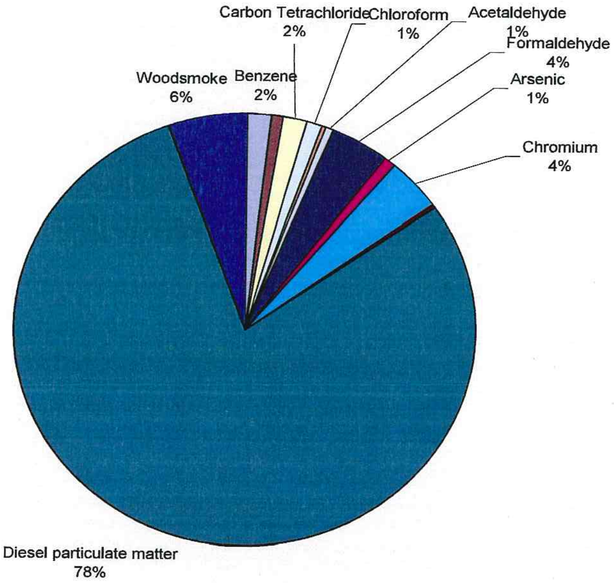
The average cancer risk estimates are also similar in the remaining three counties in the Puget Sound jurisdiction (Kitsap, Pierce, and Snohomish counties), although we do not have monitored information to confirm our findings. The estimated cancer risks range from 400 in a million for all air toxics included in the HAPEM4 model in Snohomish County, including diesel soot, to a high of 600 in a million as an average for 32 ASPEN-modeled ambient concentrations in King County, including diesel soot. All risk estimates reflect a 70-year exposure period. Upper 95th percentile risk estimates based on the modeled ambient concentrations are approximately 980 in a million for King County.

The air toxics that contribute most to the cancer risks are also consistent across the different methods of analysis. **The top toxics for all 3 methods include diesel soot, benzene, formaldehyde, and carbon tetrachloride**. **Woodsmoke** also contributes to the risk estimates based on the monitored data.

In addition, the percent contribution of the top air toxics is also very similar across the different methods of analysis. For example, at Beacon Hill, diesel soot accounts for over 75% of the potential cancer risks (see Figure ES-2) with another 10% or so coming from volatile organic compounds (VOCs) associated with mobile sources. The King County results from the outdoor

NATA model estimate diesel particulate matter at 86%, with other mobile-source-related chemicals at about 8%, and stationary-source-related chemicals at about 6%. Similarly, the NATA human exposure results indicate a diesel soot contribution of 86%, with other mobile-source-related chemicals at 7%, and stationary sources at about 4%. ***This indicates that mobile sources are likely to account for approximately 85% to 95% of the potential cancer risks among outdoor air toxics.***

Figure ES-2: Contributions to Potential Cancer Risk at Beacon Hill (2001)



The only emission source that ranks high in the monitoring data but not in the modeled data is woodsmoke. This is because woodsmoke emissions are estimated differently. The modeled concentrations associated with woodsmoke reflect very few chemicals in the woodsmoke mixture, while the concentrations based on monitored data reflect a greater number of chemicals present in woodsmoke.

Uncertainties

The large number of assumptions necessary in our study reflects the amount of uncertainty and variability associated with the health risk estimates. It is possible that risk is underestimated because (1) not all air toxics are considered in this analysis, and (2) many chemicals have been shown to accumulate in indoor micro-environments, which could increase exposure. In addition, potential cancer estimates will underestimate risk for those individuals living near large point sources or "hot spots". Alternatively, risk may be underestimated or overestimated by assuming that the concentration at the monitor accurately reflects lifetime exposure to ambient pollutants. Obviously, chemical concentrations could increase or decrease throughout the lifetime exposure period.

It is important to note that this analysis does not evaluate indoor sources of air pollution (i.e., from paints, home furnishings, cleaning products, building materials, and other indoor sources). Uncertainties in the toxicity information could also serve to over- or underestimate potential risk estimates. These are only a few of the uncertainties associated with this study. A more detailed discussion can be found in Chapter 5.

In summary, we use screening risk estimates as a tool to focus Clean Air Agency attention on those compounds and mixtures that are likely to present the greatest risk of cancer and some non-cancer effects. Concentrations, and corresponding risks, were relatively consistent among areas measured and modeled throughout the Puget Sound region. Although some differences were apparent, overall it is clear that the sites and the region as a whole have similar emission sources of concern (e.g., diesel particulate matter, mobile-source-related VOCs, and probably woodsmoke).

Diesel soot ranks high in potential contributions to cancer risk, higher than other air toxics measured in this study. However, volatile organics associated with mobile sources, such as benzene and formaldehyde, contribute significantly to the potential cancer risks from air toxics. Diesel soot, benzene, 1,3-butadiene, and formaldehyde are classified as class A or B carcinogens under the USEPA cancer rating system. This indicates that USEPA is relatively confident that these chemicals probably cause cancer in humans. These chemicals should have high priority during development of an air toxics reduction program for the Puget Sound area. Finally, acrolein appears to present a potential non-cancer risk as well. As stated earlier, the non-cancer health effects associated with the particulate-matter-related combustion mixtures (e.g., woodsmoke and diesel soot) are not evaluated here, but present serious non-cancer health risks.

Chapter 1: Introduction

1.1 Purpose

The purpose of this study is to characterize air emissions and to identify those air toxics and sources that may pose the greatest risks to residents of the Puget Sound area. This analysis uses results from a monitoring study conducted in the greater Seattle/King County area and modeling studies conducted in the four counties in the Puget Sound Clean Air Agency jurisdiction (King, Kitsap, Pierce, and Snohomish counties). The United States Environmental Protection Agency (USEPA) performed the modeling in its National-scale Air Toxics Assessment (NATA) project to estimate potential cancer and non-cancer risks associated with the ambient air concentrations of those toxics. In addition, results from a human exposure study provide a general view of the potential exposures and health risks when average or typical human behaviors are considered.

The Puget Sound Clean Air Agency will use the results from this study to evaluate existing air toxics regulations, to focus on compounds of greatest concern, and to identify areas of potential improvement in its air toxics program. These results are intended to provide general direction to planners and managers. These results are *not* intended to provide exact estimates of potential health risk.

The estimates of cancer and non-cancer health effects should not be viewed as actual cancer or non-cancer cases resulting from air pollution, but as an estimate of relative impact of the toxic air pollutants evaluated in order to prioritize Agency efforts at reducing exposures. The estimates are based on a combination of average and reasonably conservative or health-protective assumptions. This is expected to lead to risk estimates that are reasonably high for the chemicals included in the analysis, but not the worst case scenario.

1.2 Methods

Regulatory agencies typically employ risk-based approaches to evaluate potential health impacts from exposures to toxic chemicals. This study uses basic risk assessment concepts and models to provide a general overview of the potential air toxics problems that could be due to air toxics. However, we have not performed a comprehensive risk assessment, which would include more detailed discussions of toxicity and exposure parameters used to calculate risk estimates.

For the purposes of conducting the screening analysis, potential cancer risks are calculated using the following equation:

Cancer Risk = Exposure concentration x Toxicity

where: Exposure concentration = annual average ($\mu g/m^3$)
Toxicity = unit risk for carcinogens (cancer risk/1 $\mu g/m^3$)

Similarly, non-cancer risks are estimated by calculating a hazard index, using the following equation:

Hazard Index (HI) = Exposure concentration/Toxicity

where: Exposure concentration = annual average ($\mu g/m^3$)
Toxicity = reference concentration ($\mu g/m^3$)

Exposure concentrations used to calculate potential cancer and non-cancer health risks were obtained through three different methods. These methods are discussed generally below, and in more detail in Chapters 3 and 4 of this report.

Because resources were not available, a complete risk assessment was not conducted. However, the report includes the primary risk assessment components such as a toxicity or dose-response section, an exposure assessment section, and a risk characterization section. It includes a general discussion of the two major types of exposure models (ASPEN and HAPEM4, discussed later) used to calculate exposure concentrations. More comprehensive descriptions of these models were not included for two reasons. First, adequate resources were not available to the Agency, and second, these models are described and discussed extensively in technical support documents that accompany the NATA project.[1] However, general descriptions of the model

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[1] USEPA. ***National-Scale Air Toxics Assessment for 1996.*** Office of Air Quality Planning and Standards. EPA-453/R-01-003. January 2001.

assumptions are included when appropriate, and the supporting documentation is referenced accordingly throughout this document.

1.3 Exposure

In this evaluation, three separate methods are used to provide exposure estimates. These include:

1. Monitored ambient concentrations
2. Modeled ambient concentrations
3. Modeled "human exposure concentrations" (where human activities and locations are considered in estimating exposures to air pollutants)

Results from each method of predicting exposure are presented and compared with toxicity values and evaluated for potential or relative risk.

1.4 Toxicity

Although several different methods are used to estimate exposures, essentially one method is used to evaluate toxicity associated with airborne toxics. In most cases, USEPA-recommended toxicity factors are used as the basis for quantitative dose-response information. These values are usually obtained from the USEPA Integrated Risk Information System (IRIS) database. However, in some cases neither IRIS values nor USEPA values in the NATA project were available. In these instances, the alternative values were usually chosen from other sources. The basis for each toxicity factor and rationale for any adjustments are included in Chapter 2.

1.5 Conclusions and Recommendations

In the last chapter, the results from the different methods used in the evaluation are compared. Discrepancies and similarities are discussed. In addition, the uncertainties and limitations of the evaluation and the impact on the results are described. Finally, recommendations for Agency priorities are presented.

Chapter 2: Toxicity Estimates

Although several different methods are used to evaluate potential exposures, the same toxicity values are used for each of the analyses. Rather than describe toxicity in each section, toxicity estimates and the details associated with them are described in this section.

2.1 Separating Carcinogenic and Non-carcinogenic Impacts

Toxicity estimates for carcinogens and non-carcinogens are derived through different processes and reflect fundamentally different concepts in toxicity. Toxicity values for non-cancer effects are based on the idea that a threshold exists for these health effects. USEPA believes that carcinogenic effects may not have thresholds, and that any exposure is associated with some corresponding (although very low) risk of disease. Physiological changes leading to cancer may occur over many years or decades.

Carcinogenic health effects are presented as a probability or risk of developing cancer. This can be viewed in two ways. First, the risk concept can be viewed as an additional cancer risk for each exposed individual. For example, a risk of one in a million could be added to the existing lifetime cancer risk of one in two to one in three (this excludes consideration of genetic or other susceptibilities) for most individuals.[2] USEPA also interprets risk estimates as potential cancer cases over the population of potentially exposed individuals. For example, a one in a million risk can also be viewed as one additional cancer case for every million people exposed to that concentration.[3,4]

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[2] Ries LAG, Eisner MP, Kosary CL, Hankey BF, Miller BA, Clegg L, Mariotto A, Fay MP, Feuer EJ, Edwards BK (eds). *SEER Cancer Statistics Review, 1975-2000*, National Cancer Institute. Bethesda, MD, http://seer.cancer.gov/csr/1975_2000, 2003. http://seer.cancer.gov/csr/1975_2000/results_merged/topic_lifetime_risk.pdf

[3] USEPA IRIS Glossary defines the unit risk value as **Unit Risk:** The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 μg/L in water, or 1 $\mu g/m^3$ in air. The interpretation of unit risk would be as follows: if unit risk = 1.5×10^{-6} μg/L, 1.5 excess tumors are expected to develop per 1,000,000 people if exposed daily for a lifetime to 1 μg of the chemical in 1 liter of drinking water.

[4] USEPA also defines "one in a million risk" in the NATA glossary (http://www.epa.gov/ttn/atw/nata/gloss1.html) as follows: **1 in a Million Cancer Risk:** A risk level of 1 in a million implies a likelihood that up to one person, out of one million equally exposed people would contract cancer if exposed continuously (24 hours per day) to the specific concentration over 70 years (an assumed lifetime). This would be in addition to those cancer cases that would normally occur in an unexposed population of one million people. Note that this assessment looks at **lifetime** cancer risks, which should not be confused with or compared to **annual** cancer risk estimates. To compare an annual cancer risk estimate with the results in this assessment, multiply that annual estimate by a factor of 70 or alternatively divide the lifetime risk by a factor of 70. A 1 in a million lifetime risk to the U.S. public in 1996 was 250 cancer cases over a 70-year period.

In contrast to carcinogenic health effect evaluation, non-carcinogenic effects are presented as exceeding (or not exceeding) a particular guideline, referred to as a hazard index. The hazard index is a ratio of the estimated exposure concentration, divided by a concentration deemed to have no adverse effect from a lifetime exposure to that level. This non-carcinogen evaluation does not calculate a probability but instead determines whether a particular exposure is above or below a threshold above which there will be an adverse effect. Levels below the hazard index are deemed to be of no risk. Because of these differences, carcinogenic effects are evaluated separately from non-carcinogenic effects.

2.2 Carcinogenic Effects

Potential carcinogenic effects are measured using unit risk factors. USEPA defines the unit risk factor (URF) as "a measure of the potential cancer risk of exposure to 1 microgram chemical per cubic meter of air over a 70-year period."[5] URFs are typically derived from animal laboratory studies, although human data from epidemiological or clinical studies can sometimes provide appropriate dose-response information. In addition, the URF is considered to be highly conservative or protective of health (it is based on the upper 95th percentile of the potency slope). In other words, if we use URFs, it is unlikely that the potential cancer-risk values underestimate the true cancer risk associated with the specified exposure concentrations, and very likely overestimate the true risk.

In addition to the quantitative evaluation, USEPA also assigns each carcinogen a confidence rating based on the certainty associated with the supporting toxicological and health data. The values in this rating are A through E, with Group A being associated with the greatest certainty of evidence for causing cancer in humans and Group E having evidence that the chemical does not cause cancer in humans.

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[5] See USEPA IRIS definition in footnote #2 above.

URFs used in this report are listed in Table 2-1 below. We used the same values as those in the NATA project. Most of the unit risk factors were obtained from the USEPA IRIS database, however if alternative sources are used, they are noted.[6]

It is important to note that most chemicals lack sufficient information to develop URFs. For example, adequate health information on which to base risk estimates is not available for the majority of chemicals used in commerce.[7] In addition, synergistic and/or antagonistic effects among the chemicals are not considered in these potency estimates. In other words, we do not know how the toxicity of these chemicals changes when administered in a mixture with other chemicals (except for woodsmoke and DPM which are discussed below). Finally, USEPA typically notes that the cancer risks associated with carcinogens could be as low as zero. Uncertainties associated with the risk estimates are discussed more fully in the last chapter of this document.

Specific URFs are available for two complex chemical mixtures, woodsmoke and diesel particulate matter, although they are not endorsed by USEPA. These two mixtures account for 46% of the total PM2.5 measured in Seattle, and could present potential cancer risk.[8] These values and the supporting documentation for each are also discussed below.

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[6] USEPA. ***National-Scale Air Toxics Assessment for 1996.*** Office of Air Quality Planning and Standards. EPA-453/R-01-003. January 2001.

[7] National Research Council. ***Toxicity Testing: Strategies to Determine Needs and Priorities.*** Steering Committee on Identification of Toxic and Potentially Toxic Chemicals for Consideration by the National Toxicology Program. National Academy Press. Washington DC. 1984.

[8] Maykut N, J Lewtas, E Kim, T Larson. *Source Apportionment of PM2.5 at an urban IMPROVE site in Seattle, WA.* Manuscript accepted to Environmental Science and Technology, August 2003.

Table 2-1: Unit Risk Factors and Cancer Ratings

Chemical	Unit Risk Factor (risk /µg/m^3)	USEPA Cancer Rating	Reference
1) Acrylonitrile	6.8E-05	B1	IRIS
2) Benzene	7.80E-06	A	USEPA IRIS file, downloaded 10/22/01
3) 1,3-Butadiene	3.0E-05	A	USEPA NATA[9]: EPA NCEA[10]
4) Carbon tetrachloride	1.50E-05	B2	USEPA IRIS file, downloaded 10/22/01
5) Chloroform	2.30E-05	B2	USEPA IRIS file, downloaded 10/22/01
6) Dichloromethane	4.70E-07	B2	USEPA IRIS file, downloaded 10/22/01
7) 1,3-Dichloropropene	4.0E-06	B2	USEPA NATA: IRIS
8) Diesel particulate matter (DPM)	3.0E-04	B2	CALEPA/OEHHA
9) Ethylene dibromide	2.2E-04	B2	USEPA NATA: IRIS
10) Ethylene dichloride	2.6E-05	B2	USEPA NATA: IRIS
11) Ethylene oxide	8.8E-05	B1	CalEPA
12) Hexachlorobenzene	4.6E-04	B2	USEPA NATA: IRIS
13) Hydrazine	4.9E-03	B2	USEPA NATA: IRIS
14) 7-PAHs	2.0E-04	B2	USEPA NATA: OAQPS
15) PCBs	1.0E-04	B2	USEPA NATA: IRIS
16) POM	5.5E-04	NA	USEPA NATA: OAQPS
17) Propylene dichloride	1.9E-05	C	USEPA NATA: HEAST
18) Quinoline	3.4E-03	C	USEPA NATA: HEAST
19) 1,1,2,2-Tetrachloroethane	5.8E-05	C	IRIS
20) Tetrachloroethylene	5.6E-06	B2	USEPA NATA: CalEPA
21) Trichloroethylene	2.00E-06	B2	USEPA NATA: CalEPA
22) Acetaldehyde	2.20E-06	B2	USEPA NATA: IRIS
23) Formaldehyde	1.30E-05	B1	IRIS
24) Arsenic	4.30E-03	B1	IRIS
25) Beryllium compounds	2.4E-03	B1	IRIS
26) Cadmium	1.80E-03	B1	IRIS
27) Chromium (VI)	1.2E-02	A	USEPA NATA: IRIS
28) Lead	1.20E-05	B2	USEPA NATA: CalEPA
29) Nickel	4.8E-04	A	USEPA NATA: IRIS
30) Woodsmoke	1.0E-05	NA	Lewtas, 1988

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[9] USEPA. NATA Appendix G: *Health Effects Information Used In Cancer and Noncancer Risk Characterization for the NATA 1996 National-scale Assessment.* http://www.epa.gov/ttn/atw/nata/nettables.pdf

[10] EPA National Center for Environmental Assessment.

2.2.1 Woodsmoke Unit Risk Factor

Woodsmoke is comprised of a variety of chemicals, including but not limited to: particulate matter, nitrogen oxides, carbon monoxide, sulfur oxides, volatile organic compounds, and polycyclic aromatic hydrocarbons (PAHs).[11] Many of the chemicals listed as constituents in woodsmoke have been identified as probable or likely human carcinogens. However, woodsmoke as a mixture has not been thoroughly evaluated for its carcinogenicity by USEPA or other health agencies. Evaluations by the World Health Organization suggest that vegetative burning, primarily woodsmoke, is likely to be carcinogenic, although sufficient data is not yet available.[12,13,14]

The unit risk factor for woodsmoke was developed through a comparative potency method where the mutagenicity and tumor initiating potency from particles emitted from several sources (e.g., diesels, woodsmoke and gasoline-powered automobiles) are systematically evaluated (Lewtas 1988). Lewtas uses bioassay-directed fractionation, a combination of several chemical separation and bioassay techniques, to identify the more toxic elements of several complex mixtures. In the Lewtas study, mutagenicity tests are conducted on different segments of the total mixtures. Segments showing higher mutagenic potencies are further divided into groups and tested until the components or segments with the highest potencies are identified.[15] The unit risk factor calculated for woodsmoke is listed in Table 2-1.

We recognize the Lewtas woodsmoke URF has not undergone the same rigorous evaluation as the other URFs used in our analysis. Although USEPA or CalEPA have not reviewed the

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[11] USEPA. *Emission Inventory Improvement Program, Vol. III, Chapter 2: Residential Wood Combustion.* Revised final. January 2001.

[12] World Health Organization (WHO). *Health Guidelines for Vegetation Fire Events.* Edited by DH Schwela, JG Goldammer, LH Morawska, O Simpson (Findings of the WHO-UNEP-WMO expert task force, Lima, Peru) 1999.

[13] WHO. The *Health Effects of Indoor Air Pollution Exposure in Developing Countries.* N Bruce, R Perez-Padilla, R Albalak. WHO/SDE/OEH/02/05. 2002.

[14] WHO. *Health Impacts of Biomass Air Pollution.* M. Brauer. Health Guidelines for Vegetation Fire Events, Lima Peru. Background papers. 1999.

[15] Lewtas J. *Genotoxicity of Complex Mixtures: Strategies for the Identification and Comparative Assessment of Airborne Mutagens and Carcinogens from Combustion Sources.* Funda and Appl Tox 10, 571-589. 1988.

woodsmoke URF, it is developed through a method recommended by the National Academy of Sciences and is published in a respected peer-reviewed journal.[16]

Also, as one reviewer of the draft of this report noted, vegetative burning could include other materials in addition to wood. Therefore, the woodsmoke unit risk factor may not appropriately estimate cancer risk from vegetative burning. As a result of these uncertainties, we use the woodsmoke unit risk as a general indicator of potency and potential risk.

2.2.2 Diesel Particulate Matter (DPM) Unit Risk Factor

Combustion of diesel fuel results in hundreds and probably thousands of organic and inorganic compounds in the diesel exhaust mixture. This mixture includes gaseous compounds such as carbon dioxide, carbon monoxide, aldehydes, benzene, and a wide range of PAHs. Dioxins have also been found in trace quantities in diesel exhaust.[17]

DPM is a component of diesel exhaust. DPM contains elemental carbon, organic carbon, and small amounts of nitrate, metals, and unidentified compounds. We focus on the particulate component of diesel exhaust because it is thought to contain the majority of the toxicity associated with the mixture. These particles and their adsorbed toxics penetrate deep into the lung during inhalation.

While specific knowledge of the role of the adsorbed chemicals is not known, it is hypothesized that the presence of such substances may influence particle toxicity. However, relatively little is known about the cumulative toxicity of the multiple toxics present in certain combustion mixtures. For example, it is possible that antagonism or synergism occurs among the chemicals and/or particles. In addition, there may be a variety of carcinogenic or toxic chemicals present in the mixture that have not yet been identified.[18] Therefore, we use unit risk factors for the whole

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[16] National Academy of Sciences. ***Complex Mixtures: Methods for In Vivo Toxicity Testing.*** National Academy Press. Washington DC, 1988.

[17] USEPA. ***Health Assessment Document for Diesel Engine Exhaust.*** Office of Research and Development. EPA/600/8-90/057F. Washington DC, May 2002.

[18] National Academy of Sciences, 1988.

mixture to estimate potential risk for diesel particulate and woodsmoke, rather than unit risk factors for individual carcinogens and summing the individual risks.

The carcinogenicity of diesel particulate matter is widely recognized by a number of health agencies including the USEPA,[19] CalEPA,[20] the US Department of Health and Human Services,[21] and the International Agency for Research on Cancer (IARC).[22] Because USEPA has not yet developed a unit risk factor for diesel particulate matter, the CalEPA value is used in this analysis.[23] CalEPA conducted an extensive literature review and analysis to develop the unit risk factor for DPM.[24] This value is listed in Table 2-1.

We recognize that USEPA has not identified a final unit risk factor for diesel particulate matter. However, USEPA states firmly that diesel particulate matter is a B1 or probable human carcinogen. In the absence of a confirmed URF, USEPA provides a range of potential cancer risks associated with environmental exposures (i.e., exposure levels typically experienced by the general population) in Section 8.4, entitled "Perspectives on Cancer Risk" of their Health Assessment Document. USEPA estimates this risk range to be approximately 6E-05 to 8E-04. This range assumes average environmental exposures of 0.8 - 4.0 $\mu g/m^3$ over a lifetime.[25] The annual estimate for Beacon Hill is 1.4 $\mu g/m^3$, within the range identified by USEPA. Therefore, we believe it is important to characterize potential risks associated with DPM in relation to other air pollutants.

The risk range used by EPA is also comparable to the unit risk estimate calculated by CalEPA. For example, assuming an environmental exposure of 1 $\mu g/m^3$, the range recommended by

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[19] USEPA. May 2002.

[20] CalEPA/OEHHA. *For the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant. Part B: Health Risk Assessment for Diesel Exhaust.* May 1998.

[21] National Toxicology Program. Public Health Service, US Department of Health and Human Services. ***9th Report on Carcinogens.*** Revised January 2001.

[22] International Agency for Research on Cancer (IARC). ***IARC Monograph on the Evaluation of Carcinogenic Risks to Humans. Vol. 46: Diesel and Gasoline Engine Exhausts.*** 1989.

[23] CalEPA, 1998.

[24] CalEPA, 1998.

[25] USEPA 2002.

USEPA could be approximately 8E-05 to 2E-02.[26] The unit risk factor recommended by CalEPA, 3E-04, is also within USEPA's range if one assumes an exposure of 1 $\mu g/m^3$. This suggests that the CalEPA unit risk factor is not as highly conservative as USEPA's high-end estimates. The potential risk could also be zero.

One reviewer suggested that the cancer risks from DPM could be adequately evaluated by using the unit risk factors for individual carcinogenic PAHs and 6 metals. Unfortunately, this approach would only account for a small percentage of the potentially toxic chemicals found in DPM. USEPA and CalEPA state that the mechanism of action for DPM carcinogenesis has not yet been established.[27] In fact, both USEPA and CalEPA suggest that Diesel Particulate Matter (DPM) toxicity is related to a complex combination of factors such as:

- The physical characteristics of fine particles. USEPA states "The carcinogenicity of diesel particles…appears to be related, as least to some extent, to their small size and convoluted shape, which results in a large specific particle surface area."[28] It is possible that this large surface area may act as a carrier for many chemicals.
- Diesel particles may enhance PAH toxicity, suggesting a possible synergistic relationship between PAHs and particles.[29] If so, carcinogenic potency would be underestimated by using PAHs alone to evaluate cancer risk.
- Exposure to both DPM-related organics and carbon particles (i.e., DPM without organics such as PAHs) may produce reactive oxygen species that could result in a cascade of events leading to DNA damage.

In summary, it is simply not clear how DPM causes cancer or what the causative agents might be. Therefore, reliance on the toxicity of a limited number of PAHs to estimate potential cancer risk for a complex mixture such as DPM could dramatically underestimate potential risk.

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[26] Assuming an environmental exposure of 1 $\mu g/m^3$, an EM ratio of 1 to 252 can be calculated using the "broad concentration range" for occupational exposures described in Section 8.4 of the USEPA 2002 report. Multiplying these values by the 2% excess risk due to diesel particulate matter exposures, results in 8E-05 to 2E-02.

[27] USEPA, 2002.

[28] USEPA, 2002.

[29] USEPA, 2002.

The Clean Air Agency uses a more appropriate approach based on accepted California risk numbers that have been widely cited and are the basis for a diesel retrofit program in place for several years in California. This approach evaluates 100% of the highly toxic diesel particulates as a complete and complex mixture. This method is more likely to account for potential interactions (i.e., synergism and antagonism) among the hundreds and/or thousands of chemicals in DPM.

2.3 Non-carcinogenic Effects

Many chemicals also have non-cancer health effects. Non-carcinogenic effects are presumed to have a threshold of exposure below which no effect occurs, although this is not always the case (e.g., fine particulate matter). Non-carcinogenic effects from air exposures are evaluated using reference concentrations. Reference concentrations (RfCs), like unit risk factors, are based on animal or human studies. RfCs are derived by examining the literature to find a critical study, which is defined as a well-designed chronic exposure study that has identified the non-carcinogenic adverse effect that occurs at the lowest level of inhalation exposure. The no-observable-effect-level (NOEL) or a lowest-observable-adverse-effect-level (LOAEL) from animal or human studies is determined. Adjustments for exposure times are made to extrapolate exposures to 24 hours, 7 days per week, and conversion to units of mg/m^3 are made. A human equivalent concentration is calculated by considering the nature of the contaminant and its behavior in inhaled air; the region of the respiratory system impacted; and the surface area and respiratory rate of the test organism, relative to the same parameters in humans. This concentration is then divided by factors of 10 to account for uncertainties such as extrapolating from animals to humans, from healthy adult individuals to sensitive individuals, or from sub-chronic to chronic exposures. The RfCs also include confidence statements that speak to the extent and quality of the database, and the certainty of the RfC, based on supporting literature aside from the critical study.

As a result of these types of derivations, the RfC is also considered to be highly conservative or protective of human health. Similar to the unit risk factors used for carcinogens, USEPA considers the RfC to be unlikely to underestimate potential risks to humans. It is important to recognize that many chemicals can have a variety of effects that occur at different levels of exposure. The RfC only looks at the effect that occurs at the lowest level of exposure. The assumption is made that protection at this level also provides protection at the higher doses as well.

To determine a hazard index for these chemicals, the RfC is compared to the annual average or median concentration for each of the three exposure data sets (e.g., the monitoring results, the ambient modeling results, and the human exposure modeling results). We compare the RfC to the median concentration for the human exposure modeling estimates because they are the only estimate of central tendency available. For the Seattle monitoring data and the ambient exposure modeling exercise, we compare the RfC to the annual average. We also compare the RfC to an upper-bound concentration for the ambient modeling exercise as it was available. However, this value may overestimate exposures over the lifetime of the exposed individual. RfCs used in this evaluation are listed in Table 2-2 below. The name of the chemical is listed with the RfC value, the uncertainty factors and modifying factors used in calculating the RfC, the critical effect, and the source for the information. The information used in the analysis and listed in the table was taken from the USEPA NATA report.

The non-cancer health effects associated with diesel particulate matter and woodsmoke, and the fine particulate fraction of these mixtures specifically are not included in this evaluation. Non-cancer health effects associated with fine particles, such as morbidity related effects such as increased asthma attacks, upper respiratory irritation, and increased mortality are analyzed elsewhere.

APPENDIX E

Sampling and Analysis Plan and Quality Assurance Project Plan

Appendix E Contents

List of Tables

List of Attachments

E1 Introduction

This Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) has been prepared for the of the Texaco Strickland Cleanup Site at 6808 196th Street SW in Lynnwood, Washington (herein referred to as the Site) as Appendix E of the Supplemental Remedial Investigation Work Plan (RI WP). The purpose of this SAP/QAPP is to ensure that field sample collection, handling, and laboratory analysis will generate data to meet project-specific data quality objectives (DQOs) in accordance with the Model Toxics Control Act (MTCA) requirements (WAC 173-340-350). This SAP/QAPP is comprised of two major components: a Field Sampling Plan (FSP) defining field protocols and a Quality Assurance Project Plan (QAPP) defining analytical protocols.

Environmental investigation activities to be performed under this SAP/QAPP are on behalf of two parties, Strickland Real Estate, LLC (Strickland) and Chevron Environmental Management Company (CEMC) according to the Agreed Order 14315. The Field Sampling Plan (Section E2) and Quality Assurance Project Plan (Section E3) are presented below.

E2 Field Sampling Plan

E2.1 Soil Borings and Soil Sampling

Soil samples from soil borings and monitoring well installations will be obtained using direct-push or hollow-stem auger drilling methods, as appropriate. The soil samples will be collected from locations marked on Figure 5 of the RI WP. The borings may be advanced to depths of approximately 20 feet below ground surface (bgs) to evaluate residual concentrations of contaminants of concern (COCs) in the subsurface. Soil samples will be collected continuously if using direct-push drilling or every 2.5 feet if a hollow-stem auger is used. Up to three soil samples per boring will be submitted for analysis, based on the results of field observations and field screening for volatile organic vapors using a photoionization detector (PID). In areas where oil-range petroleum impacts have been historically observed, at least one shallow soil sample will be submitted for laboratory analysis of TPH-O.

The following subsections detail the procedures for soil sample collection, handling, identification, and sample quality assurance/quality control (QA/QC).

The responsible lead party will subcontract with a Washington-licensed resource protection well driller to complete soil borings and monitoring well installations in accordance with requirements of Chapter 173-160 WAC.

E2.1.1 Soil Sample Collection and Handling Procedures

A geologist/engineer/scientist from Aspect will oversee the drilling activities and prepare a geologic log for each of the explorations completed, including an examination of the full length of each soil core recovered. The field representative will visually classify the soils in accordance with American Society of Testing and Materials (ASTM) Method D2488 and record soil descriptions, field screening results, and other relevant details (e.g., staining, debris, odors, etc.) on the boring log form. If samples are collected for chemical analysis, the sample ID and depth will also be recorded on the log.

Headspace Vapor

Each sample will be field screened to obtain a relative estimate of its volatile organic carbon (VOC) concentration. This field screening will be performed by measuring the concentration of VOCs in the headspace above the sample in a closed container using a field flame-ionization detector (FID) or photoionization detector (PID). The field screening will be performed by placing the soil into a sealed plastic bag (e.g., Ziploc), disaggregating the soil by hand, allowing the sample to equilibrate for at least five minutes, and then opening the bag slightly, inserting the instrument probe, and measuring the VOC concentration in the headspace. If the ambient temperature is below 65ºF, the sample will be warmed (e.g., in a heated vehicle) before the headspace measurement is made.

The PID will be calibrated daily in the field using the manufacturer’s calibration standard (100 ppm isobutylene gas). A calibration test, referred to as a “bump test,” will be performed as necessary in the field using the calibration gas to check that the PID remains properly calibrated throughout the day.

Sheen Testing

Sheen testing will be conducted by placing soil in a pan of water and observing the water surface for signs of sheen. Sheens are classified as follows:

- **Slight Sheen:** Light, colorless, dull sheen. The spread is irregular and dissipates rapidly.
- **Moderate Sheen:** Light to heavy sheen, may show color/iridescence. The spread is irregular to flowing. Few remaining areas of no sheen are evident on the water surface.
- **Heavy Sheen:** Heavy sheen with color/iridescence. The spread is rapid, and the entire water surface may be covered with sheen.

Sample Collection for Laboratory Analysis

All soil samples to be submitted for gasoline-range total petroleum hydrocarbons (TPH-Gx) and VOC analyses will be collected in accordance with U.S. Environmental Protection Agency (EPA) Method 5035A. To minimize disturbance of potential VOCs in the soil, soil samples will be collected from the center of the soil core, as practical. The soil aliquot for these analyses will be collected from the undisturbed soil sample core using a laboratory-supplied modified disposable plastic syringe as required by EPA Method 5035A and placed in reweighed laboratory-supplied vials.

For all other analyses, the soil samples will be removed from the sampler using a stainless-steel spoon and placed in a stainless-steel bowl for homogenization with the stainless-steel spoon. Gravel-sized material greater than approximately 0.5 inch will be removed from the sample during mixing. A representative aliquot of the homogenized soil will be placed into certified-clean jars supplied by the analytical laboratory.

Samples will be selected based on field screening and to provide proper horizontal and vertical characterization. Soil samples will be submitted to a state-certified laboratory and analyzed for the following COCs:

- Total petroleum hydrocarbons (TPH) as gasoline-range organics (GRO) by Ecology Method NWTPH-Gx
- Total petroleum hydrocarbons (TPH) as diesel-range organics (DRO) and oil-range organics (ORO) by Ecology Method NWTPH-Dx (without Silica Gel Cleanup)
- Benzene, Toluene, Ethylbenzene, and Total Xylenes (BTEX) by U.S. Environmental Protection Agency (EPA) Method 8260

Based on the highest observed field screening results (PID and sheen testing), select soil samples may also be submitted for the following analyses:

- Methyl tert-butyl ether (MTBE), 1,2-Dibromethane (EDB), 1,2-Dichloroethane (EDC), and naphthalene via EPA Method 8260
- Total lead by EPA Method 6010

Samples from soil borings and monitoring wells along the western portion of the Subject Property (B-06, MW-14, MW-16, MW-18, and MW-19) will be analyzed for halogenated VOCs using EPA Method 8260C.

QC soil samples (e.g., field duplicates and trip blanks) will be collected at the respective frequencies prescribed in Section E3.5 of the SAP/QAPP.

Each soil boring will be decommissioned with hydrated granular bentonite in accordance with requirements of Chapter 173-160 WAC.

E.2.1.2 Soil Sample Identification

Each soil sample collected for chemical analysis will be assigned a unique sample identification number including the boring number and the depth from which the sample was collected. For example, the soil sample collected from boring B-9 at a depth of 4 feet below ground surface (bgs) would be identified as B-9-4.

E2.2 Groundwater Sampling

E2.2.1 Monitoring Well Installation

Monitoring wells are planned to be installed via direct-push methods. Soil samples will be collected in acetate liners using direct-push technology prior to the installation of the monitoring well. Soils well be logged and sampled, and an appropriate well screen interval will be selected. The drillers will advance a 3-inch diameter stainless steel casing with a 3-inch expendable stainless-steel point. Once the appropriate depth has been reached, the well will be will be constructed in accordance with Washington Administrative Code (WAC) 173-160 inside the stainless-steel casing. As the outer casing is removed from the boring, the expendable point will be left behind, and the annulus of the well will be filled with sand and bentonite, as appropriate. Wells will consist of 2-inch diameter, Schedule 40 PVC blank casing and 0.010-inch slot (10-slot) pre-packed well screen. Well screens will be 15 feet in length to accommodate seasonal groundwater fluctuations. With documented depths to water of 7 to 15 feet below grade, the pre-packed well screens are planned to be set from 5 to 20 feet below grade, contingent on field observations. All wells will be completed with an appropriate protective seal and secured with locking well caps.

Should direct-push drilling prove infeasible, the monitoring wells will be installed using a hollow-stem auger. The auger will be advanced to the planned depth, the well will be constructed inside the augers as described in the preceding paragraph, and the appropriate filter pack and annulus seal will be placed as the augers are withdrawn from the boring.

E2.2.2 Monitoring Well Development

Following installation, each monitoring well will be developed to remove fine-grained material from inside the well casing and filter pack, and to improve hydraulic communication between the well screen and the surrounding water-bearing formation. Wells containing light non-aqueous phase liquid (LNAPL) will be developed by hand using a bailer. All other wells will be developed using a 12-volt submersible pump. During development, the pump will be surged along the entire length of submerged well screen. Each well will be developed until visual turbidity is reduced to minimal levels, or until a maximum of 10 casing volumes of water has been removed. Field parameters will be recorded on a Well Development Record form. Groundwater produced during well development will be collected and stored at the Site in sealed and labeled 55-gallon drums pending profiling and disposal.

E2.2.3 Groundwater Sampling Procedure

Ground water samples will be collected and handled in accordance with the procedures described below:

- The locking well cap will be removed, and the presence of LNAPL will be evaluated in all wells after installation. The depth-to-LNAPL and/or depth-to-water will be measured from the surveyed location to the nearest 0.01 foot using an electronic oil/water interface probe. The oil/water interface probe will be decontaminated between wells.
- Each monitoring well will be purged at a low-flow rate less than 0.5 liter per minute (Puls and Barcelona, 1996; Ecology, 2012) using a peristaltic pump and dedicated tubing (polyethylene tubing with a short length of silicon tubing through the pump head) in order to minimize drawdown. The tubing intake will be placed just below the center of the saturated section of well screen. During purging, field parameters (temperature, pH, specific electrical conductance, dissolved oxygen, and oxidation-reduction potential [ORP]) will be monitored using a Yellow Springs Instrument (YSI) water quality meter and flow-through cell, or equivalent. These field

parameters will be recorded at 2- to 4-minute intervals throughout well purging until they stabilize. Stabilization is defined as three successive readings where the parameter values vary by less than 10 percent (or 0.5 milligrams per liter [mg/L] dissolved oxygen if the readings are below 1 mg/L). However, no more than three well casing volumes will be purged prior to ground water sample collection. Three turbidity measurements will also be made before collecting the sample using a Hach 2100Q turbidimeter, or equivalent.

- Samples with a field-measured specific electrical conductance greater than 1,000 microSiemans per centimeter (µS/cm) or turbidity greater than 25 nephelometric turbidity units (NTU) will be denoted as such on the chain-of-custody form, so that the laboratory can employ appropriate sample preparation techniques to avoid analytical interferences for specific analyses.
- If the monitoring well is completely dewatered during purging, samples will be collected when sufficient recharge has occurred to allow filling of all sample containers.
- Once purging is complete, the ground water samples will be collected using the same low-flow rate directly into laboratory-supplied sample containers. Samples for dissolved metals analyses will be filtered using an in-line 0.45 micrometer (µm) filter.
- In wells that have measurable LNAPL, samples will not be collected.
- QC ground water samples (e.g., field duplicates and trip blanks) will be collected at the respective frequencies prescribed in Section E3.5.
- Following sampling, the wells cap and monument cap will be secured. Each well's dedicated tubing will be retained in the monitoring well for subsequent sampling events. Any damaged or defective well caps or monuments will be noted and scheduled for replacement, if necessary.

E2.2.4 Groundwater Sample Laboratory Analyses

Groundwater samples will be submitted to a state-certified laboratory and analyzed for the following COCs:

- Total petroleum hydrocarbons (TPH) as gasoline-range organics (GRO) by Ecology Method NWTPH-Gx
- Total petroleum hydrocarbons (TPH) as diesel-range organics (DRO) and oil-range organics (ORO) by Ecology Method NWTPH-Dx (without Silica Gel Cleanup)
- Benzene, Toluene, Ethylbenzene, and Total Xylenes (BTEX) by U.S. Environmental Protection Agency (EPA) Method 8260
- Methyl tert-butyl ether (MTBE), 1,2-Dibromethane (EDB), 1,2-Dichloroethane (EDC), and naphthalene via EPA Method 8260
- Total lead by EPA Method 6010

E2.2.5 Groundwater Sample Identification

Each ground water sample will be assigned a unique sample identification number that includes the well number and the 6-digit date on which the sample was collected. For example, a ground water sample collected from monitoring well MW-11 on October 5, 2018, would be identified as MW-11-181005.

E2.3 Soil Vapor Sampling

E2.3.1 Vapor Point Installation

Subslab soil vapor sampling is recommended to assess the potential for vapor intrusion at the existing buildings on-property. Temporary soil vapor sampling points will be installed within the Aloha Café building to a depth of approximately 3 to 6 inches (depending on the slab thickness) to measure soil vapor concentrations while avoiding damage to underground utilities. The soil vapor sampling points will be set 5 to 10 feet away from the building edge to avoid any potential dilution from ambient air at the concrete/asphalt interface.

Proposed subslab soil vapor sampling locations are shown on Figure 7 of the RI WP and are labeled with the prefix SVS. These locations were selected to assess subsurface soil vapor concentrations for the building within areas of residual soil and groundwater impacts as well as assess soil vapor concentrations in the area where previous investigations indicated potential COCs. Vapor sampling is not proposed along underground utility corridors at this time.

E2.3.2 Soil Gas Probe Installation

Three soil gas probes are proposed to be installed at the locations shown on Figure 7 of the RI WP and are labeled with the prefix GP. The monitoring locations are intended to be as near as practicable to the southern Property boundary. For soil gas probe installation, borings will be advanced using direct-push techniques, and surface completions will be traffic-rated 8-inch-diamater flush monuments. Screen bottom depths will be approximately 5 feet bgs. Typical soil gas probe construction includes a 6-inch-long by 0.5-inch-outer-diameter stainless-steel slotted screen and 0.25-inch-outer-diameter Teflon tubing. The screen filter pack will be glass beads with an appropriate bentonite seal and concrete to grade.

E2.3.3 Soil Vapor Sampling Procedure

Prior to soil vapor sampling, the weather forecast will be monitored in an effort to synchronize sampling with a period of declining or low barometric pressure and without precipitation. However, it is recognized that this may not be possible given all the logistical considerations for the field effort. Regardless, barometric pressures will be monitored and recorded during sampling.

Soil vapor samples will be collected using laboratory-supplied, evacuated SUMMA canisters with flow controllers set to a flow rate of less than 200 mL/min in accordance with the following procedures:

- The sampling train and SUMMA canister will be leak-tested prior to sampling using a shut-in test to verify there are no leaks in the fittings or connections between the leak-testing shroud and the sample media.
- The vapor pin or gas probe monument will be enclosed in a leak-testing shroud and a known concentration (between 10 and 50 percent) of tracer gas (helium) will be added to the shroud. The selected concentration of tracer gas will be maintained and monitored for the duration of sampling.
- Prior to sample collection, the sampling train will be purged at a rate of 200 milliliters per minute using a peristaltic pump (or equivalent), taking care that the entire sampling train volume has been purged to ensure the sample is representative of subsurface conditions. Purged soil vapor will be collected in Tedlar® bags and field-screened to ensure leakage is less than 5 percent of the shroud concentration.
- After confirming there is no significant leakage in the sampling train or around the vapor point, a vapor sample will be collected by opening the valve on the SUMMA canister. Sampling will be complete when the vacuum gauge on the canister reaches -5 inches of mercury. Notes regarding the usage of each building, including windows, doorways, and HVAC, will be recorded during sampling.
- A final vacuum of -5 inches of mercury will be maintained in SUMMA canister and submitted to the laboratory for verification that the SUMMA canister did not leak in transit.

Upon completion of vapor sampling, the SUMMA canisters will be packed in their original shipping containers and maintained under chain-of-custody procedures until they are delivered to the laboratory.

Vapor samples will be analyzed using EPA Method TO-15 for BTEX, MTBE, EDB, EDC, and naphthalene and Massachusetts Department of Environmental Protection Air-Phase Petroleum Hydrocarbons (MA APH) for aliphatic and aromatic hydrocarbons. The soil vapor samples will also be analyzed for helium to confirm there was negligible atmospheric dilution (no more than 5 percent of shroud concentration) from above ground. Soil vapor samples will also be analyzed for oxygen, carbon dioxide, and methane.

E2.3.4 Soil Vapor Sample Identification

Each soil vapor sample will be assigned a unique sample identification number that includes the prefix “SVS” for sub-slab soil vapor samples or “GP” for gas probe soil vapor samples, the soil vapor sampling location ID, and the 6-digit date on which the sample was collected. For example, a soil vapor sample collected from sub-slab point SVS-1 on October 5, 2018, would be identified as SVS-1-181005.

E2.4 Sample Custody and Field Documentation

E2.4.1 Sample Custody

Upon collection, samples will be placed upright in a cooler. For soil and groundwater, ice or blue ice will be placed in each cooler to meet sample preservation requirements. Inert cushioning material will be placed in the remaining space of the cooler as needed to limit movement of the sample containers. If the sample coolers are being shipped, not hand carried, to the laboratory, the COC form will be placed in a waterproof bag taped to the inside lid of the cooler for shipment.

After collection, samples will be maintained in the consultant's custody until formally transferred to the analytical laboratory, a shipping agency, or a lab-provided courier. For purposes of this work, custody of the samples will be defined as follows:

- In plain view of the field representatives
- Inside a cooler that is in plain view of the field representative
- Inside any locked space such as a cooler, locker, car, or truck to which the field representative has the only immediately available key(s)

A COC record provided by the laboratory will be initiated at the time of sampling for all samples collected. The record will be signed by the field representative and others who subsequently take custody of the sample. Couriers or other professional shipping representatives are not required to sign the COC form; however, shipping receipts will be collected and maintained as a part of custody documentation in project files. A copy of the COC form with appropriate signatures will be kept by the consultants' project manager.

Upon sample receipt, the laboratory will fill out a cooler receipt form to document sample delivery conditions. A designated sample custodian will accept custody of the shipped samples and will verify that the COC form matches the samples received. The laboratory will notify the project manager, as soon as possible, of any issues noted with the sample shipment or custody.

E2.4.2 Field Documentation

While conducting field work, the field representative will document pertinent observations and events, specific to each activity, on field forms (e.g., boring log form, as-built well completion form, well development form, ground water sampling form, etc.) and/or in a field notebook, and, when warranted, provide photographic documentation of specific sampling efforts. Field notes will include a description of the field activity, sample descriptions, and associated details such as the date, time, and field conditions.

E2.5 Exploration Surveying

The horizontal coordinates and elevations of monitoring wells included in the RI WP will be surveyed by a licensed surveyor relative to a common horizontal and vertical datum (1988 North American Vertical Datum (NAVD 88)). Monitoring well top-of-casing elevations will be surveyed to the nearest 0.01 foot, and horizontal coordinates to the nearest 0.1 foot, or better. Each well will be surveyed at the marked spot on the top of the PVC well casing (typically the north side) from which depth-to-water measurements are collected.

E2.6 Decontamination and Investigative-Derived Waste Management

All non-disposable sampling equipment (stainless steel spoons and bowls) will be decontaminated before collection of each sample. The decontamination sequence consists of a scrub with a non-phosphate (Alconox or Liquinox) solution, followed by tap water (potable) rinse, and finished with thorough spraying with deionized or distilled water. A solvent rinse – methanol or hexane – may be used to remove petroleum product from sampling equipment prior to the decontamination procedure described above.

Investigation-derived waste (IDW) water generated during equipment decontamination and sampling will be containerized in labeled drums. The containerized IDW water will be disposed of appropriately at a permitted off-site disposal facility.

Soil cuttings from borings and disposable personal protective equipment (PPE) will be placed in labeled Department of Transportation (DOT)-approved drums pending the analytical results to determine appropriate disposal. Each drum will be labeled with the following information:

- Nonclassified IDW
- Content of the drum (soil, water, PPE) and its source (i.e., the exploration[s] from which the contents came)
- Date IDW was generated
- Name and telephone number of the contact person.

The drums of IDW will be temporarily consolidated on-site, profiled (in accordance with applicable waste regulations) based on available analytical data, and disposed of appropriately at a permitted off-site disposal facility. Containers of IDW will be on site less than 90 days from date of generation. Documentation for off-site disposal of IDW will be maintained in the project file.

E3 Quality Assurance Project Plan

This QAPP identifies QC procedures and criteria required to ensure that data collected are of known quality and acceptable to achieve project objectives. Specific protocols and criteria are also set forth in this QAPP for data quality evaluation, upon the completion of data collection, to determine the level of completeness and usability of the data. It is the responsibility of the project personnel performing or overseeing the sampling and analysis activities to adhere to the requirements of the FSP and this QAPP.

E3.1 Purpose of the QAPP

As stated in the Washington State Department of Ecology's (Ecology) Guidelines for Preparation of Quality Assurance Project Plans for Environmental Studies (Ecology Publication No. 04-03-030, July 2004), specific goals of this QAPP are as follows:

- Focus project manager and project team to factors affecting data quality during the planning stage of the project
- Facilitate communication among field, laboratory, and management staff as the project progresses
- Document the planning, implementation, and assessment procedures for QA/QC activities for the investigation
- Ensure that the DQOs are achieved
- Provide a record of the project to facilitate final report preparation

The DQOs for the project include both qualitative and quantitative objectives, which define the appropriate type of data and specify the tolerable levels of potential decision errors that will be used as a basis for establishing the quality and quantity of data needed to support the environmental assessment. To ensure that the DQOs are achieved, this QAPP details aspects of data collection including analytical methods, QA/QC procedures, and data quality reviews. This QAPP describes both quantitative and qualitative measures of data to ensure that the DQOs are achieved. DQOs dictate data collection rationale, sampling and analysis designs that are presented in the main body of the RI WP, and sample collection procedures that are presented in the FSP (Section E2 of this Appendix).

E3.2 Project Organization and Responsibilities

The project organization for completion of the remedial investigation, including identification of key personnel and their responsibilities, is described below.

The remedial investigation will be conducted for the current owner of the Site, Strickland Real Estate Holdings, LLC. Aspect has been contracted by the owner to plan and implement the remedial investigation as part of Ecology Agreed Order No. 14315. The project contact information for the current owner is:

Strickland Real Estate Holdings, LLC
12199 Village Center, Suite 201
Mukilteo, WA 98275

The Project Manager and primary contact for Aspect is Mr. William V. Goodhue, LG, LHG, Senior Associate Hydrogeologist. The document control clerk is Mr. Michael Maisen. The QA/QC officer is Mr. Jason Yabandeh. The contact information for Aspect is:

Aspect Consulting, LLC
710 Second Ave, Suite 550
Seattle, Washington 98104
Telephone: (206) 328-7443

As a named potentially liable person in Ecology Agreed Order No. 14315, Chevron Environmental Management Company (CEMC) will review and approve the RI WP. The Project Manager for CEMC is Mr. Eric Hetrick, and the project contact information for CEMC is:

Chevron Environmental Management Company
Marketing Business Unit
6001 Bollinger Canyon Road, C2096
San Ramon, CA 94583

Ecology has jurisdiction over the remedial investigation, as stipulated in Chapter 70.105 of the Revised Code of Washington, and the MTCA. The remedial investigation is being conducted as part of Ecology's Agreed Order No. 14315. The Project Manager for Ecology is:

Mr. Dale Myers
Washington State Department of Ecology
Northwest Regional Office
3190 160th Avenue SE
Bellevue, Washington 98008

Aspect will contract with Friedman and Bruya, Inc. (F&B), a state-certified laboratory. The laboratory project manager is responsible for ensuring that all laboratory analytical work for soil and water media complies with project requirements, and acting as a liaison with the project manager, field manager, and data quality manager to fulfill project needs on the analytical laboratory work. This responsibility also applies to analyses the laboratory project manager subcontracts to another laboratory. The laboratory contact information is:

Friedman & Bruya, Inc.
3012 16th Ave SW
Seattle, WA 98199

E3.3 Analytical Methods and Reporting Limits

Laboratory analytical methods for soil and ground water analyses to be performed during this environmental characterization are as follow:

Chemical Group and Analyte	Analytical Method	Matrix
Gasoline Range Organics	NWTPH-Gx	Soil and Groundwater
Diesel & Residual Range Organics	NWTPH-Dx	Soil and Groundwater
BTEX	EPA 8260	Soil and Groundwater

MTBE, EDB, EDC, and Naphthalene	EPA 8260	Soil and Groundwater
Halogenated Volatile Organic Compounds	EPA 8260	Soil and Groundwater
Total/Dissolved Lead	EPA 6000 series	Soil and Groundwater
BTEX, MTBE, EDB, EDC, and Naphthalene	EPA TO-15	Soil Vapor
Aliphatic and Aromatic Hydrocarbons	MA APH	Soil Vapor

Table E-1 lists samples containers, preservation, and analytical holding times for each analysis.

E3.3.1 Method Detection Limit and Method Reporting Limit

The method detection limit (MDL) is the minimum concentration of a compound that can be measured and reported with a 99-percent confidence that the analyte concentration is greater than zero. MDLs are established by the laboratory using prepared samples, not samples of environmental media.

The method reporting limit (RL) is defined as the lowest concentration at which a chemical can be accurately and reproducibly quantified, within specified limits of precision and accuracy, for a given environmental sample. The RL can vary from sample to sample depending on sample size, sample dilution, matrix interferences, moisture content, and other sample-specific conditions. As a minimum requirement for organic analyses, the RL should be equivalent to or greater than the concentration of the lowest calibration standard in the initial calibration curve. The expected MDLs and RLs from F&B laboratory are summarized in Tables E-3, E-4, and E-5 for groundwater, soil, and soil vapor samples, respectively.

E3.4 Data Quality Objectives

DQOs, including the Measurement Quality Indicators (MQIs)—precision, accuracy, representativeness, comparability, completeness, and sensitivity (namely PARCCS parameters) —and sample-specific RLs are dictated by the data quality objectives, project requirements, and intended uses of the data. For this project, the analytical data must be of sufficient technical quality to determine whether contaminants are present and, if present, whether their concentrations are greater than or less than applicable screening criteria based on protection of human health and the environment.

The quality of data generated will be assessed against the MQIs set forth in this QAPP. Specific QC parameters associated with each of the MQIs are summarized in Table E-2. Specific MQI goals and evaluation criteria (i.e., MDLs, RLs, percent recovery (%R)) for accuracy measurements, relative percent difference (RPD) for precision measurements, are defined in Tables E-3 through E-5. Definitions of these parameters and the applicable QC procedures are presented below.

E3.4.1 Precision

Precision measures the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared with their average values. Analytical precision is measured through matrix spike/matrix spike duplicate (MS/MSD) samples and laboratory control samples/laboratory control sample duplicate (LCS/LCSD) when there is sufficient sample volume. A laboratory duplicate sample or just an LCS/LCSD may be used in place of an MS/MSD if there is insufficient volume.

Analytical precision is quantitatively expressed as the relative percent difference (RPD) between the LCS/LCSD, MS/MSD, or laboratory duplicate pairs and is calculated with the following formula:

$$RPD\ (\%) = 100 \times \frac{|S - D|}{(S + D)/2}$$

where:
S = analyte concentration in sample
D = analyte concentration in duplicate sample

Analytical precision measurements will be carried out at a minimum frequency of 1 per 20 samples for each matrix sampled, or one per laboratory analysis group. Laboratory precision will be evaluated against laboratory quantitative RPD performance criteria as defined in Tables E-3 through E-6 for specific analytical methods and sample matrices. If the control criteria are not met, the laboratory will supply a justification of why the limits were exceeded and implement the appropriate corrective actions. The RPD will be evaluated during data review and validation. The data reviewer will note deviations from the specified limits and will comment on the effect of the deviations on reported data.

E3.4.2 Accuracy

Accuracy measures the closeness of the measured value to the true value. The accuracy of chemical test results is assessed by “spiking” samples with known standards (surrogates, blank spikes, or matrix spikes) and establishing the average recovery. Accuracy is quantified as the %R. The closer the %R is to 100 percent, the more accurate the data.

Surrogate recovery will be calculated as follows:

$$\text{Recovery}\ (\%) = \frac{MC}{SC} \times 100$$

where:
SC = spiked concentration
MC = measured concentration

MS percent recovery will be calculated as follows:

$$\text{Recovery}\ (\%) = \frac{MC - USC}{SC} \times 100$$

where:
SC = spiked concentration

MC = measured concentration
USC = unspiked sample concentration

Accuracy measurements on MS samples will be carried out at a minimum frequency of 1 in 20 samples per matrix analyzed. Blank spikes will also be analyzed at a minimum frequency of 1 in 20 samples (not including QC samples) per matrix analyzed. Surrogate recoveries for organic compounds will be determined for each sample analyzed for respective compounds. Laboratory accuracy will be evaluated against the performance criteria defined in Tables E-3 through E-6. If the control criteria are not met, the laboratory will supply a justification of why the limits were exceeded and implement the appropriate corrective actions. Percent recoveries will be evaluated during data review and validation, and the data reviewer will comment on the effect of the deviations on the reported data.

E3.4.3 Representativeness

Representativeness measures how closely the measured results reflect the actual concentration or distribution of the chemical compounds in the matrix sampled. The FSP sampling techniques and sample handling protocols (e.g., homogenizing, storage, preservation, and use of duplicates and blanks) have been developed to ensure representative samples. Only representative data will be deemed usable. Sampling locations are described in Section 6 of the RI WP. The field sampling procedures are described in the FSP (Section E2) of this SAP.

The representativeness of a data point is determined by assessing the integrity of the sample upon receipt at the laboratory (e.g., consistency of sample ID and collection date/time between container labels versus COC forms, breakage/leakage, cooler temperature, preservation, headspace for VOA containers, etc.); compliance of method required sample preparation and analysis holding times; the conditions of blanks (trip blank, rinsate blank, field blank, method/preparation blank, and calibration blank) associated with the sample; and the overall consistency of the results within a field duplicate pair.

E3.4.4 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. This goal will be achieved through the use of standard techniques to collect samples, USEPA-approved standard methods to analyze samples, and consistent units to report analytical results. Data comparability also depends on data quality. Data of unknown quality cannot be compared.

E3.4.5 Completeness

Completeness is defined as the percentage of measurements made that are judged to be valid. Results will be considered valid if the precision, accuracy, and representativeness objectives are met and if RLs are sufficient for the intended uses of the data. Completeness is calculated as follows:

$$Completeness\ (\%) = \frac{V}{P} \times 100$$

where:

V = number of valid measurements
P = number of measurements taken

Valid and invalid data (i.e., data qualified with the R flag [rejected]) will be identified during data validation. The target completeness goal for this project is 95 percent.

E3.4.6 Sensitivity

Sensitivity depicts the level of ability an analytical system (i.e., sample preparation and instrumental analysis) has in detecting a target component in a given sample matrix with a defined level of confidence. Factors affecting the sensitivity of an analytical system include: analytical system background (e.g., laboratory artifact or method blank contamination), sample matrix (e.g., mass spectrometry ion ratio change, co-elution of peaks, or baseline elevation), and instrument instability.

E3.5 Quality Control Procedures

Field and laboratory QC procedures are outlined below.

E3.5.1 Field Quality Control

Beyond use of standard sampling protocols defined in the FSP, field QC procedures include maintaining the field instrumentation used. Field instruments (e.g., PID for evaluating presence of VOCs in soil samples, and the YSI meter for measuring field parameters during ground water sampling) are maintained and calibrated regularly prior to use, in accordance with manufacturer recommendations.

In addition, field QC samples will be collected and submitted for analyses to monitor the precision and accuracy associated with field procedures. Field QC samples to be collected and analyzed for this RI include field duplicates, trip blanks, and equipment rinsate blanks. The definition and sampling requirements for field QC samples are presented below.

Blind Field Duplicates

Blind field duplicate samples are used to check for sampling and analysis reproducibility; however, the field duplicate sample results include variability introduced during both field sampling and laboratory preparation and analysis, and EPA data validation guidance provides no specific evaluation criteria for field duplicate samples. Advisory evaluation criteria are set forth at 35 percent for RPD (if both results are greater than five times the RL) and two times the RLs for concentration difference (if either result is less than five times the RL) between the original and field duplicate results.

Field Duplicates will be submitted “blind” to the laboratory as discrete samples (i.e., given unique sample identifiers to keep the duplicate identity unknown to the laboratory), but will be clearly identified in the field log. Field duplicate samples will be collected at a frequency of 5 percent (1 per 20) of the field samples for each matrix and analytical method, but not less than one duplicate per sampling event per matrix.

If a given soil sample depth interval lacks sufficient volume (recovery) to supply material for a planned analysis and its field duplicate analysis, the field duplicate aliquot will be collected for that analysis from another depth interval in that same location if practical.

Trip Blank

Trip blank samples will be used to monitor possible VOC cross-contamination occurring during sample transport. Trip blank samples are prepared and supplied by the laboratory using organic-free, reagent-grade water into a VOC vial prior to the collection of field samples. The trip blank sample vials are placed with and accompany the VOC and TPH-Gx samples through the entire transporting process. One trip blank will be collected for each soil sampling round and each ground water sampling round where VOC or TPH-Gx analyses are conducted.

In case a target compound is present in a trip blank, results for all samples shipped with this trip blank will be evaluated and data qualified accordingly if determined that the results are affected.

Equipment Rinsate Blank

Equipment rinsate blanks are collected to determine the potential of cross-contamination introduced by nondedicated equipment (e.g., bladder pump and YSI meter) that is used at multiple sample locations. Deionized water (obtained from the laboratory) is rinsed through the decontaminated sampling equipment and collected into adequate sample containers for analysis. The equipment rinsate blank is then handled in a manner identical to the primary samples collected with that piece of equipment. The blank is then processed, analyzed, and reported as a regular field sample. The rinsate blank collection frequency will be 1 per 20 samples for each matrix and analytical method, but not less than one equipment rinsate per sampling event per matrix. When dedicated equipment is used, equipment rinsate blanks will not be collected.

E3.5.2 Laboratory Quality Control

The laboratories' analytical procedures must meet requirements specified in the respective analytical methods or approved laboratory standard operating procedures (SOPs), e.g., instrument performance check, initial calibration, calibration check, blanks, surrogate spikes, internal standards, and/or labeled compound spikes. Specific laboratory QC analyses required for this project will consist of the following at a minimum:

- Instrument tuning, instrument initial calibration, and calibration verification analyses as required in the analytical methods and the laboratory standard operating procedures (SOPs).
- Laboratory and/or instrument method blank measurements at a minimum frequency of 5 percent (1 per 20 samples) or in accordance with method requirements, whichever is more frequent.

- Accuracy and precision measurements as defined in Table E-2, at a minimum frequency of 5 percent (1 per 20 samples) or in accordance with method requirements, whichever is more frequent. In cases where a pair of MS/MSD or MS/laboratory duplicate analyses are not performed on a project sample, a set of LCS/LCSD analyses will be performed to provide sufficient measures for analytical precision and accuracy evaluation.

The laboratory's QA officers are responsible for ensuring that the laboratory implements the internal QC and QA procedures detailed in the laboratory's Quality Assurance Manual.

E3.6 Corrective Actions

If routine QC audits by the laboratory result in detection of unacceptable conditions or data, actions specified in the laboratory SOPs will be taken. Specific corrective actions are outlined in each SOP used and can include the following:

- Identifying the source of the violation
- Reanalyzing samples if holding time criteria permit
- Resampling and analyzing
- Evaluating and amending sampling and analytical procedures, and/or
- Accepting but qualifying data to indicate the level of uncertainty

If unacceptable conditions occur, the laboratory will contact the project manager to discuss the issues and determine the appropriate corrective action. Corrective actions taken by the laboratory during analysis of samples for this project will be documented by the laboratory in the case narrative associated with the affected samples.

In addition, the project data quality manager will review the laboratory data generated for this investigation to ensure that project DQOs are met. If the review indicates that non-conformances in the data have resulted from field sampling or documentation procedures or laboratory analytical or documentation procedures, the impact of those non-conformances on the overall project data usability will be assessed. Appropriate actions, including re-sampling and/or re-analysis of samples may be recommended to the project manager to achieve project objectives.

E3.7 Data Reduction, Quality Review, and Reporting

All data will undergo a QA/QC evaluation at the laboratory which will then be reviewed by the responsible data quality manager. Initial data reduction, evaluation, and reporting at the laboratory will be carried out in full compliance with the method requirement and laboratory SOPs. The laboratory internal review will include verification (for correctness and completeness) of electronic data deliverable (EDD) accompanied with each laboratory report. The responsible database manager will verify the completeness and correctness of all laboratory deliverables (i.e., laboratory report and EDDs) before releasing the deliverables for data validation.

E3.7.1 Minimum Data Reporting Requirements

The following sections specify general and specific requirements for analytical data reporting to provide sufficient deliverables for project documentation and data quality assessment.

General Requirements

The following requirements apply to laboratory reports for all types of analyses:

- A laboratory report will include a cover page signed by the laboratory director, the laboratory QA officer, or his/her designee to certify the eligibility of the reported contents and the conformance with applicable analytical methodology.
- Definitions of abbreviations, data flags and data qualifiers used in the report.
- Cross reference of field sample names and laboratory sample identity for all samples in the SDG.
- Completed COC document signed and dated by parties of acquiring and receiving.
- Completed sample receipt document with record of cooler temperature and sample conditions upon receipt at the laboratory. Anomalies such as inadequate sample preservation, inconsistent bottle counts, and sample container breakage, and communication record and corrective actions in response to the anomalies will be documented and incorporated in the sample receipt document. The document will be initialed and dated by personnel that complete the document.
- Case narrative that addresses any anomalies or QC outliers in relation to sample receiving, sample preparation, and sample analysis on samples in the sample delivery group (SDG). The narrative will be presented separately for each analytical method and each sample matrix.
- All pages in the report are to be paginated. Any insertion of pages after the laboratory report is issued will be paginated with starting page number suffixed with letters (e.g., pages inserted between pages 134 and 135 should be paginated as 134A, 134B, etc.)
- Any resubmitted or revised report pages will be submitted to project manager with a cover page stating the reason(s) and scope of resubmission or revision, and signed by laboratory director, QA officer, or the designee.

Specific Requirements

The following presents specific requirements for laboratory reports:

- Sample results: All soil sample results will be reported on a dry-weight basis. The report pages for sample results (namely Form 1s) will, at minimum, include sample results, RLs, unit, proper data flags, preparation, and analysis, dilution factor, and percent moisture (for solid samples).
- Method blank results.
- LCS and LCSD (if matrix spike duplicate analysis is not performed) results with laboratory acceptance criteria for %R and RPD.
- Surrogate spike results with laboratory acceptance criteria for %R.
- MS and MSD results with laboratory acceptance criteria for %R and RPD. In cases where MS/MSD analyses were not performed on a project sample, LCS/LCSD analyses should be performed and reported instead.

E3.8 Data Quality Verification and Validation

Reported analytical results will be qualified by the laboratory to identify QC concerns in accordance with the specifications of the analytical methods. Additional laboratory data qualifiers may be defined and reported by the laboratory to more completely explain QC concerns regarding a particular sample result. All data qualifiers will be defined in the laboratory’s narrative reports associated with each case.

Data validation will be performed on all data consistent with United States Environmental Protection Agency Stage 2A requirements. In cases where a systematic QC problem is suspected, such as unusual detections of an analyte or consistent outlying results of a QC parameter, a more detailed review will be performed on laboratory records pertinent to the concerned analysis to further evaluate the extend of the QC issue and the final data quality and usability. The actual level of validation for each data point will be entered in the electrical database submitted to the Ecology Environmental Information Management system (EIMs). Data validation will be conducted following the guidance below:

- EPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Methods Data Review, Office of Superfund Remediation and Technical Innovation, U.S. Environmental Protection Agency, January 2017, OLEM 9355.0-135, EPA-540-R-2017-001.
- EPA Contract Laboratory Program National Functional Guidelines for Organic Superfund Methods Data Review, Office of Superfund Remediation and Technical Innovation, U.S. Environmental Protection Agency, January 2017, OLEM 9355.0-136, EPA-540-R-2017-002.

The data validation will examine and verify the following parameters against the method requirements and laboratory control limits specified in Tables E-3 through E-5:

- Sample management and holding times

- Laboratory and field blank results
- Detection and reporting limits
- Laboratory replicate results
- MS/MSD results
- LCS and/or standard reference material results
- Field duplicate results
- Surrogate spike recovery (organic analyses only)
- Internal standard recovery (internal calibration methods only)
- Inter-element interference check (ICP analyses only)
- Serial dilution (metals only)

Data qualifiers will be assigned based on outcome of the data validation. Data qualifiers are limited to and defined as follows:

- U—The analyte was analyzed for but was determined to be non-detect above the reported sample quantitation limit, or the quantitation limit was raised to the concentration found in the sample due to blank contamination.
- J—The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
- UJ—The analyte was not detected above the reported quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
- X—The numerical value of the result is accurate. However, the analyte was not positively identified at that value because the chromatographic pattern in the sample did not match that of the associated fuel standard. This qualifier is applicable only to TPH results.
- R—The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet QC criteria. The presence or absence of the analyte cannot be verified.
- DNR—Do not report from this analysis; the result for this analyte is to be reported from an alternative analysis.

In cases of multiple analyses (such as an undiluted and a diluted analysis) performed on one sample, the optimal result will be determined and only the determined result will be reported for the sample.

The scope and findings of the data validation will be documented and discussed in the Data Validation Report(s). The Data Validation Report(s) will be appended to the RI report.

E3.9 Preventative Maintenance Procedures and Schedules

Preventative maintenance in the laboratory will be the responsibility of the laboratory personnel and analysts and ensured by the laboratory project manager. This maintenance includes routine care and cleaning of instruments and inspection and monitoring of carrier gases, solvents, and glassware used in analyses. Details of the maintenance procedures are addressed in the respective laboratory SOPs.

Precision and accuracy data are examined for trends and excursions beyond control limits to determine evidence of instrument malfunction. Maintenance will be performed when an instrument begins to change as indicated by the degradation of peak resolution, shift in calibration curves, decrease in sensitivity, or failure to meet one or another of the method-specific QC criteria.

Maintenance and calibration of instruments used in the field for sampling (e.g., PID for evaluating presence of VOCs in soil samples, and the YSI meter for measuring field parameters during ground water sampling) will be conducted regularly in accordance with manufacturer recommendations prior to use.

E3.10 Performance and System Audits

The project manager has responsibility for reviewing the performance of the laboratory QA program; this review will be achieved through regular contact with the analytical laboratory's project manager. To ensure comparable data, all samples of a given matrix to be analyzed by each specified analytical method will be processed consistently by the same analytical laboratory.

E3.11 Data and Records Management

Records will be maintained documenting all activities and data related to field sampling and chemical analyses.

E3.11.1 Field Documentation

Raw data received from the analytical laboratory will be reviewed, entered into a computerized database, and verified for consistency and correctness. The database will be updated based on data review and independent validation if necessary.

The following field data will be included in the database:

- Sample location coordinates
- Sample type (i.e., ground water or soil)
- Soil or ground water sampling depth interval

Information regarding whether concentrations represent total phase (unfiltered samples) or dissolved phase (filtered samples) will be compiled and stored in the database. Data will be submitted to Ecology's Environmental Information Management (EIM) database once data have been reviewed and validated.

E3.11.2 Analytical Data Management

Raw data received from the analytical laboratory will be reviewed, entered into a computerized database, and verified for consistency and correctness. The database will be updated based on data review and independent validation if necessary.

The following field data will be included in the database:

- Sample location coordinates
- Sample type (i.e., ground water or soil)
- Soil or ground water sampling depth interval

Information regarding whether concentrations represent total phase (unfiltered samples) or dissolved phase (filtered samples) will be compiled and stored in the database. Data will be submitted to Ecology's Environmental Information Management (EIM) database once data have been reviewed and validated.

E4 References for Appendix E

Puls, R.W. and M.J. Barcelona, 1996, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures, EPA Ground Water Issue, EPA/540/S-95/504.

U.S. Environmental Protection Agency (EPA), 2009, Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use, January 13 2009. EPA 540-R-08-005.

U.S. Environmental Protection Agency (EPA), 2017a, Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Methods Data Review, Office of Superfund Remediation and Technical Innovation, U.S. Environmental Protection Agency, January 2017, OLEM 9355.0-135, EPA-540-R-2017-001.

U.S. Environmental Protection Agency (EPA), 2017b, Contract Laboratory Program National Functional Guidelines for Organic Superfund Methods Data Review, Office of Superfund Remediation and Technical Innovation, U.S. Environmental Protection Agency, January 2017, OLEM 9355.0-135, EPA-540-R-2017-001.

Washington State Department of Ecology (Ecology), 2004, Collecting and Preparing Soil Samples for VOC Analysis, Implementation Memorandum Number 5, June 17, 2004.

Washington State Department of Ecology (Ecology), 2012, Guidance for Groundwater Monitoring at Landfills and Other Facilities Regulated Under Chapters 173-304, 173-306, 173-350, and 173-351 WAC, Publication No. 12-07-072.

TABLES

Table E-1. Analytical Methods, Sample Containers, Preservation, and Holding Times

Project No. 180357, Aloha Café
Lynwood, Washington

Sample Matrix	Analytical Parameter	Analytical Method	Sample Container	No. Containers	Preservation Requirements	Holding Time
Soil	Gasoline Range TPH	NWTPH-Gx	Method 5035A, 40-mL vials	4	4°C ±2°C, Freeze within 48 hours to <-7°C	14 days
	Diesel and Motor Oil Range TPH	NWTPH-Dx (without Silica Gel Cleanup)	4 ounce jar	1	4°C ±2°C	14 days for extraction; 40 days for analysis
	VOCs	Method 8260	Method 5035A, 40-mL vials	4	4°C ±2°C, Freeze within 48 hours to <-7°C	14 days
	MTBE, EDC, EDB, Naphthalene	Method 8260	Method 5035A, 40-mL vials	4	4°C ±2°C, Freeze within 48 hours to <-7°C	14 days
	Lead	Method 6020	4-ounce jar	1	4°C ±2°C	6 months
Water	Gasoline Range TPH	Method NWTPH-Gx	40-mL VOA vials	3	4°C ±2°C, HCl pH < 2	14 days
	Diesel and Motor Oil Range TPH	NWTPH-Dx (without Silica Gel Cleanup)	500-mL amber glass bottle	1	4°C ±2°C	7 days for extraction, 40 days for analysis
	MTBE, EDC, EDB, Naphthalene	Method 8260	40-mL VOA vials	3	4°C ±2°C, 1 with HCl pH < 2, 2 without HCl	14 days for analysis
	Halogenated VOCs	Method 8260	40-mL VOA vials	3	4°C ±2°C, 1 with HCl pH < 2, 2 without HCl	14 days for analysis
Soil Vapor	VOCs	Method TO-15	6L SUMMA Canister	1	N/A	28 days

Notes:
HCl = hydrochloric acid
TPH = total petroleum hydrocarbons
VOA = volatile organic analysis
BTEX = benzene, toluene, ethylbenzene, xylenes
MTBE = methyl tert-butyl ether

Table E-2. QC Parameters Associated with PARCCS

Project No. 180357, Aloha Café
Lynwood, Washington

Data Quality Indicators	QC Parameters
Precision	RPD values of:
	(1) LCS/LCS Duplicate
	(2) MS/MSD
	(3) Field Duplicates
Accuracy/Bias	Percent Recovery (%R) or Percent Difference (%D) values of:
	(1) Initial Calibration and Calibration Verification
	(2) LCS
	(3) MS
	(4) Surrogate Spikes
	Results of:
	(1) Instrument and Calibration Blank
	(2) Method (Preparation) Blank
	(3) Trip Blank
	(4) Equipment Rinsate Blank (if appropriate)
Representativeness	Results of All Blanks
	Sample Integrity (Chain-of-Custody and Sample Receipt Forms)
	Holding Times
Comparability	Sample-specific Reporting Limits
	Sample Collection Methods
	Laboratory Analytical Methods
Completeness	Data Qualifiers
	Laboratory Deliverables
	Requested/Reported Valid Results
Sensitivity	MDLs and MRLs

Notes:

LCS = laboratory control sample
MDL = method detection limit
MRL = method reporting limit
MS/MSD = matrix spike/matrix spike duplicate
QC = Quality Control
PARCCS = Precision, Accuracy, Representativeness, Comparability, Completeness, Sensistivity

Table E-3. Measurement Quality Objectives for Water Samples

Friedman and Bruya, Inc
Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	MDL(A)	MRL	LCS/LCS %R(A)	RPD (%)	Surrogate %R(A)
Volatile Organic Compounds (VOCs) by SW8260C (µg/L)					
1,1,1,2-Tetrachloroethane	0.040	0.2	80 – 128	≤40	n/a
1,1,1-Trichloroethane	0.041	0.2	79 – 124	≤40	n/a
1,1,2,2-Tetrachloroethane	0.060	0.2	80 – 120	≤40	n/a
1,1,2-Trichloro-1,2,2-Trifluoroethane	0.043	0.2	76 – 124	≤40	n/a
1,1,2-Trichloroethane	0.129	0.2	80 – 120	≤40	n/a
1,1-Dichloroethane	0.053	0.2	80 – 120	≤40	n/a
1,1-Dichloroethene	0.054	0.2	74 – 120	≤40	n/a
1,1-Dichloropropene	0.034	0.2	80 – 120	≤40	n/a
1,2,3-Trichlorobenzene	0.110	0.5	80 -125	≤40	n/a
1,2,3-Trichloropropane	0.131	0.5	80 – 120	≤40	n/a
1,2,4-Trichlorobenzene	0.107	0.5	77 – 127	≤40	n/a
1,2,4-Trimethylbenzene	0.024	0.2	80 – 122	≤40	n/a
1,2-Dibromo 3-Chloropropane	0.366	0.5	79 – 129	≤40	n/a
1,2-Dibromoethane (Ethylene Dibromid	0.075	0.2	80 – 120	≤40	n/a
1,2-Dichlorobenzene	0.036	0.2	80 – 120	≤40	n/a
1,2-Dichloroethane	0.072	0.2	80 – 121	≤40	n/a
1,2-Dichloropropane	0.035	0.2	80 – 120	≤40	n/a
1,3,5-Trimethyl Benzene	0.015	0.2	80 – 120	≤40	n/a
1,3-Dichlorobenzene	0.036	0.2	80 – 120	≤40	n/a
1,3-Dichloropropane	0.062	0.2	80 – 120	≤40	n/a
1,4-Dichlorobenzene	0.040	0.2	80 – 120	≤40	n/a
2,2-Dichloropropane	0.052	0.2	72 – 133	≤40	n/a
2-Butanone	0.814	5.0	73 – 123	≤40	n/a
2-Chloro Toluene	0.024	0.2	80 – 120	≤40	n/a
2-Chloroethylvinyl Ether	0.250	1.0	62 – 130	≤40	n/a
2-Hexanone	0.902	5.0	80 – 129	≤40	n/a
4-Chloro Toluene	0.016	0.2	80 – 120	≤40	n/a
4-Isopropyl Toluene	0.026	0.2	80 – 124	≤40	n/a
4-Methyl-2-Pentanone	0.974	5.0	80 – 125	≤40	n/a
Acetone	2.057	5.0	64 – 125	≤40	n/a
Acrolein	2.476	5.0	60 – 124	≤40	n/a
Acrylonitrile	0.604	1.0	76 – 123	≤40	n/a
Benzene	0.027	0.2	80 – 120	≤40	n/a
Bromobenzene	0.060	0.2	80 – 120	≤40	n/a
Bromochloromethane	0.061	0.2	80 – 120	≤40	n/a
Bromodichloromethane	0.051	0.2	80 – 122	≤40	n/a
Bromoethane	0.041	0.2	77 – 122	≤40	n/a
Bromoform	0.062	0.2	62 – 149	≤40	n/a
Bromomethane	0.252	1.0	68 – 130	≤40	n/a
Carbon Disulfide	0.037	0.2	77 – 124	≤40	n/a
Carbon Tetrachloride	0.044	0.2	71 – 139	≤40	n/a
Chlorobenzene	0.023	0.2	80 – 120	≤40	n/a

Table E-3. Measurement Quality Objectives for Water Samples

Friedman and Bruya, Inc

Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	MDL(A)	MRL	LCS/LCS %R(A)	RPD (%)	Surrogate %R(A)
Volatile Organic Compounds (VOCs) by SW8260C (µg/L)					
Chloroethane	0.086	0.2	68 – 133	≤40	n/a
Chloroform	0.027	0.2	80 – 120	≤40	n/a
Chloromethane	0.095	0.5	77 – 122	≤40	n/a
cis 1,3-dichloropropene	0.061	0.2	80 – 127	≤40	n/a
cis-1,2-Dichloroethene	0.043	0.2	78 – 120	≤40	n/a
Dibromochloromethane	0.048	0.2	80 – 120	≤40	n/a
Dibromomethane	0.145	0.2	80 – 120	≤40	n/a
Dichlorodifluoromethane	0.052	0.2	68 – 133	≤40	n/a
Ethyl Benzene	0.037	0.2	80 – 120	≤40	n/a
Hexachloro-1,3-Butadiene	0.073	0.5	80 – 135	≤40	n/a
Iodomethane (Methyl Iodide)	0.227	1.0	76 – 123	≤40	n/a
iso-propyl Benzene	0.021	0.2	80 – 120	≤40	n/a
Methylene Chloride	0.485	1.0	71 – 125	≤40	n/a
Methyl-tert-butyl ether	0.073	0.5	79 – 121	≤40	n/a
Naphthalene	0.118	0.5	80 – 128	≤40	n/a
n-Butyl Benzene	0.025	0.2	80 – 125	≤40	n/a
n-Propyl Benzene	0.023	0.2	80 – 120	≤40	n/a
sec-Butyl Benzene	0.024	0.2	80 – 121	≤40	n/a
Styrene	0.045	0.2	80 – 121	≤40	n/a
tert-Butyl Benzene	0.026	0.2	80 – 121	≤40	n/a
Tetrachloroethene	0.047	0.2	80 – 120	≤40	n/a
Toluene	0.040	0.2	80 – 120	≤40	n/a
trans 1,3-Dichloropropene	0.081	0.2	79 – 132	≤40	n/a
trans-1,2-Dichloroethene	0.048	0.2	75 – 120	≤40	n/a
trans-1,4-Dichloro 2-Butene	0.324	1.0	47 – 147	≤40	n/a
Trichloroethene	0.049	0.2	80 – 120	≤40	n/a
Trichlorofluoromethane	0.037	0.2	74 – 135	≤40	n/a
Vinyl Acetate	0.069	0.2	74 – 120	≤40	n/a
Vinyl Chloride	0.069	0.2	74 – 120	≤40	n/a
m,p-xylene	0.052	0.4	80 – 120	≤40	n/a
o-Xylene	0.035	0.2	80 – 120	≤40	n/a
1,2-Dichloroethane-d4	n/a	n/a	80 – 130	≤40	80 – 120
1,2-Dichlorobenzene-d4	n/a	n/a	80 – 120	≤40	80 – 120
Toluene-d8	n/a	n/a	80 – 120	≤40	80 – 120
4-Bromofluorobenzene	n/a	n/a	80 – 120	≤40	80 – 120
Gasoline Range Hydrocarbons by NWTPH-Gx (µg/L)					
Gasoline Range Hydrocarbons	0.057	0.25	80 – 120	≤40	n/a
Bromobenzene	n/a	n/a	77 – 120	≤40	n/a
Diesel and Motor Oil Range Hydrocarbons by NWTPH-Dx without Silica Gel Cleanup (µg/L)					
Diesel Range Hydrocarbons	39	100	61-104	≤40	n/a
Oil Range Hydrocarbons	10	200	60 – 130	≤40	n/a
o-Terphenyl	n/a	n/a	50 – 150	≤40	n/a
Metals					
Lead	0.046	0.1	80 – 120	≤20	n/a

Notes:
(A) = Based on current laboratory control criteria. Some values may vary slightly between instruments and can be subject to change as the laboratory updates the charted values periodically.
%R = percent recovery
LCS/LCSD = laboratory control samples and laboratory control sample duplicate
MDL = method detection limit
MRL = method reporting limit
n/a = not applicable
RPD = relative percent difference
µg/L = microgram per liter
(--) = No PSL identified

Table E-4. Measurement Quality Objectives for Soil Samples

Friedman and Bruya, Inc.

Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	MDL(A)	MRL	LCS/LCS %R(A)	RPD (%)	Surrogate %R(A)
Volatile Organic Compounds (VOCs) by SW8260C (mg/kg)					
1,1,1,2-Tetrachloroethane	0.000233	0.001	80 – 120	≤40	n/a
1,1,1-Trichloroethane	0.000226	0.001	78 – 133	≤40	n/a
1,1,2,2-Tetrachloroethane	0.000253	0.001	71 – 120	≤40	n/a
1,1,2-Trichloro-1,2,2-Trifluoroethane	0.000287	0.002	72 – 142	≤40	n/a
1,1,2-Trichloroethane	0.000286	0.001	77 – 120	≤40	n/a
1,1-Dichloroethane	0.000203	0.001	65 – 139	≤40	n/a
1,1-Dichloroethene	0.000336	0.001	73 – 138	≤40	n/a
1,1-Dichloropropene	0.000312	0.001	80 – 123	≤40	n/a
1,2,3-Trichlorobenzene	0.000305	0.005	76 – 122	≤40	n/a
1,2,3-Trichloropropane	0.000517	0.002	75 – 120	≤40	n/a
1,2,4-Trichlorobenzene	0.000332	0.005	75 – 130	≤40	n/a
1,2,4-Trimethylbenzene	0.00023	0.001	77 – 125	≤40	n/a
1,2-Dibromo-3-Chloropropane	0.000586	0.005	61 – 128	≤40	n/a
1,2-Dibromoethane (Ethylene Dibromide	0.000176	0.001	79 – 120	≤40	n/a
1,2-Dichlorobenzene	0.000293	0.001	77 – 120	≤40	n/a
1,2-Dichloroethane	0.000191	0.001	77 – 120	≤40	n/a
1,2-Dichloropropane	0.000162	0.001	74 – 120	≤40	n/a
1,3,5-Trimethylbenzene	0.000254	0.001	77 – 126	≤40	n/a
1,3-Dichlorobenzene	0.000227	0.001	76 – 120	≤40	n/a
1,3-Dichloropropane	0.000209	0.001	77 – 120	≤40	n/a
1,4-Dichlorobenzene	0.000232	0.001	75 – 120	≤40	n/a
2,2-Dichloropropane	0.000292	0.001	77 – 137	≤40	n/a
2-Butanone	0.000513	0.005	64 – 120	≤40	n/a
2-Chloroethyl Vinyl Ether	0.000276	0.005	20 – 157	≤40	n/a
2-Chlorotoluene	0.0003	0.001	76 – 120	≤40	n/a
2-Hexanone	0.000439	0.005	62 – 128	≤40	n/a
4-Chlorotoluene	0.000277	0.001	75 – 121	≤40	n/a
4-Isopropyl Toluene	0.000236	0.001	78 – 131	≤40	n/a
4-Methyl-2-Pentanone	0.00042	0.005	70 – 124	≤40	n/a
Acetone	0.000482	0.005	48 – 132	≤40	n/a
Acrolein	0.003809	0.05	60 – 130	≤40	n/a
Acrylonitrile	0.001026	0.005	59 – 124	≤40	n/a
Benzene	0.000296	0.001	80 – 120	≤40	n/a
Bromobenzene	0.000153	0.001	75 – 120	≤40	n/a
Bromochloromethane	0.000323	0.001	69 – 133	≤40	n/a
Bromodichloromethane	0.000254	0.001	80 – 122	≤40	n/a
Bromoethane	0.00044	0.002	74 – 132	≤40	n/a
Bromoform	0.000297	0.001	63 – 120	≤40	n/a
Bromomethane	0.000187	0.001	40 – 172	≤40	n/a

Table E-4. Measurement Quality Objectives for Soil Samples

Friedman and Bruya, Inc.

Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	MDL(A)	MRL	LCS/LCS %R(A)	RPD (%)	Surrogate %R(A)
Volatile Organic Compounds (VOCs) by SW8260C (mg/kg)					
Carbon Disulfide	0.000559	0.001	72 – 146	≤40	n/a
Carbon Tetrachloride	0.000213	0.001	76 – 136	≤40	n/a
Chlorobenzene	0.000219	0.001	80 – 120	≤40	n/a
Chloroethane	0.000462	0.001	53 – 154	≤40	n/a
Chloroform	0.000234	0.001	75 – 126	≤40	n/a
Chloromethane	0.000263	0.001	65 – 129	≤40	n/a
cis-1,2-Dichloroethene	0.00024	0.001	75 – 124	≤40	n/a
cis-1,3-Dichloropropene	0.000226	0.001	80 – 124	≤40	n/a
Dibromochloromethane	0.000266	0.001	77 – 123	≤40	n/a
Dibromomethane	0.000147	0.001	80 – 120	≤40	n/a
Dichlorodifluoromethane	0.000207	0.001	67 – 142	≤40	n/a
Ethyl Benzene	0.000202	0.001	80 – 120	≤40	n/a
Hexachloro-1,3-Butadiene	0.00041	0.005	72 – 135	≤40	n/a
Iodomethane (Methyl Iodide)	0.000215	0.001	34 – 181	≤40	n/a
Isopropyl Benzene	0.000233	0.001	77 – 127	≤40	n/a
Methylene Chloride	0.000635	0.002	61 – 128	≤40	n/a
Methyl-t-butyl ether (MTBE)	0.000231	0.001	68 – 124	≤40	n/a
Naphthalene	0.000429	0.005	71 – 122	≤40	n/a
n-Butylbenzene	0.000262	0.001	75 – 134	≤40	n/a
n-Propyl Benzene	0.000272	0.001	76 – 126	≤40	n/a
s-Butylbenzene	0.00024	0.001	77 – 127	≤40	n/a
Styrene	0.000138	0.001	80 – 122	≤40	n/a
t-Butylbenzene	0.000306	0.001	77 – 125	≤40	n/a
Tetrachloroethene	0.000257	0.001	76 – 131	≤40	n/a
Toluene	0.000151	0.001	78 – 120	≤40	n/a
trans-1,2-Dichloroethene	0.000266	0.001	73 – 131	≤40	n/a
trans-1,3-Dichloropropene	0.000216	0.001	80 – 126	≤40	n/a
trans-1,4-Dichloro-2-Butene	0.000437	0.005	62 – 127	≤40	n/a
Trichloroethene	0.000212	0.001	80 – 120	≤40	n/a
Trichlorofluoromethane	0.000266	0.001	57 – 161	≤40	n/a
Vinyl Acetate	0.000381	0.005	54 – 138	≤40	n/a
Vinyl Chloride	0.000235	0.001	74 – 134	≤40	n/a
m,p-Xylene	0.000392	0.001	80 – 123	≤40	n/a
o-Xylene	0.000224	0.001	80 – 120	≤40	n/a
1,2-Dichloroethane-d4	*n/a*	*n/a*	*80 – 149*	*≤40*	*80 – 122*
1,2-Dichlorobenzene-d4	*n/a*	*n/a*	*80 – 120*	*≤40*	*80 – 120*
Toluene-d8	*n/a*	*n/a*	*77 – 120*	*≤40*	*80 – 120*
4-Bromofluorobenzene	*n/a*	*n/a*	*80 – 120*	*≤40*	*80 – 120*

Table E-4. Measurement Quality Objectives for Soil Samples

Friedman and Bruya, Inc.

Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	MDL[(A)]	MRL	LCS/LCS %R[(A)]	RPD (%)	Surrogate %R[(A)]
Gasoline Range Hydrocarbons by NWTPH-Gx (mg/kg)					
Gasoline Range Hydrocarbons	0.057	0.25	80 – 120	≤40	n/a
Bromobenzene	*n/a*	*n/a*	*49 – 143*	*≤40*	*n/a*
Diesel and Motor Oil Range Hydrocarbons by NWTPH-Dx without Silica Gel Cleanup (mg/kg)					
Diesel Range Hydrocarbons	1.28	5	60 – 108	≤40	n/a
Oil Range Hydrocarbons	1.57	10	60 – 130	≤40	n/a
o-Terphenyl	*n/a*	*n/a*	*50 – 150*	*≤40*	*n/a*
Metals					
Lead	n/a	0.1	80-120	≤20	75-125

Notes:
(A) = Based on current laboratory control criteria. Some values may vary slightly between instruments and can be subject to change as the laboratory updates the charted values periodically.
%R = Percent recovery
LCS/LCSD = Laboratory control samples and laboratory control sample duplicate
MDL = Method detection limit
mg/kg = milligram per kilogram
MRL = Method reporting limit
n/a = not applicable
RPD = Relative percent difference

Table E-5. Measurement Quality Objectives for Soil Vapor Samples

Friedman and Bruya, Inc.

Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	MDL$^{(A)}$	MRL	RPD (%)	Surrogate %R$^{(A)}$
Volatile Organic Compounds (VOCs) by TO-15 (µg/m^3)				
1,1,1-Trichloroethane	0.035	0.55	≤40	n/a
1,1,2,2-Tetrachloroethane	0.11	0.69	≤40	n/a
1,1,2-Trichloroethane	0.061	0.55	≤40	n/a
1,1-Dichloroethane	0.036	0.4	≤40	n/a
1,1-Dichloroethene	0.047	0.4	≤40	n/a
1,2,3-Trimethylbenzene	0.14	2.5	≤40	n/a
1,2,4-Trichlorobenzene	0.079	0.74	≤40	n/a
1,2,4-Trimethylbenzene	0.041	2.5	≤40	n/a
1,2-Dibromoethane (EDB)	0.074	0.77	≤40	n/a
1,2-Dichlorobenzene	0.08	1.2	≤40	n/a
1,2-Dichloroethane (EDC)	0.055	0.4	≤40	n/a
1,2-Dichloropropane	0.05	0.46	≤40	n/a
1,3,5-Trimethylbenzene	0.11	2.5	≤40	n/a
1,3-Butadiene	0.02	0.22	≤40	n/a
1,3-Dichlorobenzene	0.062	1.2	≤40	n/a
1,4-Dichlorobenzene	0.067	0.6	≤40	n/a
1,4-Dioxane	0.063	0.36	≤40	n/a
1-Butanol	0.098	6.1	≤40	n/a
2-Butanone (MEK)	0.038	2.9	≤40	n/a
2-Hexanone	0.023	4.1	≤40	n/a
2-Pentanone	0.04	3.5	≤40	n/a
2-Propanol	0.067	8.6	≤40	n/a
3-Hexanone	0.024	4.1	≤40	n/a
3-Pentanone	0.099	3.5	≤40	n/a
4-Methyl-2-pentanone	0.097	4.1	≤40	n/a
Acetaldehyde	0.78	9	≤40	n/a
Acetone	0.72	4.8	≤40	n/a
Acetonitrile	0.038	1.7	≤40	n/a
Acrolein	0.049	0.92	≤40	n/a
Acrylonitrile	0.037	0.22	≤40	n/a
Benzene	0.018	0.32	≤40	n/a
Benzyl chloride	0.05	0.52	≤40	n/a
Bromodichloromethane	0.057	0.67	≤40	n/a
Bromoform	0.094	2.1	≤40	n/a
Bromomethane	0.034	0.39	≤40	n/a
Butanal	0.12	2.9	≤40	n/a
Carbon disulfide	0.03	6.2	≤40	n/a
Carbon Tetrachloride	0.056	0.63	≤40	n/a
CFC-113	0.089	0.77	≤40	n/a
Chlorobenzene	0.041	0.46	≤40	n/a

Table E-5. Measurement Quality Objectives for Soil Vapor Samples

Friedman and Bruya, Inc.

Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	MDL[(A)]	MRL	RPD (%)	Surrogate %R[(A)]
Chlorodifluoromethane	0.041	0.35	≤40	n/a
Chloroethane	0.016	0.26	≤40	n/a
Chloroform	0.051	0.49	≤40	n/a
Chloromethane	0.025	0.21	≤40	n/a
cis-1,2-Dichloroethene	0.031	0.4	≤40	n/a
cis-1,3-Dichloropropene	0.036	0.45	≤40	n/a
Cyclohexane	0.035	6.9	≤40	n/a
Cyclopentane	0.03	0.29	≤40	n/a
Dibromochloromethane	0.1	0.85	≤40	n/a
Dichlorodifluoromethane	0.033	0.49	≤40	n/a
Ethanol	0.56	7.5	≤40	n/a
Ethylbenzene	0.055	0.43	≤40	n/a
F-114	0.079	0.7	≤40	n/a
Hexachlorobutadiene	0.19	1.1	≤40	n/a
Hexanal	0.13	4.1	≤40	n/a
Hexane	0.062	3.5	≤40	n/a
Iodomethane	0.061	0.58	≤40	n/a
Isobutene	0.035	0.92	≤40	n/a
Isoprene	0.022	0.28	≤40	n/a
m,p-Xylene	0.082	0.87	≤40	n/a
Methacrolein	0.033	2.9	0	0
Methyl t-butyl ether	0.039	1.8	≤40	80 – 120
Methyl Vinyl Ketone	0.029	1.1	≤40	80 – 120
Methylene chloride	0.92	87	≤40	80 – 120
Naphthalene	0.022	0.52	≤40	80 – 120
o-Xylene	0.048	0.43	≤40	80 – 120
Pentanal	0.14	3.5	≤40	80 – 120
Pentane	0.049	3	≤40	80 – 120
Propene	0.025	0.69	≤40	80 – 120
Styrene	0.034	0.85	≤40	80 – 120
Tetrachloroethene	0.041	0.68	≤40	80 – 120
Toluene	0.034	0.38	≤40	80 – 120
trans-1,2-Dichloroethene	0.038	0.4	≤40	80 – 120
trans-1,3-Dichloropropene	0.032	0.45	≤40	80 – 120
Trichloroethene	0.058	0.54	≤40	80 – 120
Trichlorofluoromethane	0.073	0.56	≤40	80 – 120
Vinyl acetate	0.046	7	≤40	80 – 120
Vinyl chloride	0.02	0.26	≤40	80 – 120
APH EC5-8 aliphatics	NA	46	≤40	80 – 120
APH EC9-12 aliphatics	NA	70	≤40	80 – 120
APH EC9-10 aromatics	NA	50	≤40	80 – 120

Table E-5. Measurement Quality Objectives for Soil Vapor Samples

Friedman and Bruya, Inc.
Project No. 180357, Aloha Café
Lynwood, Washington

Analyte Name	**MDL$^{(A)}$**	**MRL**	**RPD (%)**	**Surrogate %R$^{(A)}$**
1,1,1-Trichloroethane	0.0028	0.055	≤40	80 – 120
1,1,2,2-Tetrachloroethane	0.0046	0.069	≤40	80 – 120
1,1,2-Trichloroethane	0.0045	0.055	≤40	80 – 120
1,1-Dichloroethane	0.0025	0.04	≤40	80 – 120
1,1-Dichloroethene	0.0049	0.04	≤40	80 – 120
1,2-Dibromoethane (EDB)	0.0076	0.077	≤40	80 – 120
1,2-Dichlorobenzene	0.0061	0.06	≤40	80 – 120
1,2-Dichloroethane (EDC)	0.0028	0.04	≤40	80 – 120
1,2-Dichloropropane	0.0049	0.046	≤40	80 – 120
1,3-Butadiene	0.0039	0.022	≤40	80 – 120
1,3-Dichlorobenzene	0.0065	0.06	≤40	80 – 120
1,4-Dichlorobenzene	0.0073	0.06	≤40	80 – 120
Benzene	0.0018	0.032	≤40	80 – 120
Benzyl chloride	0.0059	0.052	≤40	80 – 120
Bromodichloromethane	0.0049	0.067	≤40	80 – 120
Chloroethane	0.0048	0.026	≤40	80 – 120
Chloroform	0.0031	0.049	≤40	80 – 120
cis-1,2-Dichloroethene	0.0047	0.04	≤40	80 – 120
Dibromochloromethane	0.0062	0.085	≤40	80 – 120
Ethylbenzene	0.0032	0.043	≤40	80 – 120
Hexachlorobutadiene	0.0086	0.11	≤40	80 – 120
m,p-Xylene	0.0059	0.087	≤40	80 – 120
Naphthalene	0.0075	0.052	≤40	80 – 120
o-Xylene	0.003	0.043	≤40	80 – 120
Tetrachloroethene	0.0044	0.068	≤40	80 – 120
Toluene	0.0037	0.038	≤40	80 – 120
trans-1,2-Dichloroethene	0.0031	0.04	≤40	80 – 120
Trichloroethene	0.0042	0.054	≤40	80 – 120
Vinyl chloride	0.0041	0.026	≤40	80 – 120
4-Bromofluorobenzene	n/a	n/a	≤40	70 - 130

Notes:

$^{(A)}$ = Based on current laboratory control criteria. Some values may vary slightly between instruments

%R = Percent recovery

MDL = Method detection limit

mg/kg = milligram per kilogram

MRL = Method reporting limit

n/a = not applicable

RPD = Relative percent difference

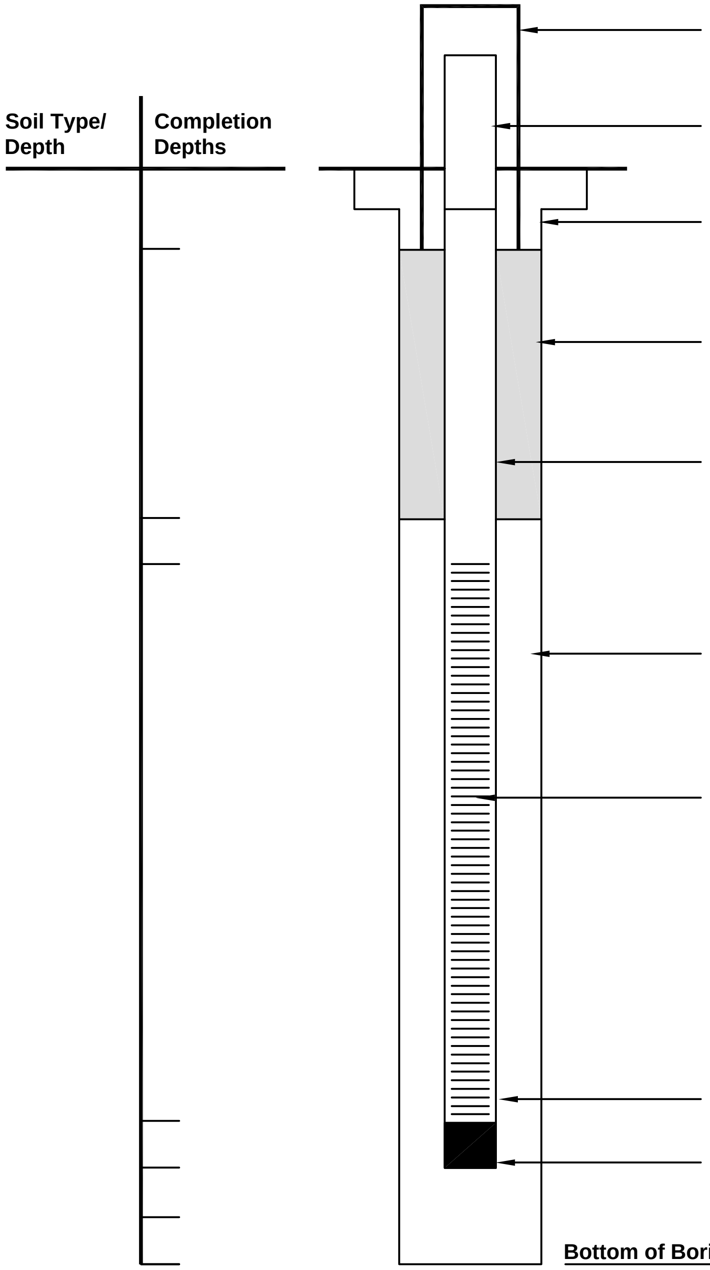
ATTACHMENT E-A

Aspect Field Forms

As-Built Well Completion Diagram

Project Number:	Boring/Monitoring Well Number: Sheet: of:
Project:	Location:
Elevation:	Drilling Contractor:
Drilling Method and Equipment Used:	Logged By:
Water Levels:	Completion Start: Finish:

Ecology Well ID ________________



Monument Type/Height ________________________________

Well Cap Type ________________________________

Surface Seal Material ________________________________

Seal Material ________________________________
(list NSF/ANSI certification)

Well Casing ID ________________________________

Type of Casing ________________________________

Type of Connection ________________________________

Filter Pack/Size ________________________________

Filter Pack Interval ________________________________

Well Screen ID ________________________________

Type of Screen ________________________________

Slot Size ________________________________

Screen Interval ________________________________

Centralizers ________________________________

Diameter of Borehole ________________________________

Sump ________________________________

Bottom of Boring ________________________________

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Materials Used:	Screen:
Sand:	Bentonite:
Blank:	Monument:
Concrete:	Other:

Q:_ACAD Standards\Standard Details\Well Diagram.dwg

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Field Staff:

DAILY REPORT

Date: **Project Name:** **Project Number:** **Weather:** **Arrival on site:** **Departure from site:**	Equipment used: Calibration:

Aspect
CONSULTING

Sample number ______________________________

GROUNDWATER SAMPLING RECORD

WELL NUMBER: _______ **Page:**____ **of** ____

Project Name: ____
Date: ________________________
Sampled by: ____
Measuring Point of Well:____
Screened Interval (ft. TOC)____
Filter Pack Interval (ft. TOC) _____________________________________

Project Number:____
Starting Water Level (ft TOC):___________________
Casing Stickup (ft):____________________________
Total Depth (ft TOC):___________________________
Casing Diameter (inches):_______________________

Casing Volume ___________ (ft Water) x ___________ (Lpfv)(gpf) = ___________ (L)(gal)

Casing volumes: 3/4"= 0.02 gpf 2" = 0.16 gpf 4" = 0.65 gpf 6" = 1.47 gpf
3/4"= 0.09 Lpf 2" = 0.62 Lpf 4" = 2.46 Lpf 6" = 5.56 Lpf

Sample Intake Depth (ft TOC):___________

PURGING MEASUREMENTS

Criteria:		Typical 0.1-0.5 Lpm	Stable	na	± 3%	± 10%	± 0.1	± 10 mV	± 10%	
Time	Cumul. Volume (gal or L)	Purge Rate (gpm or Lpm)	Water Level (ft)	Temp. (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH	ORP (mv)	Turbidity (NTU)	Comments

Total Gallons Purged: ______________________________ Total Casing Volumes Removed: ______________

Ending Water Level (ft TOC): ______________________________ Ending Total Depth (ft TOC):_______________

SAMPLE INVENTORY

Time	Volume	Bottle Type	Quantity	Filtration	Preservation	Appearance		Remarks
						Color	Turbidity & Sediment	

METHODS

Parameters measured with (instrument model & serial number):____

Purging Equipment: ____________________________________ Decon Equipment: ____________________________________

Disposal of Discharged Water: ____

Observations/Comments: ____

____

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BORING LOG

SHEET ______OF _______

LOCATION OF BORING	PROJECT NO. PROJECT NAME	BORING NO.

SKETCH OF LOCATION

DRILLING METHOD:

LOGGED BY:

DRILLER:

SAMPLING METHOD:

HAMMER WEIGHT/SAMPLER DIAMETER

OBSERVATION WELL INSTALL YES ______ NO ______

					START	FINISH
WATER LEVEL					TIME	TIME
TIME						
DATE					DATE	DATE
CASING DEPTH						

DATUM

GRADE ELEV.

SURFACE CONDITION

SIZE (%)									
GRAVEL	SAND (SIZE RANGE)	FINES	SAMPLE NO. / SAMPLE TYPE	SAMPLE DEPTH	INCHES DRIVEN / INCHES RECV'D	DEPTH IN FEET	PENETRATION RESISTANCE	USCS SUMMARY	DESCRIPTION: Density, moisture, color, minor, MAJOR CONSTITUENT. NON-SOIL SUBSTANCES: Odor, staining, sheen, scrap, slag, etc. DRILL ACTION
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			

Soil Vapor Port Sample Collection Form

Page ___ of ___

Project Name: ______________________ Address: ______________________ Aspect Project No.: ______________

Date: ______________________ Field Representative: ______________________

Brand and Model of Field Meters Used:

Photoionization Detector: ______________________

Multi-Gas Meter: ______________________

Helium Monitor: ______________________

Soil Vapor Sample Name:			Cannister ID:		Gauge ID:		
Shut-In Vacuum Test Readings			**Final Purge Readings**				
START	Time:	Vacuum (inches Hg):	PID (ppm)	CH_4 (%LEL)	CO_2 (%)	O_2 (%)	He (%)
END	Time:	Vacuum (inches Hg):					
Sampling Readings							
START			Sample Time Interval	END			
Helium Shroud: Y N (%)			Start:	Helium Shroud: Y N (%)			
Canister Vacuum (inches Hg):			End:	Canister Vacuum (inches Hg):			

Notes:

Soil Vapor Sample Name:			Cannister ID:		Gauge ID:		
Shut-In Vacuum Test Readings			**Final Purge Readings**				
START	Time:	Vacuum (inches Hg):	PID (ppm)	CH_4 (%LEL)	CO_2 (%)	O_2 (%)	He (%)
END	Time:	Vacuum (inches Hg):					
Sampling Readings							
START			Sample Time Interval	END			
Helium Shroud: Y N (%)			Start:	Helium Shroud: Y N (%)			
Canister Vacuum (inches Hg):			End:	Canister Vacuum (inches Hg):			

Notes:

Soil Vapor Sample Name:			Cannister ID:		Gauge ID:		
Shut-In Vacuum Test Readings			**Final Purge Readings**				
START	Time:	Vacuum (inches Hg):	PID (ppm)	CH_4 (%LEL)	CO_2 (%)	O_2 (%)	He (%)
END	Time:	Vacuum (inches Hg):					
Sampling Readings							
START			Sample Time Interval	END			
Helium Shroud: Y N (%)			Start:	Helium Shroud: Y N (%)			
Canister Vacuum (inches Hg):			End:	Canister Vacuum (inches Hg):			

Notes:

Last Updated 10/9/2018
KB

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WELL DEVELOPMENT RECORD

WELL NUMBER:

Project Name:
Date:
Developed by:
Measuring Point of Well:
Screened Interval (ft. BGS):
Filter Pack Interval (ft. BGS):

Project Number:
Starting Water Level (ft TOC):
Casing Stickup (ft BGS):
Total Depth (ft TOC):
Casing Diameter (inches):

Casing Volume: ft Water x gpf =
Casing volumes: 2" = 0.16 gpf 4" = 0.65 gpf 6" = 1.47 gpf

DEVELOPMENT MEASUREMENTS

Elapsed Time (min)	Cumul. Vol. (gallons)	Purge Rate (gpm)	Temp. (C or F)	pH	Specific Conductance (µmhos/cm)	Turbidity (NTU)	Imhoff Cone (ml/L)	Comments

Total Discharge (gallons):
Total Casing Volumes Removed (gallons):

Ending Water Level (ft TOC):
Ending Total Depth (ft TOC):

METHODS

Cleaning Equipment:
Development Equipment:
Disposal of Discharged Water:
Observations/Comments:

ATTACHMENT E-B

Aspect Field Standard Operating Procedures

Aspect
CONSULTING

FIELD NOTES

Provided below are general field documentation procedures for all environmental field staff. The Project Manager should discuss additional project-specific requirements with staff. Regardless of the documentation needs of the project, all written documentation of field tasks is discoverable as evidence and should be kept neat, professional and factual.

A field logbook or field form should be completed daily for each field job at each Site visited, regardless of the scope of work. Before field notes are provided to the Project Manager, all information should be accurate, complete and neat. The field staff shall sign or initial and date each page/sheet. At a minimum, field notes should include the following, as applicable:

- The times of arrival to and departure from the Site.
- Any unique weather conditions.
- Project name and project number.
- A list of all personnel on the job Site during the day, including contractors, sub-consultants, other consultants, clients, regulators, etc.
- A description, and general times for completion, of the activities conducted (however there is no need to duplicate information that may be provided on another field form, i.e. lithology type in a boring that is logged on a boring log or volume of groundwater purged from a well).
- A description of any unanticipated Site conditions.
- A description of any problems encountered and resolutions taken, including times and reasons for work delays.
- Rationale/description for any deviations from the Proposal, Work Plan, Sampling Plan, etc.
- A summary of equipment used (make, model and condition) and calibration information, if applicable (reference calibration log, if applicable).
- A description of waste generated (amount, type, container, location, etc.).
- A description of any photographic documentation of the site conditions and field work.
- A description of the samples collected and procedures to get the samples to the analytical laboratory.

Your field notes should be scanned to a PDF file and saved in the appropriate project folder with the other field documentation from the day. When all field documentation is complete, combine into a single PDF and send the link to the file to the PM.

X:\Aspect Forms\Field Forms\Field Procedures Guidance\Procedures_Field Notes.docx

GROUNDWATER SAMPLING

Field Procedures

Gauging Water Levels

- Decontaminate the water level meter tape and probe.
- Don the appropriate PPE as defined in the Site-specific Health and Safety Plan.
- Unlock and open the well monument and remove the well cap. Observe the well and document any damage to the monument, monument cover, or well cap in the daily field log.
- Remove any water that may have accumulated inside well monument using a hand pump (e.g. thirsty mate).
- Open the well and remove any dedicated equipment.
- Wait at least 30 minutes after opening/removing equipment to allow water levels to equilibrate to atmospheric pressure.
- Measure and record the depth to water from the marked reference point, or the north side of the well casing if no reference point is marked, to the nearest 0.01 foot.
- Record the time and water level measurement in a field logbook or on a field form. All times and water level measurements should be in one place (not on individual purge forms).

Low-Flow Purging and Sample Collection

Unless directed otherwise by the Project Manager or a site-specific work plan, all monitoring wells should be purged using the standard low-flow purge techniques[1]. The purging equipment will vary depending on the water level in the well and the screened interval.

- If using an aboveground pump, attach and secure the dedicated tubing to the sampling pump. Lower the tubing or, if using a submersible pump, the pump slowly into the well.
- Set the water intake (end of the tubing or pump intake) at the approximate middle of the saturated screened interval, unless directed otherwise by the Project Manager.
- Slowly lower the water level probe until it is just at the water surface and record initial water level on the purge form.
- Connect the discharge end of the tubing to a flow-through cell containing the water quality meter.

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[1] United States Environmental Protection Agency (EPA). 1996. Low Stress (low flow) Purging and Sampling Procedures for the Collection of Ground Water Samples from Monitoring Wells. Revision 2. July 30.

- Start pumping the well by selecting the lowest pump speed. Ideally, the pump rate should equal to the recharge rate with little or no water level drawdown in the well (total drawdown should be 0.3 foot or less).

- The maximum flow rate during purging should be 0.1 to 0.5 liters (100 to 500 milliliters) per minute. Measure the pumping rate using a graduated cylinder and stopwatch. Record the pumping rate and depth to water.

- Allow the flow-through cell to be "flushed" with purged groundwater twice. Monitor field parameters (temperature, pH, ORP, specific conductance and dissolved oxygen) in 3- to 5-minute intervals during purging, maintaining a consistent time interval for a single well.

- The well is considered stabilized and ready for sample collection when the indicator parameters have stabilized for three consecutive readings, as follows[2]:

    - ±0.1 for pH

    - ±3-percent for specific conductance

    - ±10-percent for dissolved oxygen

    - ±10mV for ORP

- If the recharge rate of the well is very low, do not purge the well dry. Lower the flow rate if the water level drops more than 0.3 foot or if air bubbles are observed in the purge stream. Do not lower the water intake. Turn off the pump and allow the well to recover before sampling.

- Once the field parameters have stabilized, disconnect the tubing from the flow-through cell in preparation for sampling. Gloves should be changed between purging and sampling.

- Samples should be collected by filling laboratory-supplied containers to the top. Samples for volatiles should be collected first - VOAs should be filled with no headspace or bubbles. For dissolved metals analysis, field filtering may be necessary prior to sample collection (check with your Project Manager).

- After samples have been collected, measure and record the final water level.

- Stop the pump and disconnect the tubing from the pump. Dedicated tubing can be left inside the well for future sampling events; secure the tubing so that it doesn't fall down the well.

- Close and lock the well.

- Once samples are collected, label each sample and record them on the COC form. Sample labels should be smudge-proof or covered with transparent tape. Place sample containers

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[2] In some cases, duration of purging may be appropriate to determine sampling. Contact the Project Manager if parameters do not stabilize after 1 hour of purging.

into a Ziploc bag and immediately put into an iced cooler for shipment to the laboratory. Segregate larger bottles with bubble wrap. Ice in coolers should be double-bagged to prevent leakage. Coolers should be paced to the top with bagged ice to prevent warming and bottle breakage.

Documentation

Daily field logbook or field notes
Water level summary form (or single logbook page/notes)
Groundwater Purge Form
COC copy

SOIL LOGGING & SAMPLING

Documentation

Field documentation for soil sampling varies depending on the type of work being conducted, but should include, at a minimum:

Daily field logbook or field notes (see Field Notes procedures)
Boring log/test pit log (see Soil Description guidance)

Field Procedures

Logging and Soil Descriptions

General soil logging procedures specific to drilling are provided here. These general procedures can also be applied to other types of soil explorations. Site-specific deviations should be discussed with the Project Manager. Soil classification will be addressed in a separate guidance.

- Visually classify the soils in general accordance with ASTM Method D 2488 and record soil descriptions in accordance with Aspect soil logging standards, field screening results, and other relevant details (e.g., staining, debris, odors, etc.) on the boring log.
- Record the total pounded/advanced length of core, the amount of soil recovery within that length, sampler type and diameter, and the blow counts and hammer weight or SPT data (if applicable), on the boring log.
- Note the location of each soil sample collected for potential chemical analysis, including the depth interval represented and the name, time of collection and number of sample containers. These can be noted on the boring log or in the field notes but do not need to be documented in multiple places.
- Document the depth to water at the time of drilling on the boring log, and make any notations about the observed conditions (odors, color, sheen, etc.) of the water on the boring log or in field notes.
- Note whether the water level was measured in an open hole or a cased hole, and if so, the depth of the casing at time of measurement.
- If applicable, document the temporary screened interval and specific depth of water intake (tubing, casing or pump intake) from which a grab groundwater sample is collected in the field notes.
- Document the total boring depth on the boring log.

Field Screening

Field screening procedures may vary from site to site depending on the investigation objectives. At a minimum, field screening of soil samples – whether collected from drilling samplers, test pits/excavations or stockpiles – should consist of the following.

- Visual examination – Observe the soil visually for staining and evidence of NAPL. If NAPL is observed, note its occurrence in the context of the soil lithology:
    - Sheen – as described below

    - Staining – Visible brown or black staining on soil. Can be visible as mottling or in bands. Typically associated with fine-grained soil.
    - Coating – Visible brown or black oil coating soil grains. Typically associated with coarse-grained soil.
    - Oil wetted – Visible brown or black oil wetting the soil. Oil appears as a liquid and is not held by soil grains.
- Olfactory – Observe and document any odor associated with the soil sample. Unless confident in contaminant odor identification, all odor notations should be described as contaminant-**like** (e.g. petroleum-like odor). Odors can be quantified as slight or strong, if applicable.
- Volatile organic vapor screening – Measure and record the volatile organic vapors present in the headspace of each soil sample using a photoionization detector (PID).
    - After collecting soil in laboratory-supplied containers for chemical analysis, as described below, place remaining soil into a disposable plastic bag, seal, and gently shake.
    - Let the bag sit for at least 2 minutes.
    - Open or puncture the bag (do not use the tip of the PID, as it may become clogged with plastic from the bag, and do not use the tip of a pen, as the ink may contain volatile compounds) and insert the tip of the PID into the headspace in the Ziploc bag.
    - Record the PID reading.
- Water Sheen Test – Test and observe water for the presence of sheen.
    - Place approximately 1 Tablespoon of soil into disposable container or a black-plastic gold plan that is approximately ¼ full of water. For gravel, you may need to use 4 Tablespoons of soil in a larger container that is approximately ¼ full of water.
    - Observe the water surface and sidewalls of the jar for signs of sheen, according to the nomenclature below.
    - Gently agitate the soil and record observations. Naturally-occurring sheen will dissolve or break-up upon agitation. If only naturally-occurring sheen is observed, the recorded observations should be “No Sheen”.
    - Sheen nomenclature:
        - No Sheen (NS) – no visible sheen on water surface.
        - Slight Sheen (SS) – light, colorless or dull sheen on water. Spotty to globular; spread is irregular, not rapid; areas of no sheen remain; sheen dissipates rapidly.
        - Moderate Sheen (MS) – light to heavy sheen. May have some color or iridescence, globular to stringy; spread is irregular to flowing; few remaining areas of no sheen on water surface.
        - Heavy Sheen (HS) – Heavy colorful film with iridescence. Spread is rapid; sheen flows off the sample; most of water surface covered with sheen.
        - Organic Sheen (OS) – Blocky, irregular sheen with little or no color. Where petroleum sheen is fluid looking and flowy, organic sheen is square and moves across the surface of the water very little, if at all.
    - If observed, quantify the spatial coverage (as % of total water surface), size/diameter and color of NAPL blebs.

The results of field screening activities should be recorded on the boring log when samples originate from a drilling sampler, on a test pit log or in the field logbook/field forms for other excavation or stockpile sampling.

Soil Sample Collection

As with field screening, soil samples can be collected from drilling samplers, excavator buckets, test pit sidewalls and stockpiles using variable methods. The general procedures described below should be used when collecting soil samples from a potentially-contaminated site for chemical analysis.

- Gloves should be changed between collection of each soil sample.
- If collecting soil for VOC analysis (EPA 5035A), use the laboratory-provided, dedicated sampling syringe to collect approximately 5 grams of soil from an undisturbed soil surface and insert the soil into the 40-mL VOA vial (see Ecology Technical Memoranda #5). Quickly brush off the vial threads and seal immediately with the screw cap.
- From the same soil surface, use a freshly-gloved hand or a decontaminated stainless-steel spoon/hand shovel to collect the rest of the soil into laboratory-prepared sample jars. Fill the jars as full as possible, brush off the jar threads and seal immediately with the screw cap.
- Once sample collection is complete, label each sample and record them on the COC form. Sample labels should be smudge-proof or covered with transparent tape. Place sample containers into a Ziploc bag and immediately put into an iced cooler for shipment to the laboratory. Segregate VOA vials from sample jars. Ice in coolers should be double-bagged to prevent leakage. Coolers should be paced to the top with bagged ice to prevent warming and bottle breakage.

Grab Groundwater Sample Collection

The collection of grab groundwater samples will usually be facilitated by the driller. Once groundwater is encountered and a screened interval is agreed upon, the driller will install a temporary well screen. The driller will install tubing and/or a pump and start purging water from the screen. The general grab groundwater sample collection procedures are as follows:

- Allow the pump to purge at a low-flow rate (100- to 500-mL per minute) until turbidity is reduced as much as possible (i.e., further pumping does not visibly improve groundwater quality).
- Once turbidity stabilizes, measure and record field parameters (check with the Project Manager, this step may be skipped for some projects).
- Gloves should be changed before collecting the sample.
- Fill all sample bottles by allowing the pump discharge to flow gently down the inside of the bottle with minimal turbulence. Samples for volatile analysis should be collected first. VOAs should be filled to just overflowing so that no air bubbles are entrapped inside. Other containers should be filled to nearly the top and capped thereafter.

- Once container filling is complete, label each sample and record them on the COC form. Sample labels should be smudge-proof or covered with transparent tape. Place sample containers into a Ziploc bag and immediately put into an iced cooler for shipment to the laboratory. Segregate larger bottles with bubble wrap. Ice in coolers should be double-bagged to prevent leakage. Coolers should be paced to the top with bagged ice to prevent warming and bottle breakage.

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Field Guidance for Installing and Sampling Sub-Slab Soil Gas Using Vapor Monitoring Points

1 Sub-Slab Soil Vapor Point Installation and Sampling Procedures

The purpose of this Field Guidance Procedure Field Guidance Procedure is to provide field personnel with an outline of the specific information needed to collect and document representative sub-slab soil gas samples. The recommended sub-slab soil gas sampling technique, as presented in this Field Guidance Procedure, is based on the assumption that soil gas samples should be representative of chemicals that may volatilize from the uppermost aquifer into the vadose zone.

1.1 Equipment and Materials

Temporary Installation

The following equipment and materials are required for temporary Vapor Pin™ installation:

- Rotary hammer drill.
- 5/8-inch diameter drill bit.
- 1½-inch diameter drill bit.
- ¾-inch diameter bottle brush.
- Wet/dry vacuum.
- Extension cord.
- Generator (if no power is available on site).
- Assembled Vapor Pin™.
- Vapor Pin™ installation/extraction tool.
- Dead blow hammer.
- VOC-free hole patch material (hydraulic cement) and putty knife, for hole repair after sampling.
- Appropriate personal protective equipment (PPE).

Permanent Installation

The following equipment and materials are necessary for permanent AMS vapor point installation:

- Rotary hammer drill with a 1-inch and a 2-inch carbide tipped bit.
- Extension cord and generator (if no power outlets are available).
- 3-inch (length) stainless steel (SS) screen assembly with locking cap (AMS GVP probe assembly or equivalent).
- Hose barb, stainless steel (1/4-inch).
- Teflon® tape.

- 100% Beeswax, to seal vapor port borehole annulus.
- Quick Set Concrete Patch, to seal vapor port borehole annulus.

Sample Collection

The following equipment and materials are necessary to properly conduct sub-slab soil gas sampling (see Figure 1):

- Air pump and appropriate ¼-inch fluoropolymer and silicone #15 connection tubing, tee fittings, valves, and flow metering device for purging and sampling vapor ports.
- Sufficient number of Summa canisters with appropriate flow controllers.
- Equipment required for collection of samples using Summa canisters, including appropriate wrenches and pressure gauges.
- An accurate and reliable watch that has been properly set.
- A calculator.
- Field notebook, applicable sampling analysis plan, and Chain of Custody.
- Health-and-safety equipment and supplies (e.g., personal protective equipment [PPE]) as described in the relevant site health-and-safety plan (HSP).
- Shipping package for the Summa canisters.

Leak testing equipment and materials include:

- Syringe or vacuum pump for shut-in testing.
- Leak test shroud of sufficient size to cover soil gas vapor probe or vapor pin.
- 1-liter Tedlar® bags to collect purged vapors and test for tracer gas (helium).
- A soft gasket to seal the leak test shroud to the floor.
- Tracer gas (helium).
- Flow regulator with 1/8-inch barbed outlet and tubing to connect the helium gas cylinder to the shroud.
- MGD-2002 helium meter or equivalent.

1.2 Sub-Slab Soil Vapor Point Installation

Temporary Installation

Use the following steps to install Vapor Pins™:

- Prior to beginning, clear sampling locations for utilities, verify access agreements are in place, and obtain required permits, as appropriate.
- Set up wet/dry vacuum to collect drill cuttings.
- Drill a 5/8-inch diameter hole through the slab and approximately 1-inch into the underlying soil (if present).
- Remove the drill bit, brush the hole with the bottle brush, and remove loose cuttings with the vacuum.
- Place the lower end of the Vapor Pin™ assembly into the drilled hole. Unscrew the threaded coupling from the handle of installation/extraction tool, place the small hole located in the handle of the installation/extraction tool over the Vapor Pin™ to protect the barb fitting/cap, and tap the Vapor Pin™ into place using a dead blow hammer. Make sure the installation/extraction tool is aligned parallel to the Vapor Pin™ to avoid damaging the barb fitting.

Permanent Installation

Prior to sampling, it is recommended that the sub-slab vapor point be installed at least one day in advance to allow the seal to set up properly. However, the use of quick-setting concrete will allow for same day sampling if desired.

- Prior to beginning, clear sampling locations for utilities, verify access agreements are in place, and obtain required permits, as appropriate.
- Drill a 2-inch borehole to a depth of approximately 3 inches.
- Drill a 1-inch borehole through the center of the 2-inch borehole through the floor slab of the building foundation to a depth of approximately 12 inches below the surface.
- Construct the vapor point as shown in Figure 1 and insert such that the top of the assembly is set approximately 1/8-inch below the top of the slab.
- Seal the vapor port by melting the beeswax with a small butane torch. Pour the beeswax from the rubber plug up to the bottom ½-inch of the 2-inch borehole.
- Allow beeswax to solidify and harden.
- Mix Quick Set concrete patch and apply from top of beeswax seal to within ¼-inch of the top of the slab.

1.3 Sampling Procedure

Sample Train Assembly

Assemble sampling train. The sampling train will be set up so that the Summa canister is in-line between the vapor port and the air pump, with a valve between the canister and the pump (see Figure 1):

- Verify the Summa canister number engraved on the canister matches the number listed on the certified clean tag to insure proper decontamination of the canister was completed. Fill out the sample tag.
- Verify the canister valve is closed tightly and remove the threaded cap at the inlet of the canister.
- Attach the flow controller to the inlet of the canister; the flow controller will have a built in pressure gauge.
- Connect the tubing from vapor port to inlet of a ¼-inch tee fitting.
- Connect the Summa canister/flow controller to one outlet of the tee fitting.
- Connect air pump to the other outlet of the tee fitting, insert a ¼-inch shutoff valve between the tee fitting and the air pump.

Leak Testing

Where leak testing is required, shut-in testing of the sample train will be conducted to test the sample train (excluding the vapor point) for leaks. A shroud containing tracer gas will be used to test the vapor point. The shroud consists of a plastic PVC cap or equivalent. Three holes will be drilled near the top of the shroud; one for connection of the helium gas cylinder, one for connection of the helium gas meter, and one for connection of the sample train located outside the shroud (see Figure 1).

- Before purging or sampling begins, assemble the sample train and vapor shroud. Crimp or plug the silicon tubing connection at the vapor point.
- Attach either a syringe or vacuum pump to the downstream end of the purge point valve. Draw a vacuum of at least 15 inches of mercury and shut the valve.
- The sample train should hold vacuum for 5 minutes. If the gauge vacuum decreases during this time period, check/tighten all connections and retest.
- After successful shut-in test, remove the crimp or plug and attach to the vapor point. The tubing from the tee connection above the canister will pass through the wall of the shroud to connect with the air pump outside.
- Connect the helium cylinder to the leak test shroud using tubing from the flow regulator on the cylinder, through a hole in the top of the shroud.
- Connect the helium meter to the leak test shroud.
- Use the flow regulator to slowly release helium into the leak test shroud until a concentration of 100% helium is contained within the shroud. The helium

concentration will be measured using the helium meter. Maintain helium concentrations throughout the purging and sampling period by continuously bleeding cylinder gas into the shroud as needed.

Sample Collection

Prior to collecting the canister sample, the vapor port will be purged as described below. If leak testing is performed with helium, purged vapor contained in the Tedlar® bags will be field screened using the helium meter to ensure that the concentration of helium inside the bags is less than 5 percent of the shroud concentration. If leakage is detected, the vapor port seal will be enhanced and connections will be inspected and tightened. This process will be repeated until no significant leakage has been demonstrated.

- Purge the vapor port and sampling train at approximately 100-200 ml/min using the air pump to ensure the sample is representative of subsurface conditions. Capture purged vapor in 1-liter Tedlar® bags at the outlet of the air pump and release the vapor outdoors. Three-to-five tubing volumes should be removed. If the slab is greater than 6-inches thick, the borehole volume should also be purged. Use the following equation to calculate volume to be purged:

  $$\mathbf{V = (\pi \times r_t^2 \times l_t) + (\pi \times r_h^2 \times l_h)}$$

  Where:

  V = Volume of tubing and sampling train (cubic inches)
  π = 3.14

  r_t = the inner radius of the tubing[inches]

  l_t = the length of the tubing [inches]

  r_h = the inner radius of the hole in the slab beneath vapor pin (inches)

  l_h = the length of the hole in the slab beneath vapor pin (inches)

- Convert to ml using 1-inch^3 = 16.387 ml to determine purge volume, then divide it by the pumping rate to determine purge time for one volume.
- If leak testing is performed with helium, purged soil gas collected in the Tedlar® bag will be field screened using the tracer gas (e.g., helium) using handheld meter to ensure that leakage is less than 5 percent of the shroud concentration.
- Begin sample collection by closing the ¼-inch shutoff valve between the Summa canister and the air pump and opening the valve on the Summa canister. Immediately record the pressure on the gauge as the “initial pressure” on the tag attached to the canister.
- After sampling begins and the apparatus is verified to be operating correctly, leave the canister to fill.
- Record all sample information in the field book and applicable field forms including the following:
  - Canister number and sample identification,
  - Weather including barometric pressure,

  - Purge time and purge volume, Sample start date and times,
  - Location of sample (distance from walls shown on building floor plan),
  - Initial and final pressure of canister, and
  - Notes regarding leak test, if applicable.
- Monitor canisters continuously to ensure proper operation. It is necessary to check the canister prior to completion because the accuracy of the flow regulators can vary, causing the canisters to fill faster than expected. The final pressure at the end of sampling should be approximately -5 inches mercury (Hg). If the canister has already reached this point, sampling is complete, the canister valve should be closed, and the pressure recorded as the "final pressure" on the sample tag, the field book, and applicable field forms. Sample collection will be considered complete, regardless of final pressure, after the stated sample period has elapsed.
- Record the exact pressure of the canister and time at the end of sampling on the sample tag for that canister, in the field book, and on the applicable field forms.
- Verify that the canister valve is closed tightly, remove the flow controller, and replace the threaded cap at the top of the canister. Discard all sample tubing.
- Replace the vapor point cap using Teflon tape to seal the threads if permanently installed. If using temporary vapor pints, remove them from the hole using the manufacturer-suppled extraction tool. The hole in the slab must be filled with hydraulic cement, fast-cure epoxy, or similar.

Post-Sample-Collection Procedures

Pack all Summa canisters in the original shipping containers, sealed with a custody seal, and send to the lab for analysis. The official holding time for this analysis is 30 days. However, attempt to get samples to the lab as soon as possible to allow lab time to conduct re-runs, dilutions, and low-level analyses, as necessary prior to sample expiration.

Analysis

The soil gas samples should be analyzed using EPA Methods TO-15, and when necessary/possible, low-level analysis or Selective Ion Mode (SIM) analysis to obtain the lowest achievable detection and reporting limits. When leak testing is performed, samples should additionally be analyzed for helium. Other analysis will be included on a project-specific basis. Note the desired analytical methods on the Chain-of-Custody form and be sure analysis for helium is specified for leak-tested samples.

Decontamination

Temporary vapor points must be decontaminated prior to re-use. Decontamination procedures include Alconox® wash, deionized water rinse, and heated in an oven to 130C for 30 minutes.

The Summa canisters will be individually cleaned and certified to 0.02 ppbv THC for the project-specific analyte list by the contract laboratory prior to shipment. Ensure that documentation of this certification is included on a tag attached to the canister and in the paperwork that accompanies the canister shipment from the lab.

Documentation

Label all sample containers with the following information: sample identification, date and time sample was collected, the starting and ending canister pressure, the site name, and the company name.

Include all this information in the field book plus the ending time of sample collection and transfer pertinent information to the Chain-of-Custody record. Record all field activities, environmental and building conditions, and sample documentation on the appropriate field forms and field notebook.

2 Related Field Guidance Documents

Related field guidance documents that may be relevant for completing field sampling are listed below.

- Field Notes
- Indoor Air Sampling
- Soil Gas Sampling Using Sorbent Tubes
- Sample Handling

3 References

Department of Environmental Protection, Commonwealth of Massachusetts, Indoor Air Sampling and Evaluation Guide, WSC Policy #02-430, Boston, Massachusetts, April 2002.

EPRI, Reference Handbook for Site Specific Assessment of Sub-Surface Vapor Intrusion to Indoor Air, March 2005.

New Jersey Department of Environmental Protection, Vapor Intrusion Guidance, October 2005.

New York State Department of Health, Guidance for Evaluation Soil Vapor Intrusion in the State of New York, October 2006.

USEPA, Center for Environmental Research Information, Office of Research and Development, Compendium of Methods for Determination of Toxic Organic Compounds in Ambient Air, Second Edition, Compendium Method To-14A, Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography, January 1999.

USEPA, Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway Form Groundwater and Soils, EPA530-F-02-052, November 2002.

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APPENDIX F

LNAPL Transmissivity Workbook (API, 2016)

API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis

User Guide

API PUBLICATION 4762
APRIL 2016

AMERICAN PETROLEUM INSTITUTE

API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis

User Guide

Regulatory and Scientific Affairs

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Foreword

Suggested revisions are invited and should be submitted to the Director of Regulatory and Scientific Affairs, API, 1220 L Street, NW, Washington, DC 20005.

PREFACE

LNAPL transmissivity provides a useful measure of potential hydrocarbon liquid mobility within the subsurface environment. The magnitude of LNAPL transmissivity is being accepted as a metric for hydrocarbon recovery system performance and determination of technology-specific endpoints. Baildown tests are a simple method for estimating LNAPL transmissivity. This manuscript describes a spreadsheet tool that can be used to analyze results from baildown tests.

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LIST OF SYMBOLS

b_n	LNAPL thickness in well
b_{nR}	initial LNAPL thickness in well (same as at radius of influence)
b_{nW}	limiting effective LNAPL thickness in well (see Appendix F)
DZ_{12}	depth to top of perching layer
$F(\ )$	Cooper, Bredehoeft and Papadopulos slug test function
$G(\ )$	Jacob-Lohman free-flowing discharge function
h_n	LNAPL head
J	Kirkman J-ratio (see Appendix B)
L_e	initial LNAPL column height (contacting screen) in well
N	number of increments
Q_n	LNAPL discharge
Q_{ni}	LNAPL discharge at time t_i
R	radius of influence
r_c	radius of casing
r_e	effective well radius
$r_{e(i)}$	effective well radius at time t_i (varies with LNAPL column location in well)
r_w	well borehole radius
S	coefficient of storage
s_n	LNAPL drawdown
S_n	LNAPL storage parameter
s_{ni}	LNAPL drawdown at time t_i
S_y	LNAPL specific yield
T	transmissivity
t_i	time epoch
T_n	LNAPL transmissivity
V_n	LNAPL volume
$W(\ )$	Theis well function
z_{an}	elevation of air-LNAPL interface in well
z_{nw}	elevation of LNAPL-water interface in well
Δs_n	LNAPL drawdown correction
Δt_a	time adjustment factor
ρ_r	LNAPL-to-water density ratio

ACRONYMS

BOS	Bottom of Screen
B&R	(generalized) Bouwer and Rice method
CSM	Conceptual Site Model
C&J	Cooper and Jacob method
CB&P	Cooper, Bredehoeft and Papadopulos method
CV	Coefficient of Variation
DTP	Depth to Product
DTW	Depth to Water
ITRC	Interstate Technology Regulatory Council
LNAPL	Light Non-Aqueous Phase Liquid
SOP	Standard Operating Procedure
SSD	Sum-Square-Difference
TOS	Top of Screen

API LNAPL Transmissivity Workbook:
A Tool for Baildown Test Analysis—User Guide

1. Introduction

LNAPL transmissivity is a measure of lateral mobility of free-product hydrocarbon liquid within the groundwater environment. The magnitude of LNAPL transmissivity has been suggested as a possible endpoint criterion for LNAPL mass removal using LNAPL hydraulic recovery systems (ASTM E 2531-06 [Tbl X5.1], 2006; ITRC, 2009). Such hydraulic recovery systems include skimmer wells, single-pump wells, dual-pump wells, and trenches. Coupled with the LNAPL CSM, the magnitude of LNAPL transmissivity will assist in the selection of recovery system. As such, methods and their consistent application for estimating LNAPL transmissivity are significant. Perhaps the simplest methods for estimating LNAPL transmissivity are borehole slug test methods, or baildown tests, in which a volume of LNAPL is rapidly removed from a well and the rate of fluid-level recovery (water and LNAPL) is measured and analyzed. Several analytical methods are available to analyze the data from baildown tests to estimate LNAPL transmissivity and described herein. A more general discussion of LNAPL transmissivity measurement is provided by ASTM (2011).

Following a brief description of suggested well configuration, pre-test and test measurements and methods, application of the spreadsheet tool is discussed. Subsequent sections provide a more detailed discussion of significant parameters and basis for the various analysis procedures. A number of example applications are presented. Further details on the different methods are provided in the appendices. Noteworthy is the introduction of the J-ratio (*J*) described in Appendix A, which appears to render discussions over preference between Lundy and Zimmerman (1996) versus Huntley (2000) methods moot.

2. Well Configuration Data

The following well configuration data should be gathered for baildown test analysis:

1. Elevation of ground surface. This generally serves as the datum with elevations specified as depth below ground surface, bgs. Elevations presented with the geologic log are generally expressed as depth bgs. If data are not conveniently available (or necessary), enter 0 on the spreadsheet.
2. Elevation of top of casing (depths to fluid levels are usually measured from top of casing). If data are not conveniently available (or necessary), enter 0 on the spreadsheet.
3. Well casing radius, r_c (ft).
4. Well borehole radius, r_w (ft).
5. Depth of top of screen (ft bgs). The top of screen can be interpreted to be the top of screen or filter pack, depending on the well construction and gauged fluid levels, and it is

up to professional judgment to correctly select between these. If data are not conveniently available (or necessary), enter 0 on the spreadsheet.

6. Depth of bottom of screen (ft bgs). If data are not conveniently available (or necessary), enter 0 on the spreadsheet.

3. Pre-Test Data

Certain data should be gathered before performance of the baildown test, in order to establish and verify initial conditions. The depth to product (DTP) and depth to water (DTW) should be measured over a period equal to the expected test duration; if the test duration is unknown then use of historic hydrograph data and gauging 8 hours before the test would provide a basic level of understanding for equilibrium conditions. The DTP and DTW should then be measured immediately before start of the test to confirm that fluid levels are stable and in equilibrium. The best practice to confirm equilibrium fluid levels is to gauge the well until it fully recovers as discussed in ASTM E2856-11, Section 6.1.4.16 (2011). Additionally, when conditions allow, it is useful to remove LNAPL from the well during a period before the test (e.g. within one month) to confirm equilibrium contact between formation and well hydrocarbon liquid. This is necessary especially if standing LNAPL is observed or LNAPL has not been recovered from a well for a while. Baildown tests are analyzed by slug test methods modified for two fluids, and it is important that formation and well fluids are in equilibrium. If tidal fluctuations are present the DTP and DTW must be measured regularly for at least a week leading up to the test. In any case it is imperative that the LNAPL/water interface should be positioned across the well screen for confined LNAPL conditions, or the air/LNAPL interface for perched LNAPL conditions, if not both the interfaces.

4. Baildown Test Procedures and Data

In performance of a baildown test a volume of hydrocarbon liquid is rapidly removed from the well and the DTP and DTW are measured as a function of time during the fluid recovery period. Fluid recovery rates generally vary logarithmically, so measurements should be taken more frequently during the initial period following hydrocarbon removal, and the measurement frequency decreases during the later period of the test. The ASTM standard E2856-11 provides a thorough procedure for conducting baildown tests, however, a brief description of significant features are provided below:

- Initial hydrocarbon liquid removal should be rapid. Commercial peristaltic pumps (such as Spill Buddy ™) are preferred since the pump intake can be located to remove only hydrocarbon liquid during the baildown stage. If a bailer is used then additional precautions are necessary to minimize fluid disturbance during LNAPL removal. If removal of larger LNAPL volumes is required, then vacuum trucks can be used, recognizing that significant volumes of water may be removed in addition to LNAPL.

- Following the baildown stage of hydrocarbon liquid removal, the DTP and DTW are measured as a function of time. Measurements can be taken using interface probes (optical and electrical resistivity), and data are recorded as depth (feet) below top of casing.
- In general, the interface depth measurements are taken more frequently during the initial recovery period, and the frequency decreases as recovery proceeds. If recovery rates are too rapid for (near) simultaneous measurement of DTP and DTW, then a pressure transducer can be placed below the LNAPL-water interface and connected to a data-logger. In this case only the DTP need be measured, and such measurements combined with the data-logger record and LNAPL density can be used to calculate the DTW at desired time intervals.
- When possible, recovery monitoring should continue until essentially complete LNAPL recovery is achieved. In low LNAPL transmissivity locations, time requirements might be excessive and early termination will be necessary. Nearly full recovery is especially important for confined and perched LNAPL conditions, to help verify the site conceptual model for the test.
- A record of 20 to 30 measurements (each for DTP and DTW) is generally adequate for data analysis. When possible, these data should be evenly spread in terms of recovery volume. [For example, if the initial LNAPL thickness in a well is 4 ft and the LNAPL thickness after baildown is 0.5 ft, then measurements might be taken when the LNAPL thickness roughly has the following sequence of values: 0.50, 0.52, 0.54, … 3.90, .. ft.]

5. Post-Test Data

LNAPL transmissivity value from a baildown test is estimated based on measurement of LNAPL drawdown and recharge to the well as a function of time, along with a conceptual site model that can include geologic log and well configuration data to identify possible unconfined, confined, or perched LNAPL conditions. Estimation of formation discharge (well recharge) is based on changes in DTP and DTW values. Changes in fluid levels in the well compared with screen elevations determine the effective storage associated with the well. This storage can include only the casing volume or the casing volume plus some fraction of the pore space of the filter pack that has been drained of LNAPL during the baildown stage of the test. This latter case becomes more complicated, depending on the fluid levels versus the well screen interval, since only part of the LNAPL column in the well may be in contact with the screened interval of the well. These issues are discussed in more detail in Appendix B with regard to estimation of the effective well radius, r_e.

The post-test data that must be calculated include estimation of LNAPL drawdown (s_n) and well discharge (Q_n) as a function of time, and this in turn depends on the effective well radius value along with DTP and DTW measurements.

The LNAPL drawdown is measured based on the DTP, along with any correction that is applied to account for initial non-equilibrium between formation and wellbore LNAPL. Specifically, the drawdown corresponding to time t_i is calculated using

$$s_{ni} = DTP_i - DTP_0 - \Delta s_n \tag{5.1}$$

In Eq. (5.1) DTP_0 is the initial (pre-test) depth to product and Δs_n is a possible LNAPL drawdown correction as discussed below.

The LNAPL discharge from the formation to the well is calculated based on the effective well radius ($r_{e(i)}$) and changes in DTP and DTW over time. Once the effective well radius has been determined, the well discharge from time t_i to time $t_{\mathrm{i}+1}$ is calculated using the following equation:

$$Q_{ni} = \pi\, r_{e(i)}{}^2 \left(DTP_i - DTP_{i+1} + DTW_{i+1} - DTW_i\right) \big/ \left(t_{i+1} - t_i\right) \tag{5.2}$$

This equation accounts for the increase in LNAPL storage volume over the time interval, and specifically identifies that the effective well radius might not be constant (such as a change from well casing storage to casing/screen plus filter pack storage).

6. Overview and General Discussion: Analysis of LNAPL Transmissivity Baildown Test Data

This section briefly summarizes methods for analysis of LNAPL transmissivity baildown test data. Additionally, use of time cutoff and time adjustment to eliminate early-time data influenced by filter pack drainage or other factors is discussed, and a default method for estimation of LNAPL storage coefficient is described. Finally, a flowchart that outlines the LNAPL transmissivity estimation process using this workbook is presented.

6.1. Methods for Estimating LNAPL Transmissivity

Among the variety of methods suggested in the literature for analysis of slug test data, three different methods are presented here for analysis of unconfined LNAPL transmissivity baildown tests. These three methods are designated through their original presentation in the literature as follows:

B&R -	Bouwer and Rice (1976)
C&J -	Cooper and Jacob (1946)
CB&P -	Cooper, Bredehoeft and Papadopulos (1967)

LNAPL baildown tests are inherently transient, meaning that fluid levels and flow rates change with time. Experience with transient aquifer tests suggests that at least two parameters are necessary to describe system performance. With a conventional pumping test one estimates the aquifer transmissivity and storage coefficient. For LNAPL baildown test analysis, both parameters are also necessary, though only the LNAPL transmissivity is of direct interest.

The Bouwer and Rice (B&R) method is conceptually the simplest. The method uses a linear model (Thiem equation) to relate LNAPL discharge to LNAPL drawdown, and is based on continuity of LNAPL volume within the well. LNAPL drawdown versus time data are used to determine the LNAPL transmissivity, based on an estimate of the well radius of influence provided through the empirical analysis presented by Bouwer and Rice (1976). Interesting questions remain in the literature between the applications of the B&R method for LNAPL baildown testing as presented by Lundy and Zimmerman (1996) and Huntley (2000). These approaches differ in terms of assumed fluid levels in the well during recovery. The Huntley method assumes that the water table elevation remains constant during the recovery period. The Lundy method, which proposes removal of a small slug of LNAPL from the well, assumes that the depth to water remains constant during the recovery period. This difference in assumptions results in the Huntley method including an additional factor $1/(1 - \rho_r)$ in the calculation of LNAPL transmissivity, where ρ_r is the LNAPL-water density ratio. For many LNAPL transmissivity baildown tests, neither assumption is observed. For the general case, Andrew Kirkman (personal communication) suggests introduction of the J-ratio parameter that is directly based on measured data to address this issue. The Kirkman J-ratio is described in Appendix A and the J-ratio method is used herein for both the B&R, and the CB&J methods. The magnitude of the J-ratio is determined by the user using Fig. 4 on the “Figures” worksheet. The B&R method is developed in Appendix C.

The Cooper and Jacob (C&J) method provides an estimate of the LNAPL transmissivity based on the LNAPL discharge to the well and LNAPL drawdown, as a function of time. The method also requires estimation of an LNAPL storage coefficient. Guidance on suggested magnitudes of the LNAPL storage coefficient is provided for the user. The C&J method is developed in Appendix D.

The Cooper, Bredehoeft and Papadopulos (CB&J) method provides an estimate of the LNAPL transmissivity based on measurements of LNAPL drawdown versus time. The method also requires an estimate of the LNAPL storage coefficient. The CB&P method does not directly use the LNAPL discharge to the well, and it does require an estimate of the effective initial LNAPL drawdown. The CB&P method is developed in Appendix E.

LNAPL can also be found under confined or perched conditions. Methods based on the Bouwer and Rice method of analysis are developed for confined and perched LNAPL in Appendices F and G, respectively.

Discussion

There is no *a priori* preferred method for analysis of LNAPL baildown test data. The B&R method is good for long well purging events, whereas relatively instantaneous events are used with the C&J and CB&P methods because they incorporate transient storage effects. The B&R method is independent of absolute time; rather, just the slope of the log-normalized drawdown versus change in linear time is important. However, if a straight line is not observed with B&R and it concaves upward (as a result of storage effects), then C&J or CB&P are more able to account for the effects attributed to storage. Absolute time is critical for both C&J and CB&P, and thus it is necessary to adjust the effective time origin when early-time data is eliminated because of filter pack drainage. With the B&R method, the well radius of influence is estimated using well configuration data based on analog simulation analysis described by Bouwer and Rice (1976) for flow of groundwater to a well in an unconfined aquifer. This relationship is assumed to hold for LNAPL. The C&J method is based on an approximate solution describing flow of groundwater to a well under conditions of constant discharge and variable drawdown, and constant drawdown and variable discharge. The relationship is also assumed to apply to flow of LNAPL to a well when both the LNAPL discharge and LNAPL drawdown vary with time. The CB&P method is based on an analytical solution for a slug test in a confined aquifer, and is assumed to apply for LNAPL under unconfined conditions. With the CB&P method, both the effective initial drawdown and LNAPL storage coefficient must be estimated along with the LNAPL transmissivity. Because the CB&P method does not directly consider data regarding LNAPL discharge to the well, it is possibly the most uncertain method of analysis. Nevertheless, when properly applied, the user can often estimate LNAPL transmissivity value with coefficient of variation (ratio of the standard deviation to mean value) of 20 % or less when considering analyses using all three methods.

6.2. Time Cutoff and Time Adjustment

Early-time data from baildown testing may be significantly impacted by filter-pack drainage or other effects that do not reflect LNAPL flow from the formation to the well during recovery. Such data may be eliminated by specifying a cutoff time. Data from times earlier than the cutoff time are not considered in estimation of LNAPL transmissivity. The cut-off time may be used with the B&R, C&J, and CB&P methods. The B&R method does not depend on the time origin, so no further adjustments are necessary. However, both the C&J and CB&P methods include an LNAPL storage coefficient as a parameter, which represents a capacitance factor, and time origin is significant to the theoretical model. For the C&J method a time adjustment of the apparent time origin may be applied. One may think of the Time Adjustment as accounting for the delay in LNAPL flow from the formation to the well associated with the duration of significant filter-pack drainage. Limited experience suggests that the Time Adjustment and Time_{cut} may be related through the following: Time Adjustment = (0.6 or 2/3) * Time_{cut}. The effects of Time_{cut} and Time Adjustment are shown in Figure 6.1. In this figure, it is desired to eliminate data earlier than 25 minutes because of effects from filter-pack drainage (Time_{cut} = 25 minutes); for a discussion of how this 25-minute Time_{cut} was selected, see discussion leading to Fig. 7.4 below. A Time Adjustment = 15 minutes is applied for analysis of LNAPL transmissivity using the C&J method, meaning that the apparent time origin for data later than 15 minutes is shifted as shown. For the CB&P method, one simply uses the estimated drawdown at the Time_{cut} as the initial drawdown value.

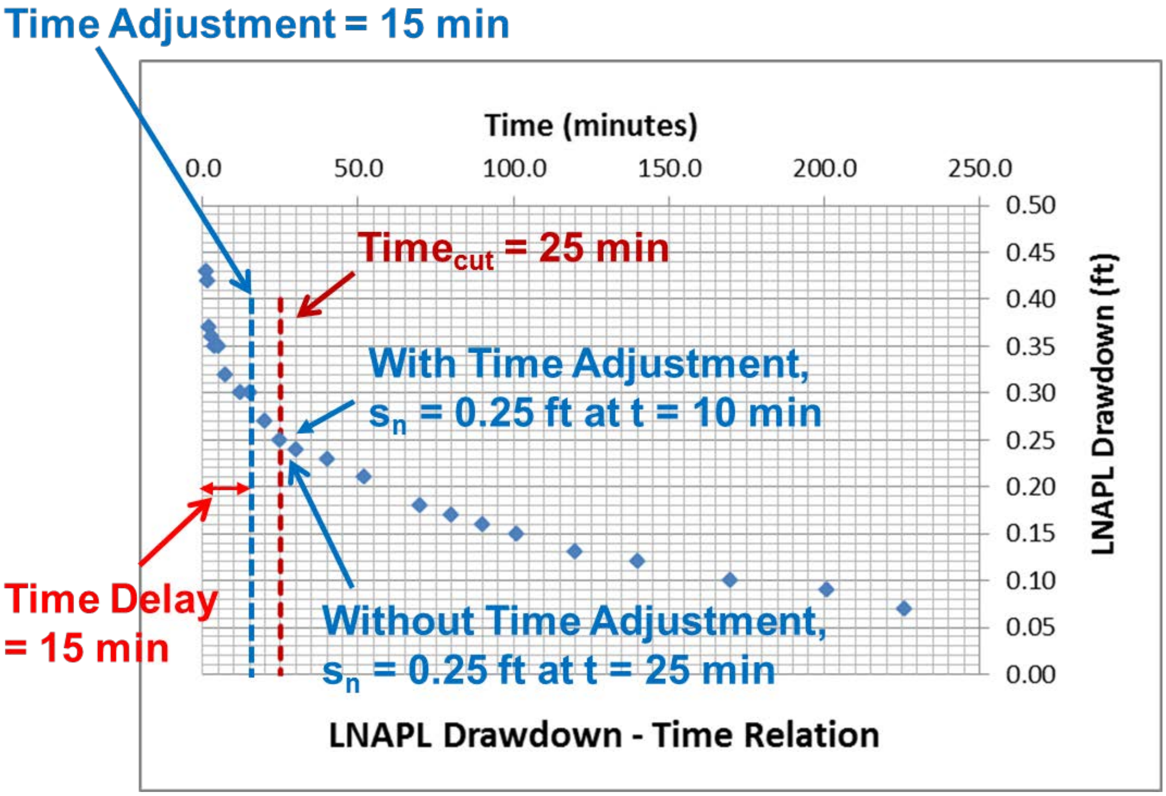


Figure 6.1. **Application of Time$_{cut}$ and Time Adjustment to eliminate early-time data influenced by filter-pack drainage or other effects**

6.3. Analysis of LNAPL Storage Coefficient

The storage parameter S_n is used in the C&J and CB&P methods. The maximum value should equal a reasonable drainable porosity value for the formation. An upper bound estimate would be 0.15 for coarse sands, 0.06 for fine sands, 0.004 to 0.025 for silts. Clays would be on the low end of silts or lower unless LNAPL exists in secondary porosity. These values assume that the recoverable fraction of LNAPL is up to 50% saturation for coarse sands and 5% for silts and clays. These values will be lower (i.e., a factor of 10 to 50) for wells with minimal LNAPL recovery. Results are relatively insensitive to this parameter if realistic values are used. The table below provides general guidance on appropriate values.

Table 6.1: Recommended Relationship between LNAPL Transmissivity and LNAPL Storage Coefficient (from ASTM, 2011)

LNAPL Transmissivity (ft^2/d)	LNAPLStorage (vol/vol)
50	0.175
20	0.122
10	0.070
5	0.053
1	0.035
0.1	0.008

A “Default” option is available for estimating the LNAPL storage coefficient for the C&J and CB&P methods. An approximate model is fit to the data in Table 6.1, as shown in Figure 6.2.

$$S_n = 0.025\sqrt{T_n} \tag{6.3.1}$$

In Eq. (6.3.1) the units of T_n are ft^2/d. The default option is selected by entering the letter d in the S_n entry cell. With the default option selected, the LNAPL storage coefficient is estimated implicitly as part of determining the LNAPL transmissivity.

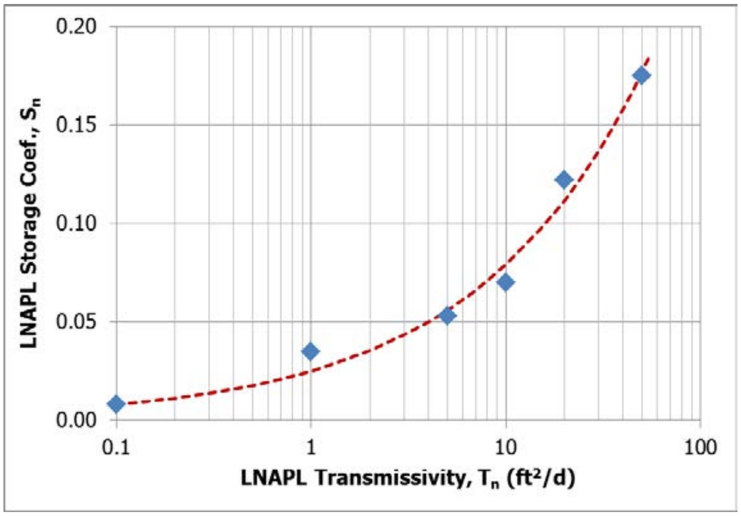
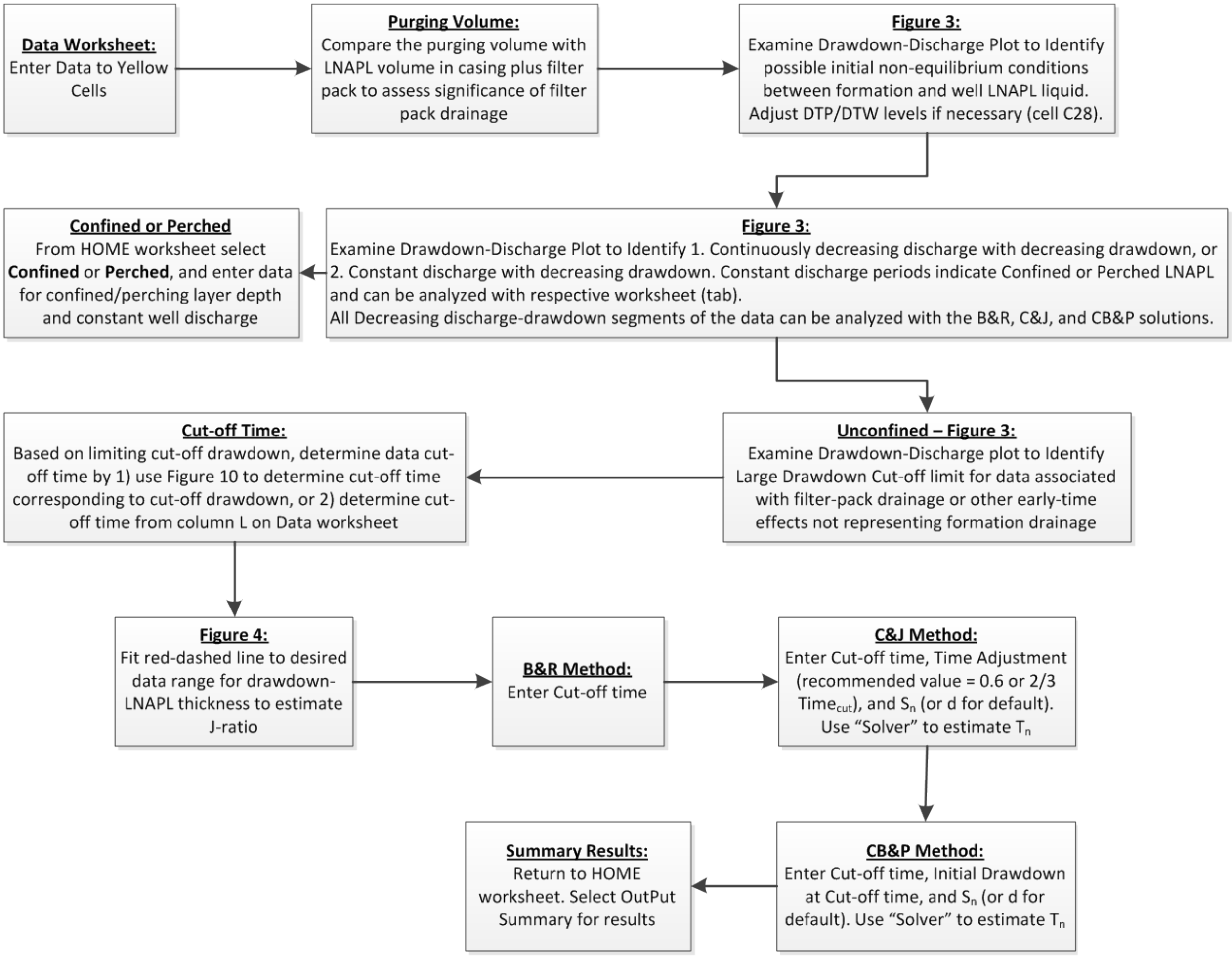


Figure 6.2. LNAPL storage coefficient vs. LNAPL transmissivity

6.4. General overview of LNAPL transmissivity estimation process

The process for estimating LNAPL transmissivity from LNAPL baildown test data using the API LNAPL Transmissivity Workbook is outlined in the flowchart shown in Figure 6.3. Further details are provided in ASTM (2011).



Data Worksheet: Enter Data to Yellow Cells

Purging Volume: Compare the purging volume with LNAPL volume in casing plus filter pack to assess significance of filter pack drainage

Figure 3: Examine Drawdown-Discharge Plot to Identify possible initial non-equilibrium conditions between formation and well LNAPL liquid. Adjust DTP/DTW levels if necessary (cell C28).

Figure 3: Examine Drawdown-Discharge Plot to Identify 1. Continuously decreasing discharge with decreasing drawdown, or 2. Constant discharge with decreasing drawdown. Constant discharge periods indicate Confined or Perched LNAPL and can be analyzed with respective worksheet (tab). All Decreasing discharge-drawdown segments of the data can be analyzed with the B&R, C&J, and CB&P solutions.

Confined or Perched From HOME worksheet select **Confined** or **Perched**, and enter data for confined/perching layer depth and constant well discharge

Unconfined – Figure 3: Examine Drawdown-Discharge plot to Identify Large Drawdown Cut-off limit for data associated with filter-pack drainage or other early-time effects not representing formation drainage

Cut-off Time: Based on limiting cut-off drawdown, determine data cut-off time by 1) use Figure 10 to determine cut-off time corresponding to cut-off drawdown, or 2) determine cut-off time from column L on Data worksheet

Figure 4: Fit red-dashed line to desired data range for drawdown-LNAPL thickness to estimate J-ratio

B&R Method: Enter Cut-off time

C&J Method: Enter Cut-off time, Time Adjustment (recommended value = 0.6 or 2/3 Time_{cut}), and S_n (or d for default). Use "Solver" to estimate T_n

CB&P Method: Enter Cut-off time, Initial Drawdown at Cut-off time, and S_n (or d for default). Use "Solver" to estimate T_n

Summary Results: Return to HOME worksheet. Select OutPut Summary for results

Figure 6.3. Flowchart outlining steps in LNAPL baildown test analysis

7. LNAPL Transmissivity Workbook

The *API LNAPL Transmissivity Workbook* tool is a Microsoft Excel ™ spreadsheet that may be used to estimate LNAPL transmissivity values from baildown test data under unconfined, confined and perched conditions. For unconfined conditions, three methods are used to calculate LNAPL transmissivity, and the results are averaged. The Kirkman J-ratio is required for two of these methods, and the magnitude of the J-ratio is determined by the User with Fig. 4 on the "Figures" worksheet. For both confined and perched LNAPL conditions, only a single estimate of LNAPL transmissivity is made based on the constant LNAPL discharge rate during part of the recovery period of the test.

The application tool has ten different worksheets that are designated as follows:

- HOME - Control and output worksheet
- Data - Entry of well configuration and fluid level data
- Figures - Basic figures showing data
- B&R - Bouwer and Rice method worksheet
- C&J - Cooper and Jacob method worksheet
- CB&P - Cooper, Bredehoeft and Papadopulos method worksheet
- B&R Type Curve - Set of type curves provided as aid to field work
- Confined - Confined LNAPL worksheet
- Perched - Perched LNAPL worksheet
- Flowchart - Flowchart outlining steps in LNAPL baildown test analysis

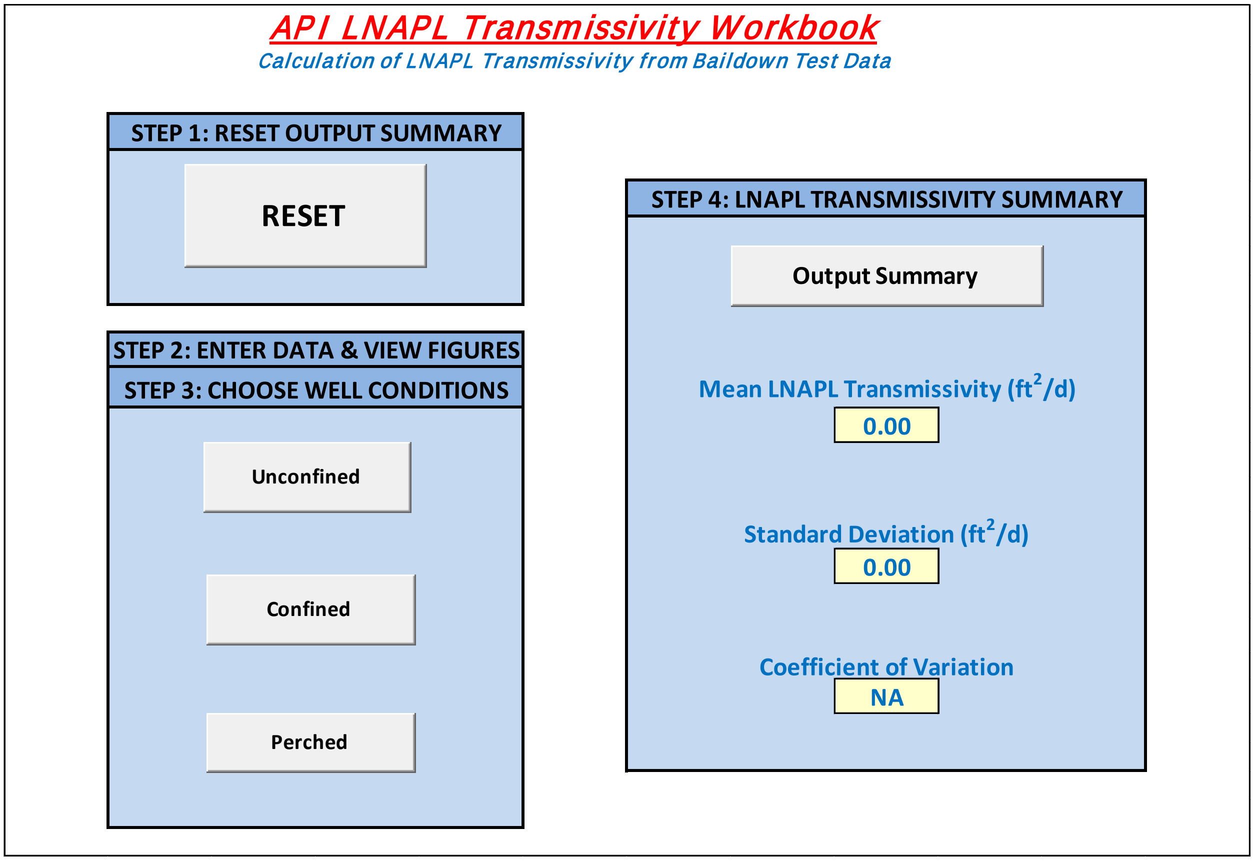
As discussed below, not all worksheets are visible at any time, though the first three worksheets and the last worksheet are always available.

7.1 "HOME" Worksheet

An example "HOME" worksheet is shown in Figure 7.1. This is the primary worksheet that outlines the steps in data analysis as follows:

1. Reset Output Summary
2. Enter Data & View Figures
3. Choose Well Conditions
4. LNAPL Transmissivity Summary

Step 1 hides the method-specific worksheets. The "Data", "Figures", and "Flowchart" worksheets remain visible and accessible. No existing data are cleared when the RESET button is selected. Step 2 requires entry of data on the "Data" worksheet and review of data on the "Figures" worksheet. Step 2 provides preliminary information to guide in selecting LNAPL condition (unconfined, confined, or perched) for analysis. If unconfined conditions are observed, then the J-ratio MUST be determined using Fig. 4 on the "Figures" worksheet. Based on Step 2 assessment, Step 3 is selection of LNAPL condition which makes visible either the worksheets appropriate for unconfined conditions, or individually, the worksheets for confined or perched conditions. Step 4, selection of the OUTPUT SUMMARY button copies results from the method-specific worksheets to summary output.



Mean LNAPL Transmissivity (ft^2/d)
0.00

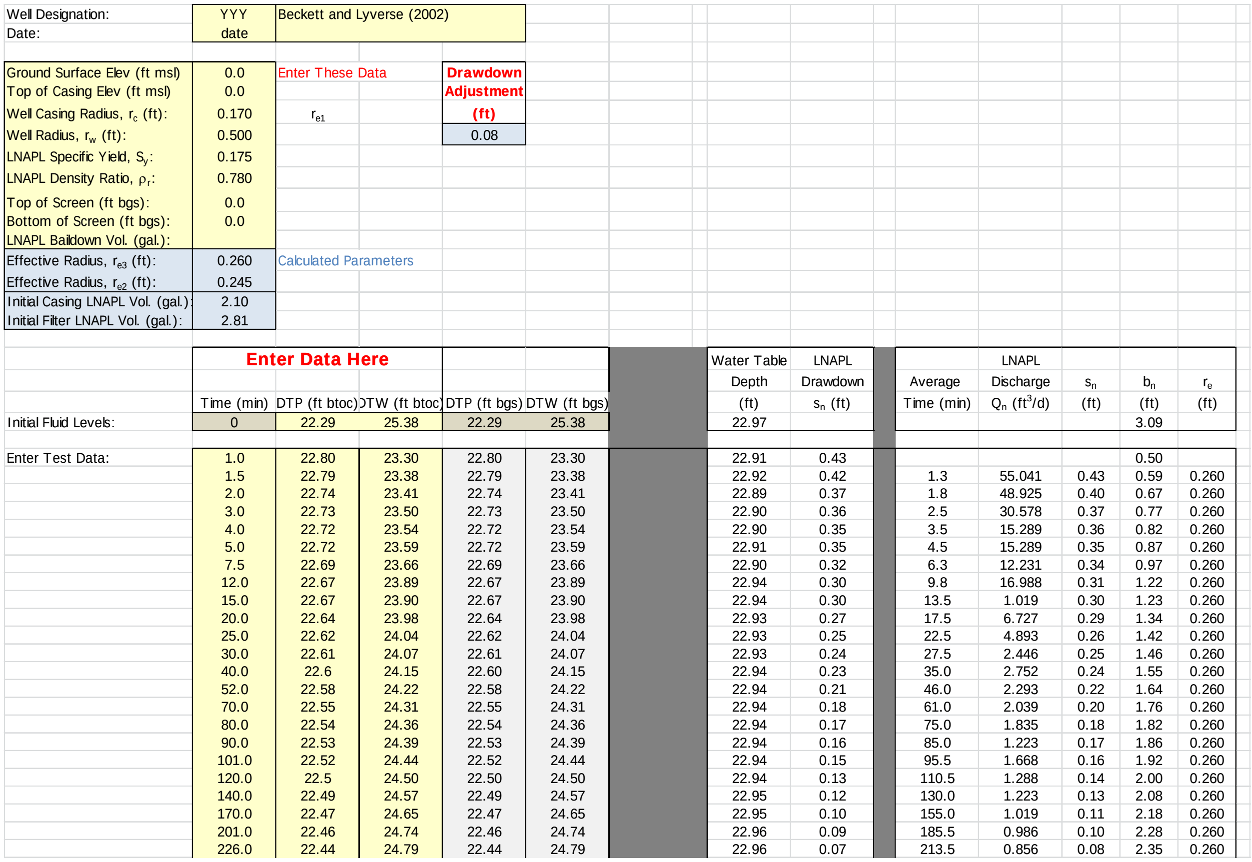
Standard Deviation (ft^2/d)
0.00

Coefficient of Variation
NA

Figure 7.1. “HOME” worksheet

7.2 “Data” Worksheet

An example “Data” worksheet page is shown in Figure 7.2. The cells for data entry are shown in light yellow color and user must input the data in the units indicated. Other cells are locked to help protect against inadvertent modification to the worksheet. This worksheet includes the well configuration data listed in Section 3, along with records of depth to product (DTP) and depth to water (DTW) as a function of time, as measured from the top of casing. The initial values of DTP and DTW are also entered. The LNAPL Specific Yield, S_y, on this worksheet refers to the filter pack. A default value 0.175 is recommended, though the value can be modified by the user. The default value is based on an assumed filter-pack porosity of 0.35, and an assumed specific yield of 50 % of the void space. The LNAPL Density Ratio, ρ_r, is estimated from field data on product type. The LNAPL Baildown Volume is entered for comparison purposes only; it is not used elsewhere in the workbook. The “Drawdown Adjustment” value is read from the data entry for Fig. 3 on the “Figures” worksheet. Calculations performed on this worksheet include adjustment of fluid levels to give depth bgs, estimation of the water table depth based on DTP and DTW along with LNAPL-water density ratio, LNAPL drawdown using Eq. (5.1) and LNAPL discharge using Eq. (5.2), and the effective well radius as outlined in Appendix B. If both the ground surface elevation and top of casing elevation are entered as zero, then no adjustment is made to DTP and DTW fluid levels. For unconfined conditions with the LNAPL column within the screened interval of the well, these data are not necessary.



Well Designation:	YYY	Beckett and Lyverse (2002)	
Date:	date		
Ground Surface Elev (ft msl)	0.0	Enter These Data	**Drawdown Adjustment (ft)**
Top of Casing Elev (ft msl)	0.0		
Well Casing Radius, r_c (ft):	0.170	r_{e1}	
Well Radius, r_w (ft):	0.500		0.08
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.780		
Top of Screen (ft bgs):	0.0		
Bottom of Screen (ft bgs):	0.0		
LNAPL Baildown Vol. (gal.):			
Effective Radius, r_{e3} (ft):	0.260	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.245		
Initial Casing LNAPL Vol. (gal.):	2.10		
Initial Filter LNAPL Vol. (gal.):	2.81		

	Enter Data Here											
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	22.29	25.38	22.29	25.38	22.97					3.09	
Enter Test Data:	1.0	22.80	23.30	22.80	23.30	22.91	0.43				0.50	
	1.5	22.79	23.38	22.79	23.38	22.92	0.42	1.3	55.041	0.43	0.59	0.260
	2.0	22.74	23.41	22.74	23.41	22.89	0.37	1.8	48.925	0.40	0.67	0.260
	3.0	22.73	23.50	22.73	23.50	22.90	0.36	2.5	30.578	0.37	0.77	0.260
	4.0	22.72	23.54	22.72	23.54	22.90	0.35	3.5	15.289	0.36	0.82	0.260
	5.0	22.72	23.59	22.72	23.59	22.91	0.35	4.5	15.289	0.35	0.87	0.260
	7.5	22.69	23.66	22.69	23.66	22.90	0.32	6.3	12.231	0.34	0.97	0.260
	12.0	22.67	23.89	22.67	23.89	22.94	0.30	9.8	16.988	0.31	1.22	0.260
	15.0	22.67	23.90	22.67	23.90	22.94	0.30	13.5	1.019	0.30	1.23	0.260
	20.0	22.64	23.98	22.64	23.98	22.93	0.27	17.5	6.727	0.29	1.34	0.260
	25.0	22.62	24.04	22.62	24.04	22.93	0.25	22.5	4.893	0.26	1.42	0.260
	30.0	22.61	24.07	22.61	24.07	22.93	0.24	27.5	2.446	0.25	1.46	0.260
	40.0	22.6	24.15	22.60	24.15	22.94	0.23	35.0	2.752	0.24	1.55	0.260
	52.0	22.58	24.22	22.58	24.22	22.94	0.21	46.0	2.293	0.22	1.64	0.260
	70.0	22.55	24.31	22.55	24.31	22.94	0.18	61.0	2.039	0.20	1.76	0.260
	80.0	22.54	24.36	22.54	24.36	22.94	0.17	75.0	1.835	0.18	1.82	0.260
	90.0	22.53	24.39	22.53	24.39	22.94	0.16	85.0	1.223	0.17	1.86	0.260
	101.0	22.52	24.44	22.52	24.44	22.94	0.15	95.5	1.668	0.16	1.92	0.260
	120.0	22.5	24.50	22.50	24.50	22.94	0.13	110.5	1.288	0.14	2.00	0.260
	140.0	22.49	24.57	22.49	24.57	22.95	0.12	130.0	1.223	0.13	2.08	0.260
	170.0	22.47	24.65	22.47	24.65	22.95	0.10	155.0	1.019	0.11	2.18	0.260
	201.0	22.46	24.74	22.46	24.74	22.96	0.09	185.5	0.986	0.10	2.28	0.260
	226.0	22.44	24.79	22.44	24.79	22.96	0.07	213.5	0.856	0.08	2.35	0.260

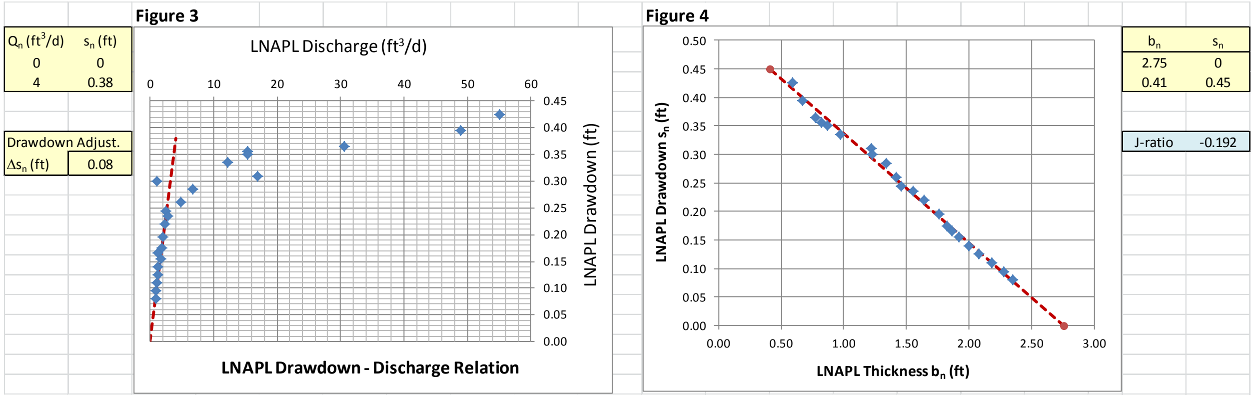
Figure 7.2. “Data” entry worksheet

7.3 “Figures” Worksheet

This worksheet contains ten miscellaneous figures showing the input and the output data. As discussed below, the most important diagnostic tools include the plot of LNAPL drawdown versus discharge, and the plot of LNAPL drawdown versus LNAPL thickness (J-Ratio). The figures (objects) are not protected to allow edits (i.e., axis scales, etc.). The figures are numbered one through ten and are described as follows:

- Fig 1: Depth to Fluid Interface vs. Time (arithmetic time scale). This figure also shows the initial DTP and DTW. Depending on the screen interval data entered on the “Data” worksheet, the screened interval of the LNAPL column is also shown. The entire screen length is not shown. Instead, only the screened interval extending one foot above and/or below the initial LNAPL well thickness is shown. Fig. 1 is useful for evaluating how the potentiometric surface varied over the test duration. Looking for trends of water-table fluctuation will help identify any significant deviations from the assumed constant background conditions.

- Fig 2: Depth to Fluid Interface vs. Time (logarithmic time scale). This figure also shows the initial DTP and DTW. Depending on the screen interval data entered on the "Data" worksheet, the screened interval of the LNAPL column is also shown. The entire screen length is not shown. Instead, only the screened interval extending one foot above and/or below the initial LNAPL well thickness is shown. Similar to Fig. 1, however the early portion of the test can be better viewed for longer term tests.
- Fig 3: LNAPL Drawdown vs. LNAPL Discharge. This is an important diagnostic tool used to determine Drawdown Adjustment that is copied to the "Data" worksheet and other worksheets to account for initial non-equilibrium between formation and well fluids. The LNAPL Drawdown-LNAPL Discharge data should extrapolate to the origin (zero value) for small values. To aid analysis, a linear model is added with data entry in the yellow-fill box adjacent to the figure, as shown in Figure 7.3(a). LNAPL drawdown-discharge should exhibit a direct relationship. Deviations from this indicate the baildown test may be significantly affected by outside factors (e.g., nearby changes in pumping) or confined or perched conditions (where constant discharge is observed).
- Fig 4: LNAPL Drawdown vs. LNAPL Thickness. This is an <u>essential</u> diagnostic tool that is used to estimate the J-ratio magnitude, as described in Appendix A, and used with the "B&R" worksheet and "CB&P" worksheet. A linear model is provided with data entry in the yellow-fill box adjacent to the figure, and with estimated J-ratio value shown in the blue-fill box adjacent, as shown in Figure 7.3(b).



Q_n (ft^3/d)	s_n (ft)
0	0
4	0.38

Drawdown Adjust.	
Δs_n (ft)	0.08

b_n	s_n
2.75	0
0.41	0.45

J-ratio	-0.192

(a) (b)

Figure 7.3. Fig. 3 and Fig. 4 from the "Figures" worksheet showing data entry boxes for estimation of drawdown adjustment and J-ratio

- Fig. 5: Depth to Product (DTP) vs. LNAPL Discharge. This figure may be helpful as a diagnostic tool to identify soil stratigraphic influences.
- Fig 6: Depth to Water (DTW) vs. LNAPL Discharge. This figure may be helpful as a diagnostic tool to identify soil stratigraphic influences.
- Fig 7: LNAPL Thickness vs. Time. This figure may be useful for evaluating if the fluid levels reach equilibrium at the end of the test.
- Fig 8: LNAPL Discharge vs. Time. This figure represents an alternative method for evaluating if the baildown test has completed and the well reaches equilibrium conditions.
- Fig 9: LNAPL Well Inflow Volume vs. Time. Fig. 9 is analogous to Fig. 7 except provided in terms of the total well volume. In addition for being useful to evaluate test completion, this figure is useful for design of future baildown tests in terms of volume to remove from the well and filter pack.
- Fig 10: LNAPL Drawdown vs. Time. Linear model tool is also added with data entry in the yellow-fill box adjacent to the figure. In combination with Fig. 3, this figure is useful in identifying cut-off time for early-time data.

7.4 “B&R” Worksheet

The “B&R”, or Bouwer and Rice worksheet calculates the LNAPL transmissivity and standard deviation based on the Bouwer and Rice (Bouwer and Rice, 1976; Bouwer, 1989) method using the method of linear least squares. As shown in Eq. (C.3), according to this method, the logarithm of the drawdown varies as a linear function of time. A straight line is automatically fit to the log-drawdown vs. time data and the slope of this line is used to determine the LNAPL transmissivity. The variance of the slope of the line is used to estimate the LNAPL transmissivity standard deviation. The ratio of the radius of influence to the effective radius is calculated using the polynomial approximation presented by Butler (2000). The user may eliminate early time data from the analysis by entering a non-zero value for the cutoff time (yellow cell). An example worksheet is shown in Figure 7.5. The only active cell on this worksheet is the cut-off time, and the LNAPL transmissivity value is automatically calculated. The lower figure on the worksheet shows the fit of the model data to the B&R Type Curve (see discussion below).

For the example shown in Figure 7.5 the cut-off time is set at 25 minutes. This cut-off time is based on eliminating early-time data associated with large filter pack drainage to the well. The drawdown-discharge curve for this example (Fig. 3 on the “Figures” worksheet) is shown in Figure 8.1 (c) and Figure 8.1 (d) (expanded scale after drawdown correction). In particular, Figure 8.1 (d) shows that the linear relationship between drawdown and discharge is reached once the LNAPL drawdown is about 0.25 ft. The LNAPL drawdown vs. time curve (Fig. 10 from the “Figures” worksheet) is shown in Figure 7.4, which gives the corresponding cut-off time 25 minutes for an LNAPL drawdown of 0.25 ft.

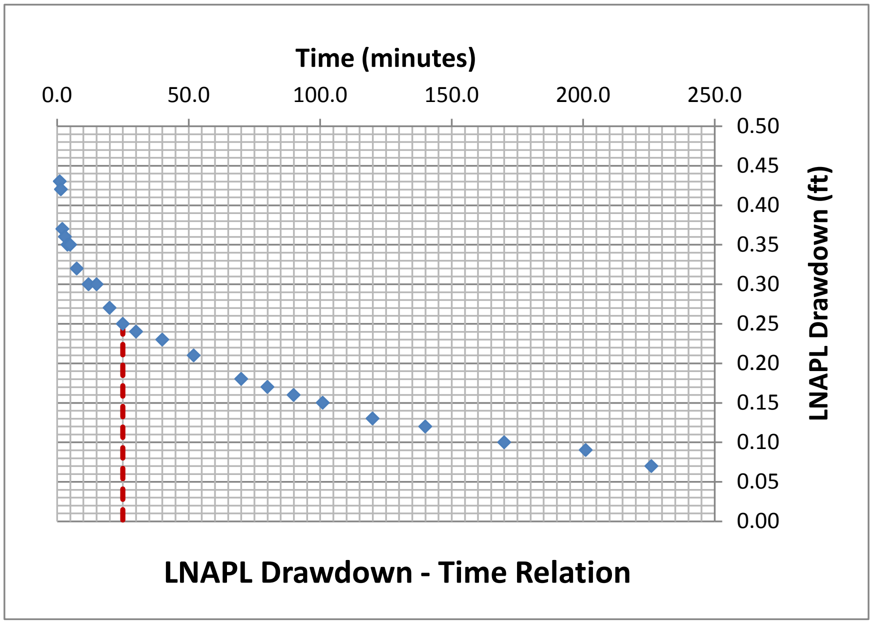
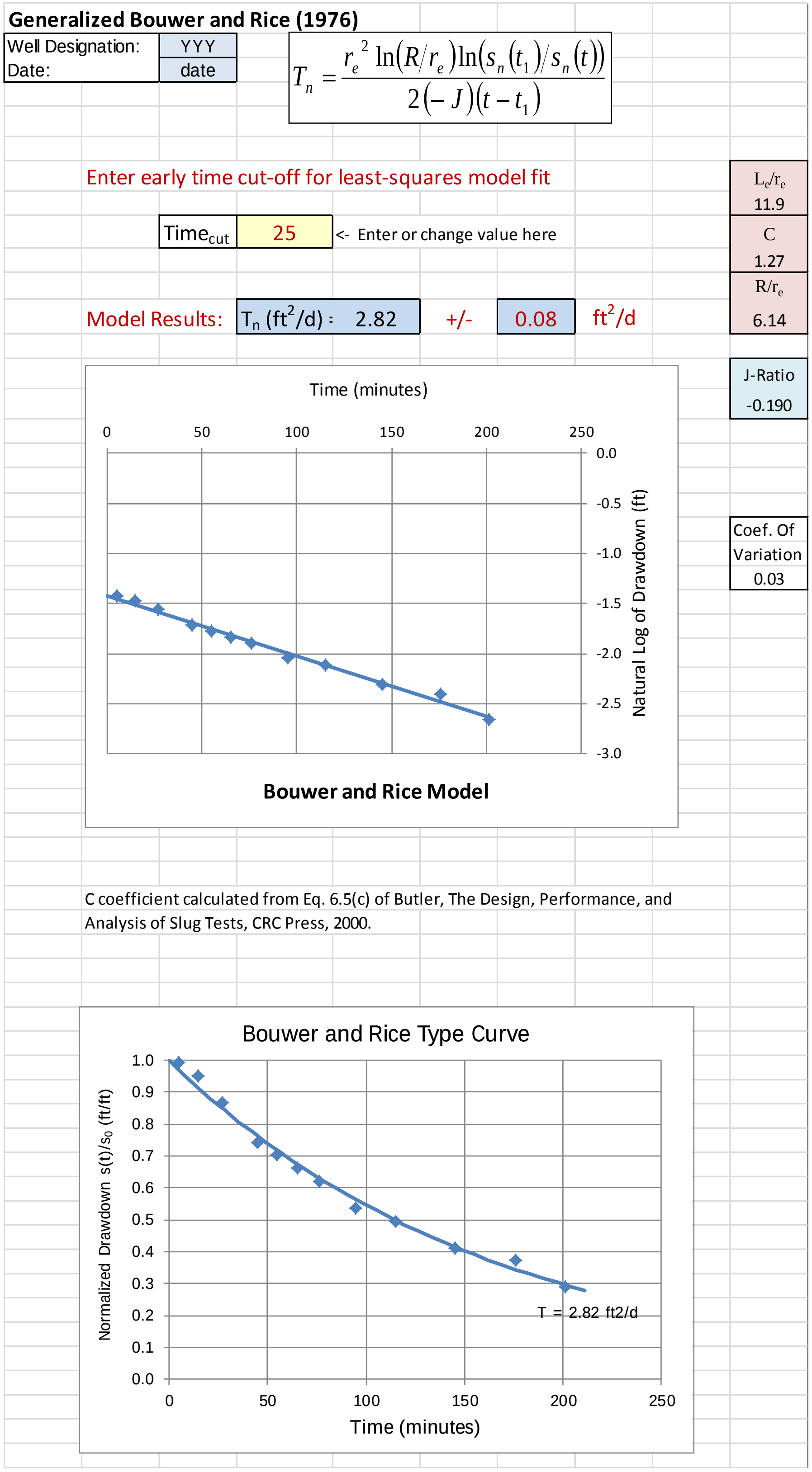


Figure 7.4. **LNAPL Drawdown vs. Time Curve (Fig. 10 from "Figures" Worksheet)**



Generalized Bouwer and Rice (1976)

Well Designation:	YYY
Date:	date

$$T_n = \frac{r_e^{\,2}\ln\left(R/r_e\right)\ln\left(s_n\left(t_1\right)/s_n\left(t\right)\right)}{2\left(-J\right)\left(t-t_1\right)}$$

Enter early time cut-off for least-squares model fit

Time_{cut} 25 <- Enter or change value here

Model Results: T_n (ft^2/d) : 2.82 +/- 0.08 ft^2/d

L_e/r_e	11.9
C	1.27
R/r_e	6.14
J-Ratio	-0.190
Coef. Of Variation	0.03

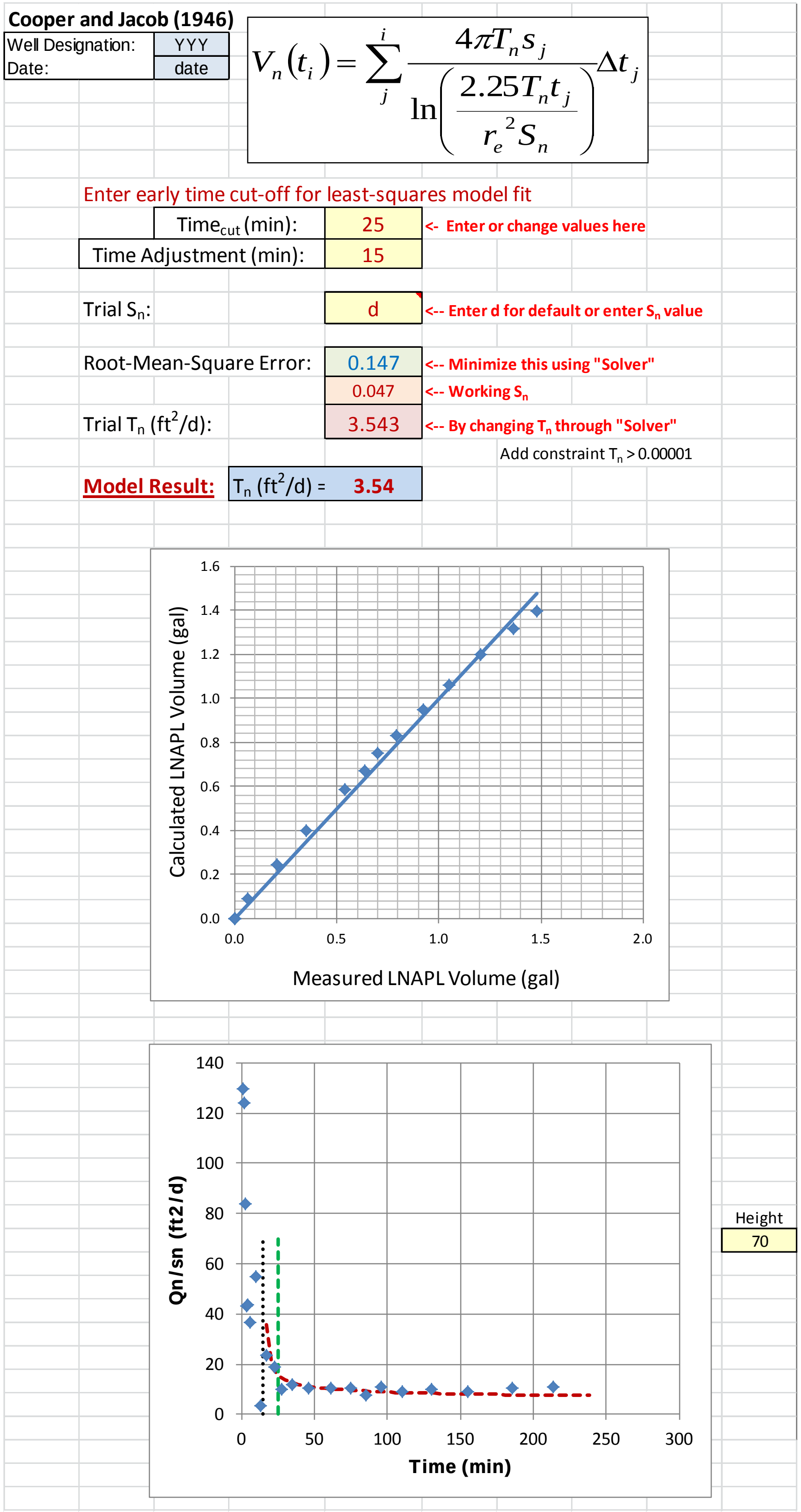
C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.

Figure 7.5. “B&R” worksheet

7.5 “C&J” Worksheet

The Cooper and Jacob (C&J) worksheet is used to calculate the LNAPL transmissivity value based on the Cooper and Jacob (1946) equation. [As described in Appendix D, the Theis equation is actually used in calculations, though the more commonly used Cooper and Jacob designation has been retained here.] The method used is modified from that presented as method three of Huntley (2000). The method is outline in Appendix D. Unlike the B&R method, both the C&J method and the CB&P method use a storage parameter (S_n) in addition to LNAPL transmissivity (T_n) to fit the model and data. Use of the storage parameter implies that the time origin is critical to data analysis for both methods. Yet, it is recognized that early-time data can be impacted by filter-pack drainage and not reflect natural LNAPL flow from the formation to the well. Thus the user may specify a cut-off time to eliminate early-time data from the analysis. To provide consistency with the model basis, the user may also adjust the time origin to a fraction of the cut-off time. There is little guidance towards an appropriate fraction, though the range 50 % to 80 % appears reasonable. Recommended values are 0.6 or 2/3, whichever is more convenient. Both the cut-off time and time adjustment values are specified by the user (light yellow cells). For further discussion, see Section 6.2. In some cases, repeating the test with alternative field methods that reduce the removal time or reduce the filter pack recharge may help reduce the need for the time adjustment.

The estimate of LNAPL transmissivity is found by minimizing the root-mean-square error between model prediction and data by varying the storage coefficient and LNAPL transmissivity. An example worksheet is shown in Figure 7.6. The Adjusted Time is set to 6 minutes, which is 60 % of the cut-off time. The Excel “Solver” function is used to find the root-mean-square error, which is the square root of the sum square difference (SSD) provided by Eq. (D.6). Instead of using “Solver” to find both S_n and T_n, it is recommended that the user select a trial value of S_n and use “Solver” to find T_n. Alternatively, the letter d may be entered as the Trial $\mathrm{S_n}$ value to select the default option described in Section 6.3.



Cooper and Jacob (1946)

Well Designation: YYY

Date: date

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^{\,2} S_n}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

Time$_{cut}$ (min): 25 <- Enter or change values here

Time Adjustment (min): 15

Trial S$_n$: d <-- Enter d for default or enter S$_n$ value

Root-Mean-Square Error: 0.147 <-- Minimize this using "Solver"

0.047 <-- Working S$_n$

Trial T$_n$ (ft^2/d): 3.543 <-- By changing T$_n$ through "Solver"

Add constraint T$_n$ > 0.00001

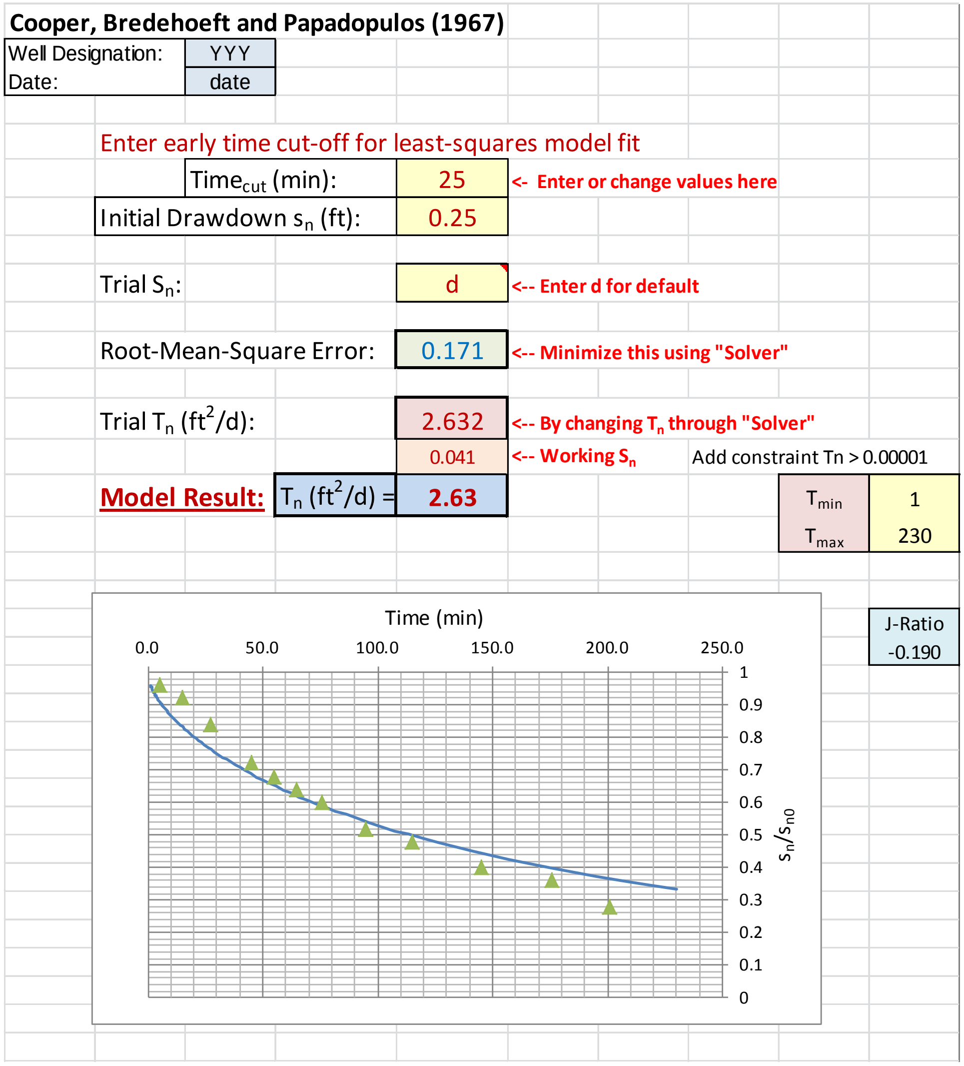
Model Result: T$_n$ (ft^2/d) = **3.54**

Height 70

Figure 7.6. “C&J” worksheet

7.6 “CB&P” Worksheet

The Cooper, Bredehoeft and Papadopulos (CB&P) worksheet is used to calculate the LNAPL transmissivity value based on the Cooper, Bredehoeft and Papadopulos (1967) slug test model. Application of this model for an LNAPL baildown test is described in Appendix E, and an example worksheet is shown in Figure 7.7. For application of this method, there are three unknown parameters: initial LNAPL drawdown $s_n(0)$, LNAPL transmissivity T_n, and LNAPL storage coefficient S_n. Trial estimates of these quantities are entered on the worksheet, and the Excel “Solver” function is used to minimize the root-mean-square error given by the square-root of Eq. (E.7). An estimate of the initial drawdown is provided by the extrapolated drawdown at the cut-off time. Alternatively, the initial drawdown is selected so that the drawdown ratio s_n/s_{n0} extrapolates to 1 at time = 0 (which includes the cut-off time adjustment). The algorithm used to evaluate the model equations is derived from Charbeneau (2000).



Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	YYY
Date:	date

Enter early time cut-off for least-squares model fit

Time_{cut} (min): 25 <- Enter or change values here

Initial Drawdown s_n (ft): 0.25

Trial S_n: d <-- Enter d for default

Root-Mean-Square Error: 0.171 <-- Minimize this using "Solver"

Trial T_n (ft^2/d): 2.632 <-- By changing T_n through "Solver"

0.041 <-- Working S_n Add constraint Tn > 0.00001

Model Result: T_n (ft^2/d) = **2.63**

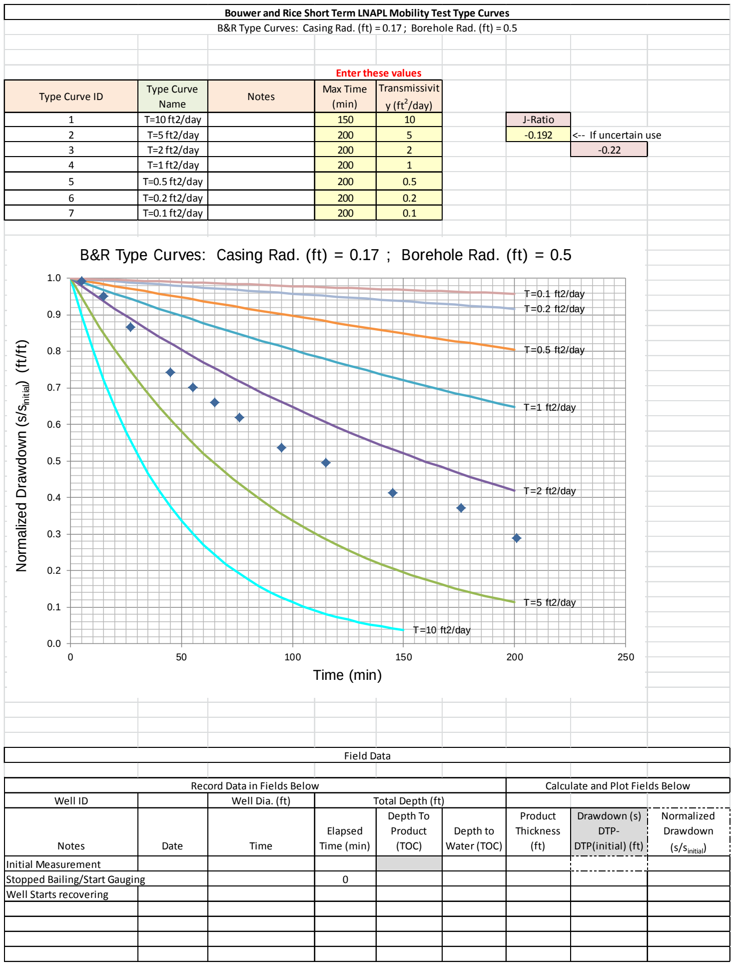
T_{min}	1
T_{max}	230

J-Ratio
-0.190

Figure 7.7. “CB&P” worksheet

7.7 “B&R Type Curve” Worksheet

This worksheet presents a type curve based on the Bouwer and Rice method along with a supporting data sheet. The type curve was developed to support rapid field evaluation of LNAPL baildown tests when the user is primarily interested in ‘order-of-magnitude’ estimates of LNAPL transmissivity and possible early termination of a field test of a particular well. The type curve is a normalized plot of the Bouwer and Rice solution present at the top of the B&R worksheet, where the type curve shows normalized drawdown as a function of time for selected values of LNAPL transmissivity. The use of the type curve requires that the well-specific construction and specific yield data be entered into the “Data” worksheet in order to generate the correct type curves. A J-ratio of ($\rho_r - 1$) is recommended unless well-specific behavior is available. The user may change the range of LNAPL transmissivity curves shown on the curve and associated maximum times (which may correspond to the test time) (light yellow cells). The lower part of the worksheet provides a data sheet that may be copied for field use. The type curve application was suggested by Andrew Kirkman. Figure 7.8 shows an example worksheet.



Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.17 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-0.192	<-- If uncertain use
	-0.22

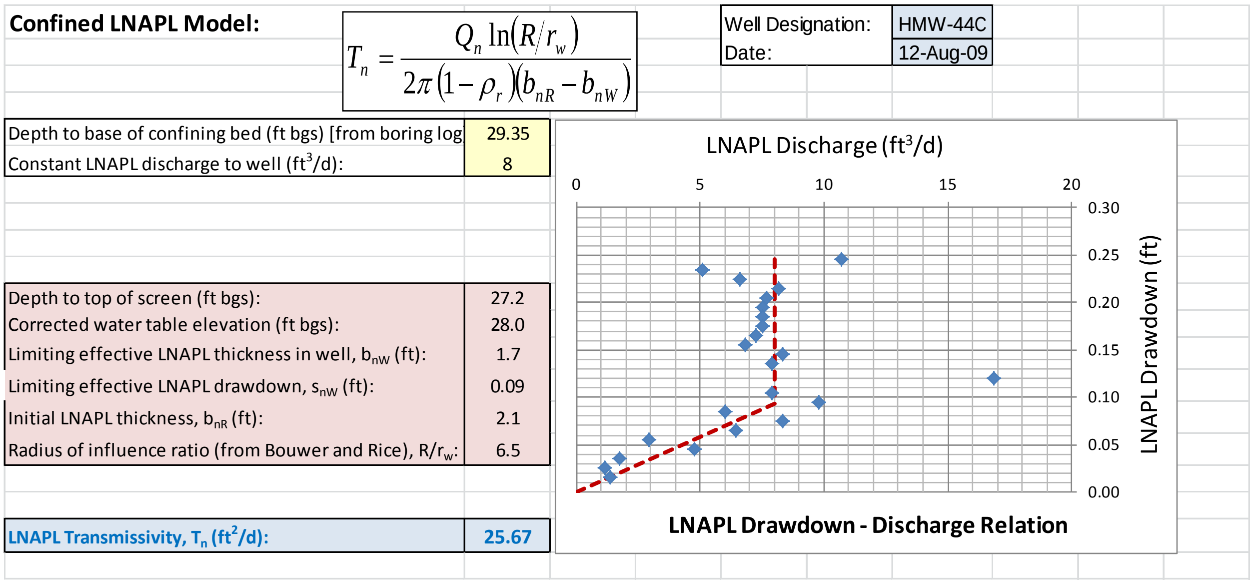
Field Data

Record Data in Fields Below						Calculate and Plot Fields Below		
Well ID		Well Dia. (ft)	Total Depth (ft)					
Notes	Date	Time	Elapsed Time (min)	Depth To Product (TOC)	Depth to Water (TOC)	Product Thickness (ft)	Drawdown (s) DTP-DTP(initial) (ft)	Normalized Drawdown ($s/s_{initial}$)
Initial Measurement								
Stopped Bailing/Start Gauging			0					
Well Starts recovering								

Figure 7.8. “B&R Type Curve” worksheet

7.8 “Confined” Worksheet

The “Confined” worksheet is used to estimate LNAPL transmissivity under confined LNAPL conditions. This worksheet is visible and available when the CONFINED button is selected under Step 3 Conditions on the “Selection and Results” worksheet. The basic equations are presented in Appendix F, and an example worksheet is shown in Figure 7.9. The depth to base of confining bed is entered to determine the effective limiting thickness of LNAPL in the well b_{nW} (see Eq. F.2). The constant discharge from the steady discharge portion of the test is then entered and used to calculate the LNAPL transmissivity. The radius of influence term for the skimmer well equation is determined from the Bouwer and Rice (B&R) worksheet.



Confined LNAPL Model:

$$T_n = \frac{Q_n \ln\left(R/r_w\right)}{2\pi\left(1-\rho_r\right)\left(b_{nR}-b_{nW}\right)}$$

Well Designation: HMW-44C
Date: 12-Aug-09

Depth to base of confining bed (ft bgs) [from boring log	29.35
Constant LNAPL discharge to well (ft^3/d):	8

Depth to top of screen (ft bgs):	27.2
Corrected water table elevation (ft bgs):	28.0
Limiting effective LNAPL thickness in well, b_{nW} (ft):	1.7
Limiting effective LNAPL drawdown, s_{nW} (ft):	0.09
Initial LNAPL thickness, b_{nR} (ft):	2.1
Radius of influence ratio (from Bouwer and Rice), R/r_w:	6.5

LNAPL Transmissivity, T_n (ft^2/d):	**25.67**

Figure 7.9. “Confined” worksheet

7.9 “Perched” Worksheet

The “Perched” worksheet is used to estimate LNAPL transmissivity under perched LNAPL conditions. The basic equations are presented in Appendix G. The depth (bgs) to the top of the perching layer, DZ_{12}, is entered to determine the effective limiting drawdown of LNAPL in the well based on the initial depth to product DTP_0. The constant discharge from the steady discharge portion of the test is then entered and used to calculate the LNAPL transmissivity. The radius of influence term for the skimmer well equation is determined from the Bouwer and Rice (B&R) worksheet. The worksheet mirrors the “Confined” worksheet and is not repeated here.

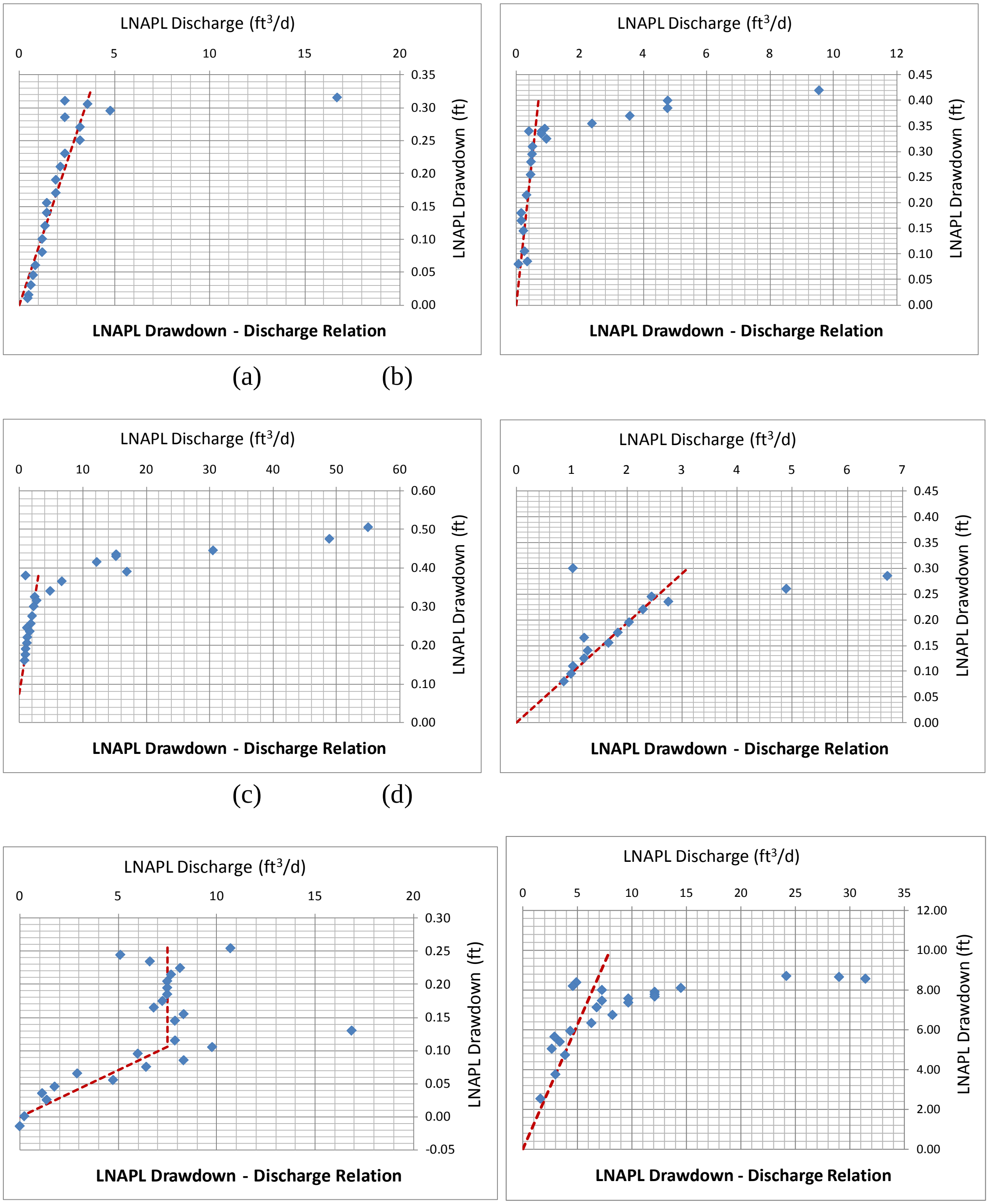
8. Examples and Important Diagnostic Tools

An important diagnostic tool is a plot of the well drawdown versus well discharge. The general shape of this relationship can be used to identify conditions with significant borehole recharge from the filter pack, screen for perched or confined LNAPL conditions, and help identify whether formation LNAPL was initially in equilibrium with well-bore LNAPL (and whether drawdown adjustment might be necessary). Some example curves are discussed below.

Figure 8.1 shows a number of drawdown-discharge curves. Figure 8.1(a) shows an example for unconfined LNAPL where significant borehole recharge from the filter pack is not an issue. While the initial calculated data (point with large Q_n, large s_n) is not consistent with other data on this figure, it is based on measurements taken at 0.5 and 1 minute into the test and could be associated with measurement uncertainty. Figure 8.1(b) gives an example where borehole recharge from the filter pack is significant. The initial data show large discharge which is primarily associated with filter pack drainage. Once the drawdown falls below 0.35 feet, consistent linear drawdown-discharge behavior is observed.

Figures 8.1(c) and (d) show the same data set. First, Figure 8.1(c) shows that significant borehole recharge does occur. Also, significantly, the linear part of the curve does not approach zero drawdown at zero discharge. Instead, it appears that the extrapolated limit has zero discharge with $s_n = 0.08$ ft. Such behavior suggests that the formation and wellbore LNAPL fluids were not initially in equilibrium, and that a drawdown correction of $\Delta s_n = 0.08$ ft should be applied to the data before LNAPL transmissivity analysis. Figure 8.1(d) shows an expanded view of this data after the correction has been applied. Such a correction does affect the resulting LNAPL transmissivity value that is calculated. With the correction $\Delta s_n = 0.08$ ft, the average LNAPL transmissivity $T_n = 2.99$ ft^2/d with CV = 0.16. For the same data and analysis without the 0.08 ft correction, the drawdowns are larger and the estimated LNAPL transmissivity is smaller with an average value $T_n = 1.89$ ft^2/d and coefficient of variation = 0.19.

Figure 8.1(e) shows behavior that suggests confined (or perched) LNAPL conditions. In this case it represents confined conditions with the water table initially located at an elevation above the confined LNAPL and with resulting exaggerated LNAPL thickness in the well. Immediately following LNAPL removal from the well, there is no LNAPL within the wellbore to “push” back against LNAPL inflow from the formation, and LNAPL discharge from the formation occurs at a constant rate while the LNAPL drawdown is declining. Once the LNAPL column within the wellbore increases in thickness to contact the mobile formation LNAPL, the inflow rate is retarded and decreases at a linear rate along with the LNAPL drawdown. One may analyze LNAPL transmissivity from the constant inflow rate along with limiting LNAPL drawdown value (about 0.1 ft in this example), or one can use standard (unconfined) equations on the data from the linear drawdown-discharge part of the curve. Figure 8.1(f) shows large initial LNAPL inflow, which in this case is likely associated with aggressive purging in addition to filter pack drainage (this corresponds to Figure B.1(c)).



(a) (b)

(c) (d)

(e) (f)

Figure 8.1. Example LNAPL drawdown-discharge curves

A couple of examples are considered in a little more detail. The first example, Figure 8.2, shows results from a baildown test with initial LNAPL thickness approximately 1.5 ft. During fluid removal from the wellbore both LNAPL and water were removed, and there is significant fluid recovery during approximately the first 6 minutes of the test, after which the calculated water table elevation remains stable. While there is significant scatter in the early-time data (larger drawdown values), the latter-time data shows a nearly linear relationship between discharge and drawdown. It also appears that the drawdown intercept with the $Q_n = 0$ axis has a residual value of about $s_n = 0.02$ ft (0.24 inch). While this magnitude correction appears small, it does represent nearly 20 % of the drawdown being analyzed during the test analysis. A drawdown correction of magnitude 0.018 ft is applied (larger corrections would result in negative drawdown and require further individual data adjustment or use of an alternative model for analysis). A cut-off of 10 minutes is assumed, and the data gives $J = -0.179$. The calculated LNAPL transmissivity is $T_n = 10.45$ ft^2/d, and the coefficient of variation (ratio of standard deviation to mean transmissivity value based on the three methods of data analysis that are discussed below) is $CV = 0.13$. [If drawdown correction is not applied the model provides a LNAPL transmissivity estimate $T_n = 5.34$ ft^2/d with CV = 0.28.]

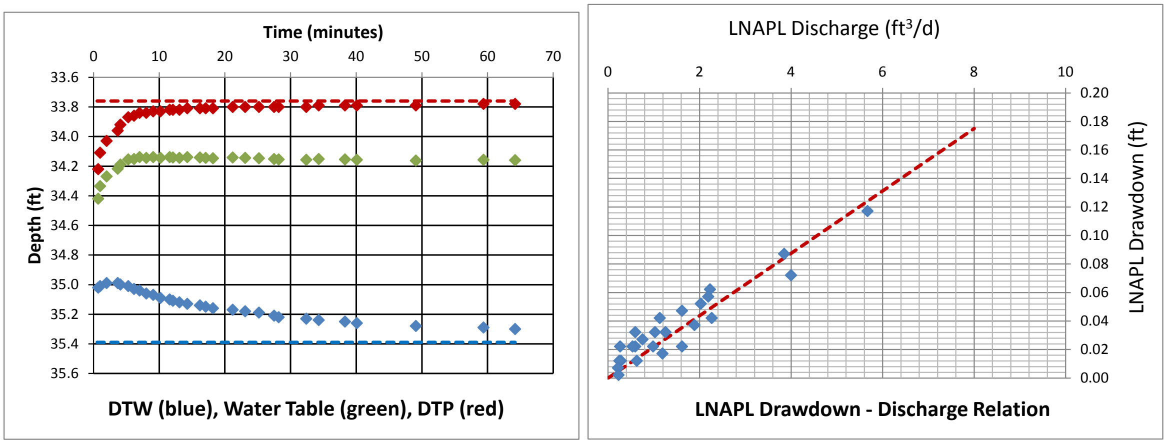
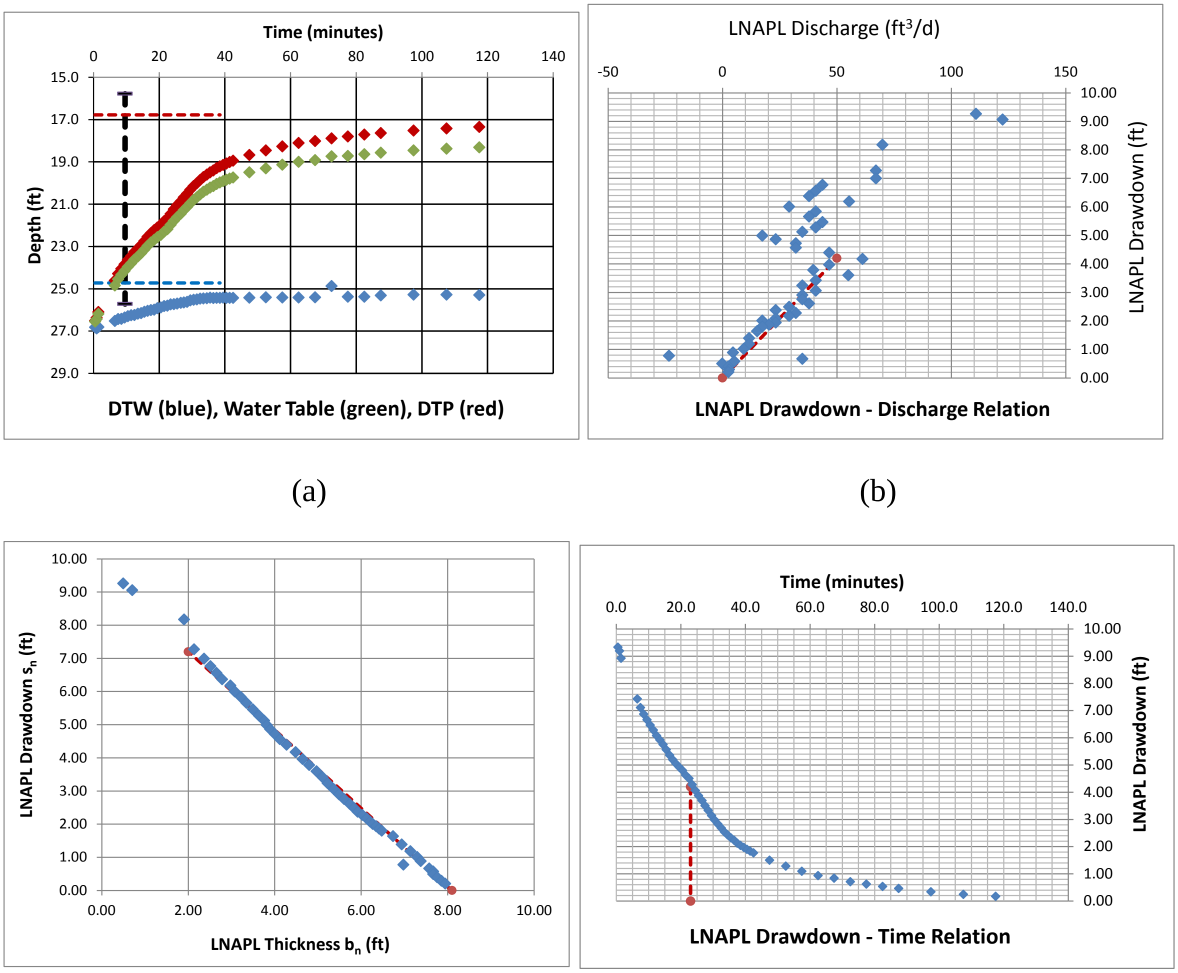


Figure 8.2. Example E1: T_n = 10.4 ft^2/d; CV = 0.13

The second example shown in Figure 8.3 represents a test where purging resulted in significant removal of both LNAPL and groundwater. The bottom of screen is located at a depth 27 ft, and this is the initial elevation for fluid interfaces in the well. Figure 8.3(b) shows the LNAPL drawdown-discharge graph. The expected linear relationship between LNAPL drawdown and discharge is not observed until the drawdown reaches approximately 4.2 ft. Figure 8.3(c) shows that the J-ratio is $J = -1.18$. This is consistent with a rising water table and LNAPL-water interface elevation throughout the test. Figure 8.3(d) is the graph of LNAPL drawdown versus time (Fig. 10 on the “Figures” worksheet). The LNAPL drawdown is 4.2 ft at a time of 24 minutes. A cut-off time of 25 minutes is assumed, with an Adjustment Time $\Delta t_a = 15$ minutes for the C&J and CB&P methods. Results from the three analysis methods give $T_n = 3.08$ ft^2/d with $CV = 0.07$.

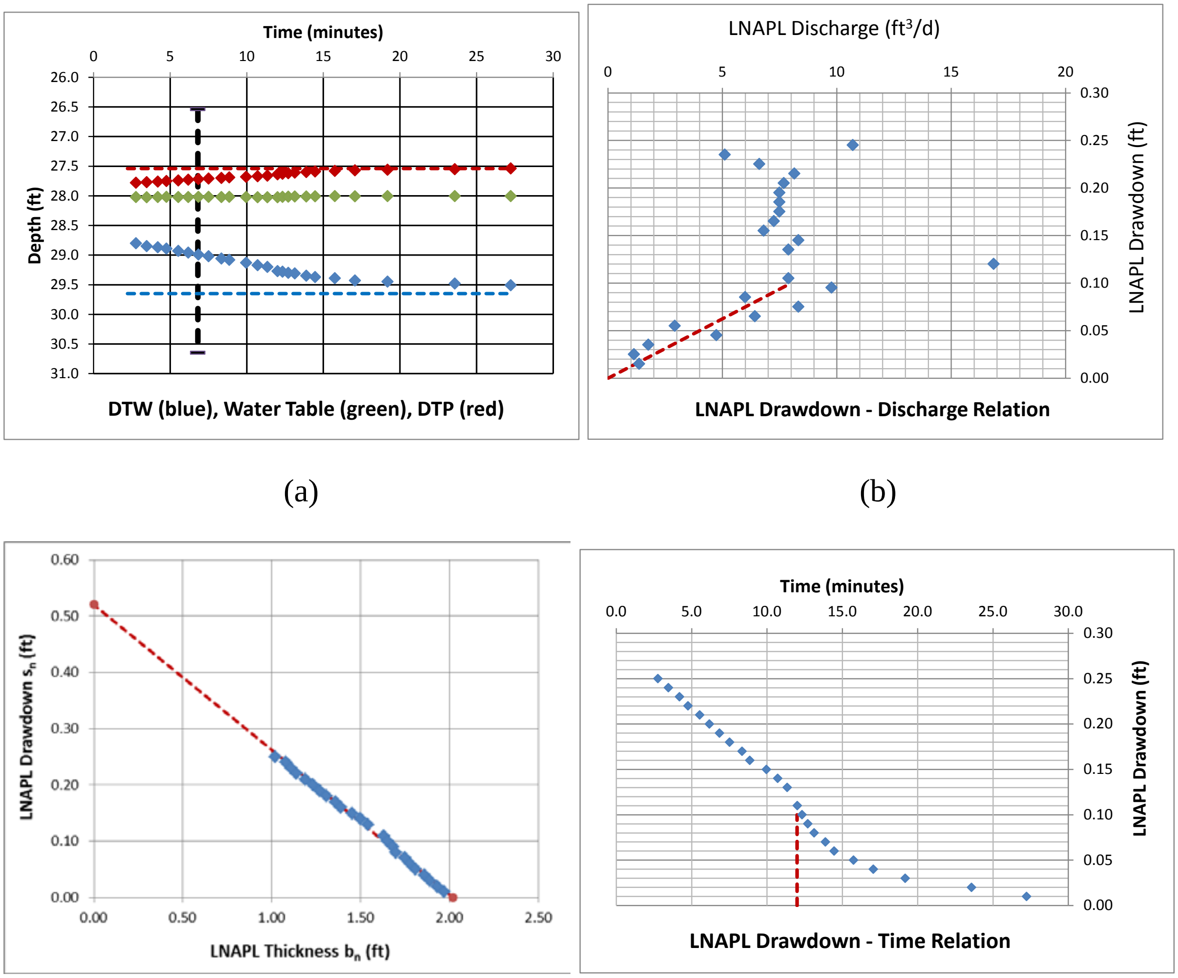


(a) (b)

(c) (d)

Figure 8.3. Example E2: T_n = 3.08 ft^2/d; CV = 0.07

A third example shown in Figure 8.4 corresponds to the confined LNAPL test shown in Figure 7.9. The LNAPL transmissivity value calculated in Figure 7.9 is based on a single data corresponding to the drawdown and discharge at the end of the "constant discharge" segment. The following example shows that consistent results can be achieved if only the late-time data is used. The drawdown-discharge curve of Figure 8.4(b) shows that the linear relationship is observed starting at a drawdown of about 0.1 ft. Figure 8.4(c) shows that J = -0.257, which is close to the values that would be used with the Huntley method of analysis (for this well, ρ_r = 0.764). Figure 8.4(d) shows that a drawdown of 0.1 ft is observed at a time 12 minutes, which serves as the cut-off for the three methods of analysis. A time adjustment Δt_a = 8 minutes is used for the C&J method. Results from the three methods give T_n = 23.56 ft^2/d with CV = 0.14. This LNAPL transmissivity estimate compares favorably with the estimate T_n = 25.67 ft^2/d from Figure 7.9.



(a) (b)

(c) (d)

Figure 8.4. Example E3: T_n = 23.56 ft^2/d; CV = 0.14

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Appendix A: Kirkman J-Ratio

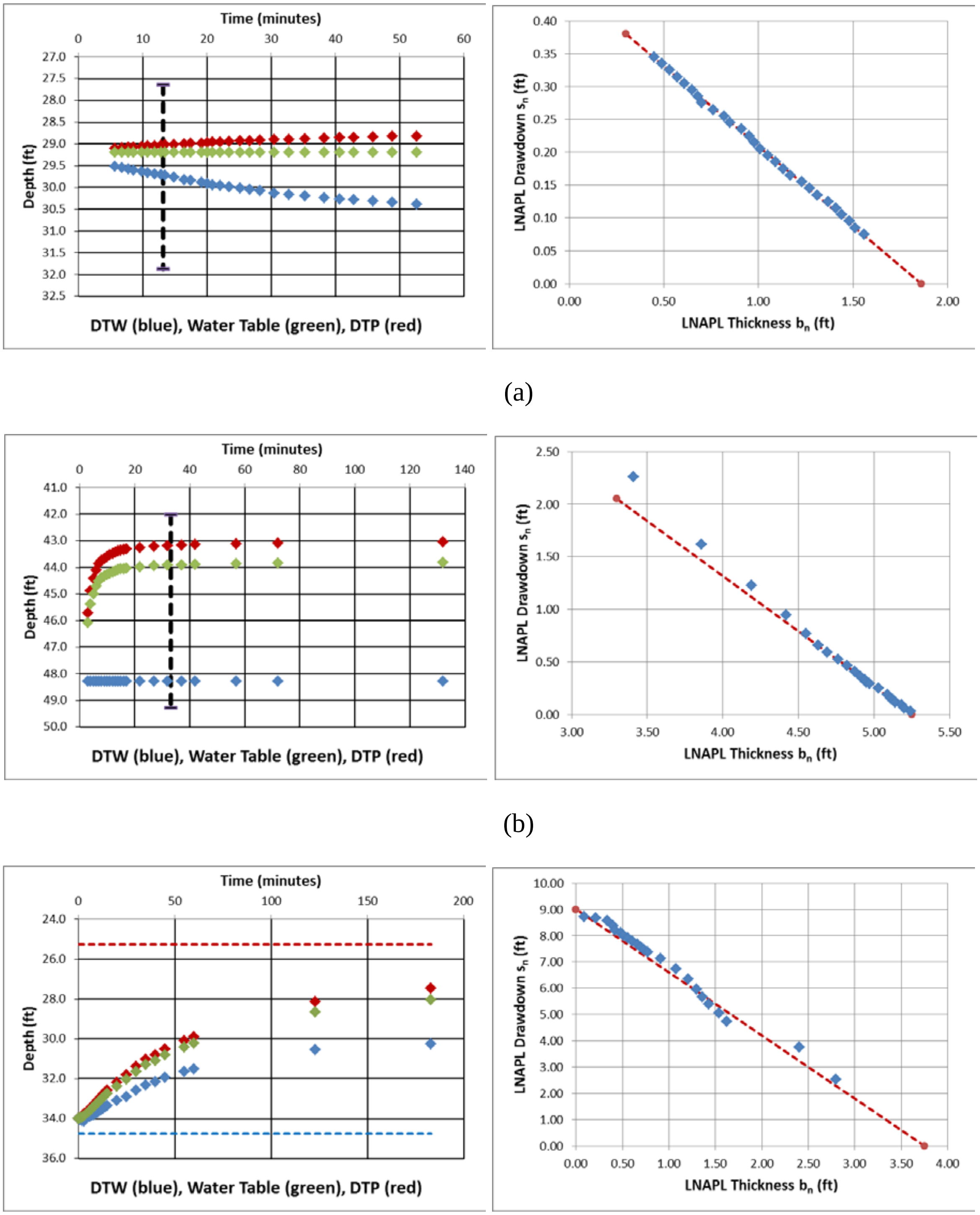
The LNAPL discharge from the formation to the well is also related to changes in LNAPL drawdown. This relationship is critical to the generalized Bouwer and Rice method and Cooper, Bredehoeft and Papadopulos method discussed herein. With the effective well radius (see Appendix B), the relationship is written

$$\text{(A.1)} \quad Q_n = \pi r_e^{\,2} \frac{db_n}{dt} = \frac{\pi r_e^{\,2}}{J} \frac{ds_n}{dt}$$

Equation (A.1) states that the LNAPL discharge is equal to the rate of LNAPL accumulation within the well. Andrew Kirkman (personal communication) has suggested that this rate can be generally related to the change in LNAPL drawdown through introduction of a J-ratio parameter. The J-ratio is the slope of the linear relationship between LNAPL drawdown and LNAPL well thickness:

$$\text{(A.2)} \quad J = \frac{\Delta s_n}{\Delta b_n}$$

The magnitude of the J-ratio varies with the nature of LNAPL recharge to the well. If, during a baildown test, LNAPL is removed from the well using a peristaltic pump with no removal of water and the water recovers quickly (i.e., water transmissivity is much greater than LNAPL transmissivity through the well screen), then the water table elevation should remain constant and $J = -(1 - \rho_r)$. If both LNAPL and water are removed during a baildown test, and if the LNAPL transmissivity greatly exceeds the water transmissivity for recharge to the well, then the elevation of the LNAPL-water interface can remain constant and $J = -1$. Values outside of this range are also observed. Three examples are shown in Figure A.1. In case (a) the water table elevation remains constant, and the value $J = -0.244$ is close to $J = –(1 - \rho_r)$ [for this well, $\rho_r = 0.764$]. For case (b), the LNAPL-water interface elevation remains constant and $J = -1.051$. For case (c) the interface elevations increase throughout the recovery period and $J = -2.400$.



(a)

(b)

(c)

Figure A.1. Variation of J-ratio with nature of recharge to the well. (a) J = -0.244; (b) J = -1.051; (c) J = -2.400

Appendix B: Effective Well Radius

During a baildown test the fluid levels in a well are monitored, and it is necessary to relate the LNAPL volume flux, dV_n, into the well to the increase in LNAPL thickness, db_n, or equivalently to the increase in LNAPL head, dh_n, or decrease in LNAPL drawdown, $-ds_n$. By definition of the J-ratio (see Eq. A.2), $ds_n = J\, db_n$. Clearly,

(B.1) $dh_n = dz_{an} = -\, ds_n = -\, J\, db_n$

(B.2) $db_n = dz_{an} - dz_{nw} \rightarrow dz_{nw} = dz_{an} - db_n = -\,(J + 1)\, db_n$

In general during a baildown test, after removal of LNAPL from the well, the air-LNAPL interface elevation increases ($dz_{an} > 0$). However, depending on test conditions, the elevation of the LNAPL-water interface can increase, decrease, or remain constant. This is accounted for through the magnitude of the J-ratio. If the J-ratio magnitude is less than -1, then the elevation of the LNAPL-water interface increases ($dz_{nw} > 0$). Otherwise, if the magnitude of the J-ratio is greater than -1, then the elevation of the LNAPL-water interface decreases ($dz_{nw} < 0$). Finally, if $J = -1$, then the elevation of the LNAPL-water interface remains constant ($dz_{nw} = 0$).

The increase in LNAPL volume within the well (well casing plus filter pack) depends on the location of the LNAPL column within the well. Three cases are shown in Figure B.1. In the first case both z_{an} and z_{nw} are located within the casing. In the second case z_{an} is located within the casing while z_{nw} is located within the screen section of the well with filter pack. Finally, in the third case both z_{an} and z_{nw} are located within the screened section with filter pack. The elevation of top of screen (TOS) and bottom of screen (BOS) are also shown.

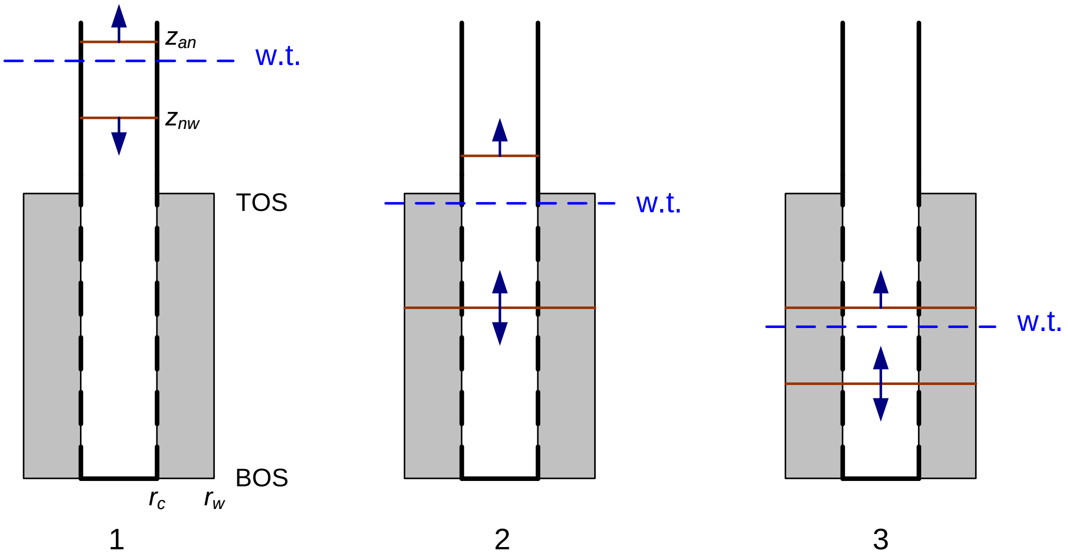


Figure B.1. Three cases showing configuration of LNAPL column in a well

To simplify analysis, it is useful to handle the three cases shown in Figure B.1 with a consistent notation by introducing the effective well radius, r_e. Then for all three cases one has

(B.3) $$dV_n = \pi r_e^2 \, db_n$$

For Case 1 one clearly has

(B.4) $$r_{e1} = r_c$$

Similarly, for Case 3 one has

(B.5) $$r_{e3} = \sqrt{r_c^2 + S_y \left(r_w^2 - r_c^2\right)}$$

Case 2 is a little more subtle. One has

$$dV_n = \pi r_{e1}^2 \left(dz_{an}\right) + \pi r_{e3}^2 \left(-dz_{nw}\right)$$

Using Eqs. (B.1) and (B.2) this may be written

$$dV_n = \pi r_{e1}^2 \left(-J \, db_n\right) + \pi r_{e3}^2 \left(\left(J+1\right) db_n\right)$$

Comparing this result with Eq. (B.3) gives

(B.6) $$r_e = \sqrt{-J \, r_{e1}^2 + \left(J+1\right) r_{e3}^2}$$

Appendix C: Generalized Bouwer and Rice Method

The Bouwer and Rice (1976) method for slug test analysis is based on combining a simple representation for flow to the well from the Thiem equation (steady state radial flow to a well) and continuity of fluids within the well. The flow equation takes the form

$$Q_n = \frac{2\pi T_n s_n}{\ln(R/r_w)} \tag{C.1}$$

Importantly, in Eq. (C.1) it is assumed that the effective radius of influence R is constant, so that there is a linear relation between the discharge Q_n into the well and the LNAPL drawdown s_n. The continuity equation for fluids in the well is problematic only in terms of determining an appropriate effective well radius r_e, as discussed above. With the effective well radius determined and with use of the Kirkman J-ratio, the continuity equation takes the form

$$Q_n = \pi r_e^{\,2} \frac{db_n}{dt} = \frac{\pi r_e^{\,2}}{J} \frac{ds_n}{dt} \tag{C.2}$$

Combining Eqs. (C.1) and (C.2) and integrating gives the generalized Bouwer and Rice formula for determining the LNAPL transmissivity

$$\frac{ds_n}{s_n} = \frac{2\,J\,T_n}{r_e^{\,2}\ln(R/r_w)} dt \quad \rightarrow \quad T_n = \frac{r_e^{\,2}\ln(R/r_w)\ln\left(s_n(0)/s_n(t)\right)}{2(-J)t} \tag{C.3}$$

Appendix D: Cooper and Jacob/Jacob and Lohman Method

Jacob and Lohman (1952) investigated the non-steady flow to a free-flowing well with constant drawdown in an extensive confined aquifer. The model assumes that the well drawdown s_w is constant (= difference between the static head measured during shut-in of the well and the outflow opening of the well). The discharge to the well is given by the following expression

(D.1) $$Q = 2\pi T s_w G(u_w)$$

The function G( ) is the Jacob-Lohman free-flowing discharge function and

(D.2) $$u_w = \frac{r_e{}^2 S}{4Tt}$$

For all but extremely small values of t, Jacob and Lohman state that the function G( ) can be approximated by G ( ) = 2/W( ), where W( ) is the Theis well function. If, in addition, $u_w < 0.01$, the Theis well function may be approximated as follows:

(D.3) $$W(u_w) \cong \ln\left(\frac{0.561}{u_w}\right)$$

Thus Eq. (D.1) becomes

(D.4) $$Q = \frac{4\pi T s_w}{\ln\left(2.25Tt/r_e{}^2 S\right)}$$

Equation (D.4) is the Cooper and Jacob (1946) approximation for the Theis well function for transient flow to a well in a confined aquifer with constant discharge and variable drawdown. Thus we find that Eq. (D.4) approximately applies both for constant drawdown and variable discharge, and for constant discharge and variable drawdown. During a baildown test both the LNAPL drawdown and discharge vary with time. With the C&J method, it is assumed that this relationship holds throughout the recovery period following baildown.

In application for baildown test analysis, Eq. (D.4) can be integrated between times t_i and t_{i+1} to give the volume inflow to the well as follows:

(D.5) $$V(t_i, t_{i+1}) = \int_{t_i}^{t_{i+1}} Q_n \, dt = \int_{t_i}^{t_{i+1}} \frac{4\pi T_n s_n}{\ln\left(2.25T_n t/r_e{}^2 S_n\right)} dt$$

The volume inflow to the well is separately measured (see Eq. 5.2). The calculated inflow volume from the right of Eq. (D.5) depends on the drawdown, which is also separately measured (see Eq. 5.1) and the parameters T_n and S_n. By comparing the measured and calculated cumulative inflow volumes for each time increment, the parameters T_n (and S_n) can be estimated using the method of least squares. The sum-square-difference (SSD) is calculated using

$$SSD = \sum_{J=1}^{N}\left[\sum_{i=1}^{J} Q_{ni}\Delta t_i - \sum_{i=1}^{J}\frac{4\pi T_n s_i}{\ln\left(2.25T_n\left(t_{i+1/2}-\Delta t_a\right)/r_e^{\,2}S_n\right)}\Delta t_i\right]^2 \tag{D.6}$$

In Eq. (D.6), N = number of time increments during the baildown test, $\Delta t_i = t_{i+1} - t_i$, $t_{i+1/2} = (t_i + t_{i+1})/2$, and Δt_a = time adjustment factor that may be applied (see discussion in Section 6.2). The LNAPL transmissivity is estimated by minimizing the SSD in Eq. (D.6).

Fitting of data and estimation of LNAPL transmissivity is based on comparing the measured volume inflow to the well versus the calculated inflow using the Cooper and Jacob equation. It is of some interest to see how the data compares directly with the Cooper and Jacob equation. For this purpose, the ratio Q_n/s_n is plotted as a function of time, as shown in Figure D.1. The red-dashed curve shown in this figure is calculated using the following:

$$\frac{Q_n}{s_n} = \frac{4\pi T_n}{\ln(2.25T_n(t-\Delta t_a)/r_e^{\,2}S_n)} \tag{D.7}$$

In Figure D.1, the vertical dotted and dashed lines show the Time Adjustment Δt_a and cut-off time, respectively. This figure is produced in the lower part of the C&J worksheet.

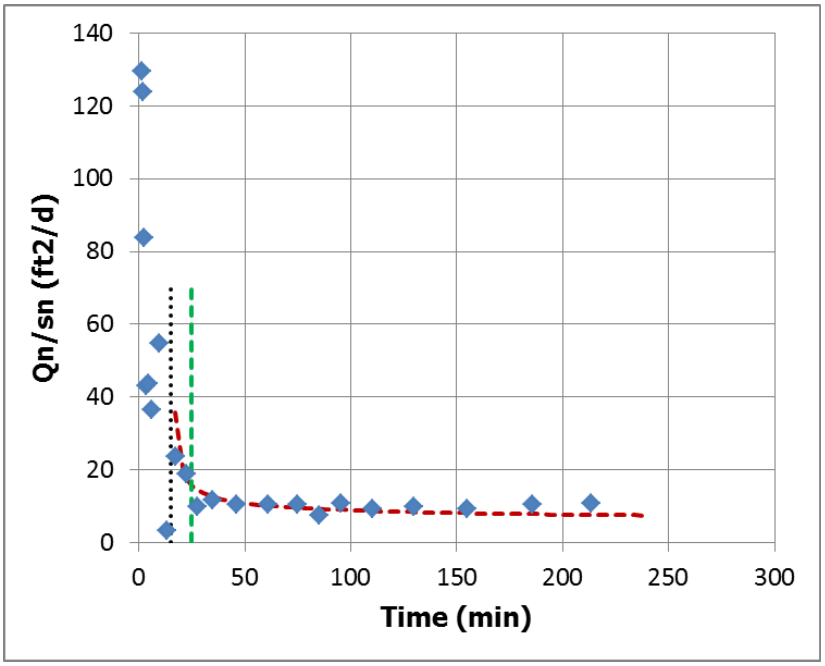


Figure D.1. Comparison of Cooper&Jacob equation with baildown test data. Red-dashed curve = C&J equation; green-dashed line (vertical) = cutoff time; black-dotted line (vertical) = time adjustment

Appendix E: Cooper, Bredehoeft and Papadopulos Method

A third model that can be used to estimate LNAPL transmissivity is based on the work of Cooper, Bredehoeft and Papadopulos (1967). The model assumes that a slug of fluid is added to the casing of a well in a confined aquifer, and the change in fluid levels is monitored. The configuration is shown in Figure E.1. The initial height of the water column above equilibrium, H_0, is related to the volume of water, V_w, added through

(E.1) $$H_0 = \frac{V_w}{\pi r_c^2}$$

The boundary conditions at the well are specified as

(E.2) $$h\left(r_s^+, t\right) = H(t)$$

(E.3) $$2\pi r_s T \frac{\partial h\left(r_s^+, t\right)}{\partial r} = \pi r_c^2 \frac{dH(t)}{dt}$$

The first of these equations states that the formation head just outside of the well screen is equal to the water column head above equilibrium within the well. The second of these equations equates the water volume flux into the formation to the change in water volume storage within the well casing. The following solution is presented by Cooper et al. (1967):

(E.4) $$\frac{H(t)}{H_0} = F\left(\frac{r_s^2 S}{r_c^2}, \frac{Tt}{r_c^2}\right)$$

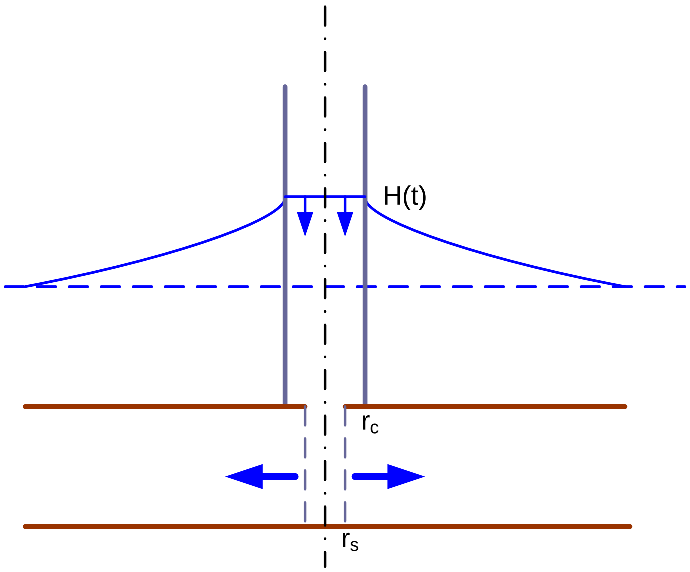


Figure E.1. Configuration for the Cooper et al. (1967) slug test

When applied to LNAPL in a well, the form of Eq. (E.4) and the boundary conditions specified by Eqs. (E.2) and (E.3) must be modified. Cooper et al. (1967) use the casing radius r_c in calculation of changes in well-bore storage. The screen radius r_s is used to designate the (radial) location where the LNAPL head (or drawdown) in the well-bore is equal to that in the formation. In analysis of LNAPL bail-down tests the effective radius r_e plays the same role as r_c. The presence of the filter pack in a bail-down test makes identification of an equivalent radius to r_s less obvious. A simple assumption is that r_e plays an equivalent role to r_s as well. Furthermore, the solution is written in term of the LNAPL drawdown, s_n. With Eq. (A.1), the boundary condition Eq. (E.3) can be written

(E.5) $$Q_n = -2\pi r_e T_n \frac{\partial s_n}{\partial r} = \pi r_e{}^2 \frac{db_n}{dt} = \frac{\pi r_e{}^2}{J}\frac{ds_n}{dt}$$

These changes imply that Eq. (E.4) must be modified to

(E.6) $$\frac{s_n(t)}{s_n(0)} = F\left(S_n, \frac{(-J)T_n t}{r_e{}^2} \right)$$

Using the LNAPL drawdown (s_{ni}) versus time (t_i) data, a measure of how well the model fits the data is provided by the sum-square error specified by

(E.7) $$\sum_{i=1}^{N} \left[\frac{s_{ni}(t_i)}{s_n(0)} - F\left(S_n, \frac{(-J)T_n t_i}{r_e{}^2} \right) \right]^2$$

In Eq. (E.7), the summation is over all data included in the analysis.

Appendix F: Confined LNAPL

Figure F.1 (a) shows LNAPL confined beneath a fine-grain soil layer. The initial LNAPL thickness in an observation well, b_{nR}, depends on the water table elevation, z_{aw}, the LNAPL/water density ratio, ρ_r, and the initial elevation of the confined LNAPL-water interface in the formation and well, z_{nw}. During a baildown test the LNAPL discharge from the formation to the well is expected to initially be large, associated with rapid drainage of the filter pack and immediate well vicinity, and then the discharge should reach a constant magnitude that is determined by the radial LNAPL head difference experienced by the confined LNAPL. This head difference is equal to $(1 - \rho_r)(b_{nR} - b_{nW})$, and remains constant until the LNAPL column thickness in the well $b_n = b_{nW}$. For $b_n > b_{nW}$, the LNAPL head difference equals $(1 - \rho_r)(b_{nR} - b_n)$, and this magnitude decreases to zero ($b_n \rightarrow b_{nR}$) with further LNAPL inflow to the well. For this analysis it is assumed that the water table elevation remains constant and $J = -(1 - \rho_r)$. This is reasonable because for LNAPL under confined conditions, it is expected that the water transmissivity of the well will be much greater than the LNAPL transmissivity.

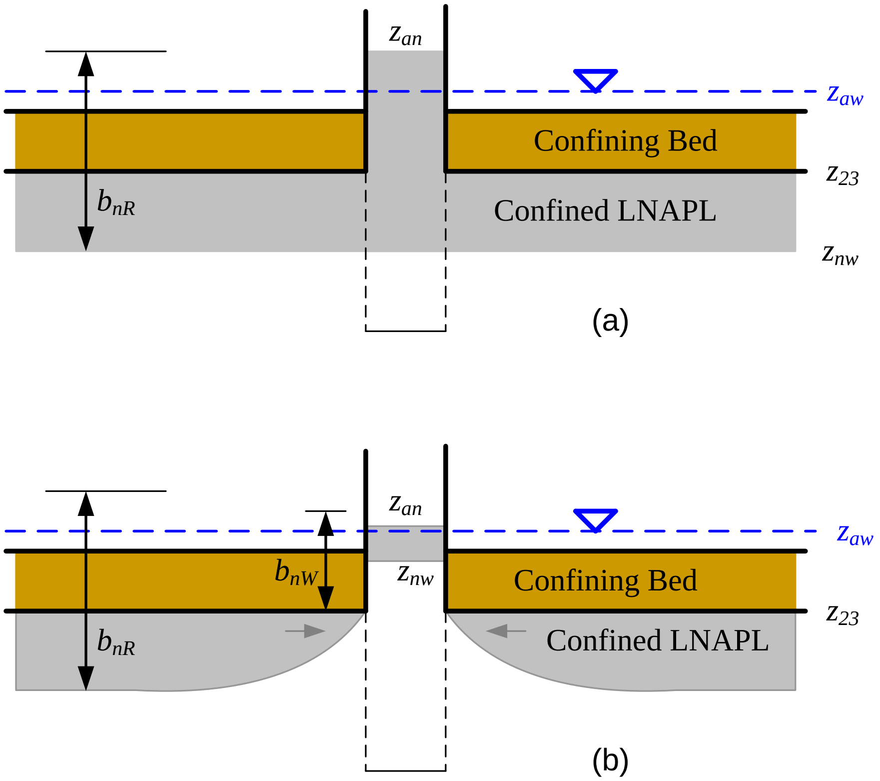


Figure F.1 Confined LNAPL conditions

The constant LNAPL discharge magnitude Q_n for the period with $b_n < b_{nW}$ can be used to estimate the LNAPL transmissivity:

(F.1)
$$T_n = \frac{Q_n \ln(R/r_w)}{2\pi(1-\rho_r)(b_{nR} - b_{nW})}$$

With the configuration shown in Figure F.1, the limiting effective well thickness is

(F.2)
$$b_{nW} = \frac{z_{aw} - z_{23}}{\rho_r}$$

The corresponding LNAPL drawdown is

(F.3)
$$s_{nW} = (1-\rho_r)\left(b_{nR} - \left(\frac{z_{aw} - z_{23}}{\rho_r}\right)\right)$$

Figure F.1 (b) shows the well and LNAPL configuration under conditions with $b_n < b_{nW}$, and suggests that the effective LNAPL thickness at the well is equal to b_{nW}. Actually, under these cut-off conditions for the LNAPL column in the well, there will be a seepage face extending downward from the facies contact at elevation z_{23}. The thickness of the seepage face is unknown, but it may be anticipated that the limiting effective LNAPL thickness at the well might be greater than calculated using Eq. (F.2). Correspondingly, the effective elevation z_{23} as determined from the plot of z_{nw} (DTW) vs. LNAPL discharge (Fig. 6 on the "Figures" worksheet) might have a lower elevation from that estimated using a geologic log.

Appendix G: Perched LNAPL

Figure G.1 shows LNAPL perched upon a low-permeability unit. Analysis of perched LNAPL is essentially the same as that for confined LNAPL. The initial depth to product is DTP_0 and the depth to the top of the perching layer is DZ_{12} (the top of the perching layer is at elevation z_{12}). During a baildown test the LNAPL discharge from the formation to the well is expected to initially be large, associated with rapid drainage of the filter pack and immediate well vicinity, and then the discharge should reach a constant magnitude that is determined by the radial LNAPL head difference experienced by the perched LNAPL. This head difference is equal to $DZ_{12} - DTP_0$, and remains constant until the LNAPL column thickness in the well, b_n, increases in magnitude because of LNAPL inflow from the formation, until $z_{an} = z_{12}$. For $z_{an} > z_{12}$, the LNAPL head difference equals $DTP - DTP_0$, and this magnitude decreases to zero ($DTP \rightarrow DTP_0$) with further LNAPL inflow to the well.

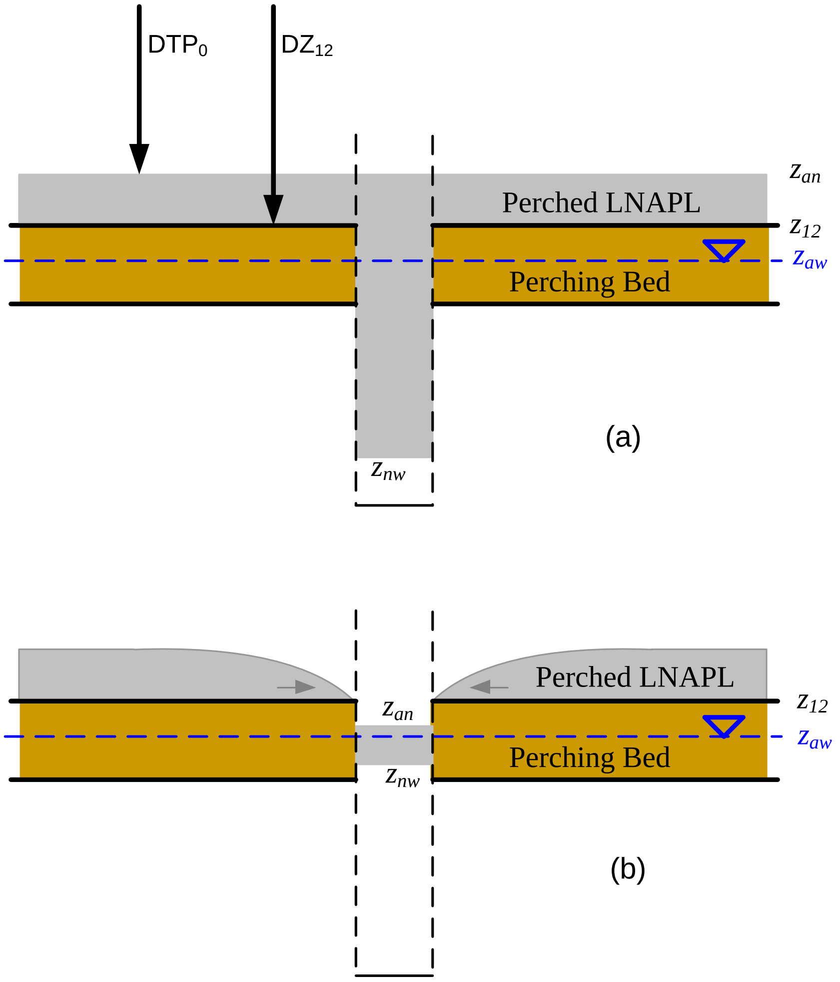


Figure G.1. Perched LNAPL conditions

The constant LNAPL discharge magnitude Q_n for the period with $DTP > DZ_{12}$ can be used to estimate the LNAPL transmissivity:

(G.1)
$$T_n = \frac{Q_n \ln\left(R/r_w\right)}{2\pi\left(DZ_{12} - DTP_0\right)}$$

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APPENDIX G

Health and Safety Plan

PROJECT-SPECIFIC HEALTH AND SAFETY PLAN

Property Name:	Texaco Strickland Cleanup Site		
Project Number:	180357		
Prepared By:	Andrew Yonkofski	Date:	10/04/18
Reviewed By:	Bob Hanford	Date:	

1 INTRODUCTION

This project-specific health and safety plan establishes procedures and practices to protect employees of Aspect Consulting, LLC (Aspect) from potential hazards posed by field activities at the subject site. In this health and safety plan, measures are provided to minimize potential exposure, accidents, and physical injuries that may occur during daily activities and adverse conditions. Contingency arrangements are also provided for emergency situations.

2 EMERGENCY CONTACT INFORMATION

PROPERTY LOCATION	6808 196th Street SW Lynwood, WA 98036
NEAREST HOSPITAL	Swedish Edmonds Campus 21601 76th Ave W Edmonds, WA 98026 **Field staff will review route to the nearest hospital and either print directions or have directions available on their smartphone, tablet, or GPS device.**
EMERGENCY RESPONDERS	Police, Ambulance, Fire ……………………………………….**911**
OTHER CONTACTS	Bob Hanford (mobile) ……………………………..(206) 276-9256 Aspect, Seattle Office ……………………………(206) 328-7443
IN EVENT OF EMERGENCY, CALL FOR HELP AS SOON AS POSSIBLE	Give the following information: ✓ **Where You Are:** address, cross streets, or landmarks ✓ **Phone Number** you are calling from ✓ **What Happened:** type of accident, injury ✓ **How Many Persons** need help ✓ **What is Being Done** for the victims ✓ **You Hang Up Last:** let whomever you called hang up first

In case of serious injuries or other emergency, immediately call Bob Hanford, Aspect Corporate Safety Officer, at (206) 780-7729 or (206)-276-9256. If no response, call Doug Hillman at (206) 328-7443 or Tim Flynn at (206) 780-9370.

3 PERSONNEL ORGANIZATION AND CHAIN OF COMMAND

The Aspect Project Manager assigns the Site Safety Supervisor and other field personnel for this project, and has ultimate responsibility for developing this project-specific health and safety plan and ensuring it is complied with during project execution. The Aspect Site Safety Supervisor has responsibility and authority for Aspect employees' safety during site activities. Other Aspect personnel on site have the responsibility to comply with this project-specific health and safety plan in coordination with the Site Safety Supervisor.

Aspect Personnel			
Role	**Name**	**Office Phone**	**Mobile/Cell Phone**
Project Manager	Chip Goodhue	206-838-6582	206-778-7022
Site Safety Supervisor	Andrew Yonkofski	206-413-5411	404-272-3488
Other Aspect Field Personnel			

Aspect will inform its subcontractors working onsite of potential fire, explosion, health, safety or other hazards associated with planned site activities, and can make available to them this project-specific health and safety plan. **However, all subcontractors are solely responsible for preparation of their own health and safety plan, and for the safety of their employees.**

4 SITE CONTROL PLAN

4.1 Property Description

Property Name:	Texaco Strickland Cleanup Site	
Property Location or Address:	6808 196th Street SW Lynwood, WA 98036	
Owners/Tenants:	Strickland Properties / Aloha Café	
Current Property Use: **Past Use of Property (if different):**	Restaurant Service station, lube oil facility	
Designated Hazardous Waste Site?	(yes or no) NO	If yes, specify federal, state, or other:
Industrial Site?	NO	
Topography:	Generally flat	
Surround Land Use/Nearest Population:	Residential and commercial	
Drinking Water/Sanitary Facilities:	Water and restrooms are available at the Aloha Café building	
Site Map:	See attached Site Map	

4.2 Site Access Control

Describe controls to be used to prevent entry by unauthorized persons:

- The site has no barrier to unauthorized persons.
- Field vehicles, traffic cones, barriers, and caution tape will be used as appropriate to keep persons away from wells and potentially contaminated groundwater during sampling.

Describe how exclusion zones and contamination reduction zones will be designated:

- The area immediately surrounding each monitoring well being sampled will be considered an exclusion zone at the time of purging/sampling.
- Aspect field personnel will remain vigilant about preventing unauthorized persons from approaching the exclusion zone.

4.3 Worker Hygiene Practices

Aspect personnel will use the following hygiene practices while working on site:

- No person will eat, drink, chew gum or tobacco in potentially contaminated areas. Drinking of replacement fluids for heat stress control will be permitted only in areas that are free from contamination, except in emergency situations.
- Smoking is prohibited except in designated areas of the site.
- Long hair will be secured away from the ace so that it does not interfere with any activities.
- All personnel leaving potentially contaminated areas will wash their hands and face prior to entering any eating areas.
- Personnel leaving potentially contaminated areas will shower (including washing hair) and change to clean clothing as soon as practical after leaving the property.

4.4 Emergency Communications

Aspect workers on site will have a mobile (cell) phone on site, which will be used for communications should an emergency arise. Phone numbers for Aspect site personnel are listed in Section 3: Personnel Organization and Chain of Command.

4.5 Nearest Medical Assistance

FIRST CALL 911. The route from the site to the nearest hospital is available via a smartphone, tablet, or GPS device. The address of the nearest hospital is provided in Section 2: Emergency Contact Information.

5 SITE WORK PLAN

Proposed Work Activities On Site:	• Task 2 – Geophysical Survey • Task 3 – Subsurface Borings and Monitoring Well Installation • Task 4 – Soil Vapor Sampling • Task 5 – Soil and Groundwater Analysis • Task 7 – LNAPL Recovery Testing
Objectives of Site Activities:	• Identify presence of pre-1977 underground service station infrastructure • Determine lateral and vertical extents of Site soil impacts. • Determine lateral extents of Site groundwater impacts. • Determine LNAPL recoverability • Assess soil vapor migration
Proposed Work Dates:	*TBD*
Will On-site Personnel Potentially be Exposed to Hazardous Substances?	If yes, describe: Groundwater and soil may contain petroleum hydrocarbons and aromatic volatile organic compounds such as benzene.
Do Personnel Conducting Site Activities have Training in Accordance with WAC 296-843-200?	Yes

6 DECONTAMINATION

Goals	Procedures
To prevent the distribution of contaminants outside the exclusion zone or cross-contamination of samples, the following procedures will be used to decontaminate sample equipment.	• Decontamination process involving Alconox wash and tap water rinse (with air dry).
To minimize or prevent worker exposure to hazardous substances, all personnel working in the exclusion zone and contamination reduction zones will comply with the following decontamination procedures:	• Wash boots and rain gear that have come into contact with soil or groundwater with Alconox/tap water and air dry. • Collect disposable personal protective equipment (PPE such as gloves, Tyvek) in garbage bags and dispose of in the trash upon return from the field. • To prevent distribution of contaminants outside the exclusion zone, do not allow unnecessary vehicles inside the exclusion zone.
Investigation derived waste will be managed in the following manner:	• Place soil cuttings, decon water, and purged groundwater into DOT-approved 55-gallon drums at the property for future disposal. Each drum should be secured with a locking lid and labeled with the date of sampling and contents.

7 HAZARD ANALYSIS

The potential hazards and corresponding control measures for planned site work activities are as follows:

Work Activity	Primary Potential Hazards	Control Measures
All	• Chemical exposure (skin contact, ingestion).	• Modified Level D PPE • Securely join pump tubing and other connectors.
	• Vehicle traffic	• Wear traffic vest. • Stay back from roads and stay alert • Position field vehicle in a protective position.
	• Cold Stress	• Wear layered clothing, take breaks.
	• Heat Stress	• Take breaks, seek shade, and increase fluid intake.

Potentially Hazardous Chemicals Known or Suspected at the Property and Permissible Exposure Limits (air)					
Substance	**Medium**	**OHSA PEL**	**OSHA STEL**	**IDLH**	**Carcinogen or Other Hazard**
Gasoline-Range Petroleum	Soil, GW	10 ppmv	15 ppmv	250 ppmv	T
Diesel- and Oil-Range Petroleum	Soil, GW	1 ppmv	5 ppmv	500 ppmv	T
Benzene	Soil, GW	1 ppmv	5 ppmv	500 ppmv	C
Toluene	Soil, GW	200 ppmv	--	500 ppmv	T
Ethylbenzene	Soil, GW	100 ppmv	--	800 ppmv	T
Xylenes	Soil, GW	100 ppmv	150 ppmv	900 ppmv	T
Heavy Metals, lead	Soil, GW	Pb: 0.05 mg/m^3	Pb: --	Pb: 0.05 mg/m^3	

Notes:
-- = none established
C = carcinogen
cPAH = carcinogenic polycyclic aromatic hydrocarbon
GW = groundwater
IDLH = immediately dangerous to life or health
N/A = not applicable/not available
OHSA = Occupational Safety and Health Administration
T = toxic
PCB = polychlorinated biphenyl
PEL = permissible exposure level (8-hour time-weighted average)
STEL = short-term exposure level

Chemicals Known or Suspected On-site (check box)			
Chemical Class	**Known**	**Possible**	**Unlikely**
Corrosive (if expected, specify)			x
Ignitable (if expected, specify)		x	
Reactive			x
Volatile	x		
Radioactive			x
Explosive			x
Biological Agent			x
Particulate or Fibers			x
If known or likely, describe:			

8 PERSONAL PROTECTIVE EQUIPMENT

Based on the hazards identified above, the following personal protective equipment (PPE) will be required for the following field activities. This section specifies both an initial level of protection and a more protective (contingency) level or protection, in the event conditions should change. The contingency defines the PPE that will be available on site.

Work Activity	Level of Protection	
	Initial	Contingency
Drilling	D	Mod. D
Sample handling	D	Mod. D
Other activities (list):		

Each level of protection will incorporate the following equipment (specify type of protective clothing, boots, gloves, respiratory cartridges or other protection, safety glasses, hardhat, and hearing protection):

Level of Protection	Specific PPE
Level D	Work clothing, traffic vest, rubber (nitrile) gloves, steel toe and shank boots, safety glasses, hearing protection, and hardhat.
Modified D	Level D plus Tyvek coveralls or rain gear, and neoprene outer gloves.

NOTE: Project personnel are not permitted to deviate from the specified levels of protection without the prior approval of the Site Safety Supervisor. A traffic vest is not needed if work clothes are suitably visible (e.g., orange/yellow rain gear or white/yellow chemical protective clothing).

9 AIR MONITORING

Air monitoring is not required.

10 SAFETY EQUIPMENT

The following safety equipment will be on site during the proposed field activities:

Other Required Items (check items required)	
First aid kit	x
Eyewash (e.g., bottled water)	x
PID	x
Drinking water	x
Fire extinguisher	x
Brush fan	
Wind sox	
Other:	

11 SPILL CONTAINMENT

Will the proposed field work include the handling of bulk chemicals?	Yes	No X
If yes, describe spill containment provisions for the property:		

12 CONFINED SPACE ENTRY

Will the proposed field work include confined space entry?	Yes	No X
If yes, attach to this plan the confined space entry checklist and permit.		

13 ASPECT TRAINING AND MEDICAL MONITORING

Aspect employees who perform site work are responsible for understanding potential health and safety hazards of the site. All Aspect site workers will have health and safety training for hazardous waste operations, in accordance with WAC 296-843-200. In addition, Aspect requires medical monitoring for all employees potentially exposed to chemical hazards in concentrations in excess of the permissible exposure limit (PEL) for more than 30 days per year, as required under WAC 296-843-210. Employees who use respirators for their work will have a respirator medical evaluation as required under Chapter 296-842-WAC.

14 DISCLAIMER

Aspect Consulting, LLC does not guarantee the health or safety of any person entering this property. Because of the potentially hazardous nature of this property and the activity occurring thereon, it is not possible to discover, evaluate, and provide protection for all possible hazards that may be encountered. Strict adherence to the health and safety guidelines set forth herein will reduce, but not eliminate, the potential for injury and illness at this property. The health and safety guidelines in this plan were prepared specifically for this site and should not be used on any other property without prior evaluation by trained health and safety personnel.

Aspect
CONSULTING

FIELD SAFETY PLAN CONSENT AGREEMENT

Aspect Consulting Employees

I have reviewed the project specific health and safety plan, dated *January 11, 2017* for the Ohop Valley Grocery groundwater sampling fieldwork. I understand the purpose of the plan and I consent to adhere to its procedures and guidelines while conducting activities on site that are described in the plan.

Employee Printed Name	Signature	Date

Site Visitors

I have been briefed on the contents of the project-specific health and safety plan. I am responsible for my own health and safety.

Visitor Printed Name and Organization/Company	Signature	Date

Aspect
CONSULTING

FIELD SAFETY MEETING MINUTES

Site Name ______________________________________**Project No.** ______________________

Meeting Location ____

Meeting Date _____________ **Time** ________________ **Conducted by**____________________

Pre-field Work Orientation______ **Weekly Safety Meeting**________ **Other**________________

Subject Discussed ____

____

____

____

Site Safety Supervisor Comments ____

____

____

____

Participants

Printed Name (and company if subcontractor)	Signature

APPENDIX H

Report Limitations and Guildelines for Use

REPORT LIMITATIONS AND USE GUIDELINES

Reliance Conditions for Third Parties

This report was prepared for the exclusive use of the Client. No other party may rely on this report or the product of our services without the express written consent of Aspect Consulting, LLC (Aspect). This limitation is to provide our firm with reasonable protection against liability claims by third parties with whom there would otherwise be no contractual conditions or limitations and guidelines governing their use of the report. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and recognized standards of professionals in the same locality and involving similar conditions.

Services for Specific Purposes, Persons and Projects

Aspect has performed the services in general accordance with the scope and limitations of our Agreement. This report has been prepared for the exclusive use of the Client and their authorized third parties, approved in writing by Aspect. This report is not intended for use by others, and the information contained herein is not applicable to other properties.

This report is not, and should not, be construed as a warranty or guarantee regarding the presence or absence of hazardous substances or petroleum products that may affect the subject property. The report is not intended to make any representation concerning title or ownership to the subject property. If real property records were reviewed, they were reviewed for the sole purpose of determining the subject property’s historical uses. All findings, conclusions, and recommendations stated in this report are based on the data and information provided to Aspect, current use of the subject property, and observations and conditions that existed on the date and time of the report.

Aspect structures its services to meet the specific needs of our clients. Because each environmental study is unique, each environmental report is unique, prepared solely for the specific client and subject property. This report should not be applied for any purpose or project except the purpose described in the Agreement.

This Report Is Project-Specific

Aspect considered a number of unique, project-specific factors when establishing the Scope of Work for this project and report. You should not rely on this report if it was:

- Not prepared for you
- Not prepared for the specific purpose identified in the Agreement
- Not prepared for the specific real property assessed
- Completed before important changes occurred concerning the subject property, project or governmental regulatory actions

If changes are made to the project or subject property after the date of this report, Aspect should be retained to assess the impact of the changes with respect to the conclusions contained in the report.

Geoscience Interpretations

The geoscience practices (geotechnical engineering, geology, and environmental science) require interpretation of spatial information that can make them less exact than other engineering and natural science disciplines. It is important to recognize this limitation in evaluating the content of the report. If you are unclear how these "Report Limitations and Use Guidelines" apply to your project or site, you should contact Aspect.

Discipline-Specific Reports Are Not Interchangeable

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually address any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding the subject property.

Environmental Regulations Are Not Static

Some hazardous substances or petroleum products may be present near the subject property in quantities or under conditions that may have led, or may lead, to contamination of the subject property, but are not included in current local, state or federal regulatory definitions of hazardous substances or petroleum products or do not otherwise present potential liability. Changes may occur in the standards for appropriate inquiry or regulatory definitions of hazardous substance and petroleum products; therefore, this report has a limited useful life.

Property Conditions Change Over Time

This report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time (for example, Phase I ESA reports are applicable for 180 days), by events such as a change in property use or occupancy, or by natural events, such as floods, earthquakes, slope failure or groundwater fluctuations. If more than six months have passed since issuance of our report, or if any of the described events may have occurred following the issuance of the report, you should contact Aspect so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

Phase I ESAs – Uncertainty Remains After Completion

Aspect has performed the services in general accordance with the scope and limitations of our Agreement and the current version of the “Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process”, ASTM E1527, and U.S. Environmental Protection Agency (EPA)'s Federal Standard 40 CFR Part 312 "Innocent Landowners, Standards for Conducting All Appropriate Inquiries".

No ESA can wholly eliminate uncertainty regarding the potential for recognized environmental conditions in connection with subject property. Performance of an ESA study is intended to reduce, but not eliminate, uncertainty regarding the potential for environmental conditions affecting the subject property. There is always a potential that areas with contamination that were not identified during this ESA exist at the subject property or in the study area. Further evaluation of such potential would require additional research, subsurface exploration, sampling and/or testing.

Historical Information Provided by Others

Aspect has relied upon information provided by others in our description of historical conditions and in our review of regulatory databases and files. The available data does not provide definitive information with regard to all past uses, operations or incidents affecting the subject property or adjacent properties. Aspect makes no warranties or guarantees regarding the accuracy or completeness of information provided or compiled by others.

Exclusion of Mold, Fungus, Radon, Lead, and HBM

Aspect’s services do not include the investigation, detection, prevention or assessment of the presence of molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts. Accordingly, this report does not include any interpretations, recommendations, findings, or conclusions regarding the detection, assessment, prevention or abatement of molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts. Aspect’s services also do not include the investigation or assessment of hazardous building materials (HBM) such as asbestos, polychlorinated biphenyls (PCBs) in light ballasts, lead based paint, asbestos-containing building materials, urea-formaldehyde insulation in on-site structures or debris or any other HBMs. Aspect’s services do not include an evaluation of radon or lead in drinking water, unless specifically requested.