PENNSYLVANIA LAND RECYCLING PROGRAM
SITE CHARACTERIZATION REPORT

ARG REFINERY
BRADFORD, PENNSYLVANIA

July 2007

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ES1.0 EXECUTIVE SUMMARY

On behalf of Crompton Corporation, Conestoga-Rovers & Associates (CRA) has prepared this Site Characterization Report (SCR) for the American Refining Group (ARG) Refinery facility (formerly owned by Crompton-Witco Corporation) in Bradford, Pennsylvania. The report has been prepared in response to the Consent Order and Agreement dated June 8, 2004, which has been executed between the Commonwealth of Pennsylvania Department of Environmental Protection (PADEP), Crompton Corporation, and ARG. It is noted that on July 1, 2005 Crompton Corporation changed its name to Chemtura Corporation.

This Site Characterization Report (SCR) has been prepared in accordance with:

i) the outline that was described in the submission to PADEP entitled "Pennsylvania Land Recycling Program – Supplemental Site Delineation Work Plan" (SSD Work Plan) dated September 2003 (revised January 15, and February 19, 2004), approved by PADEP on June 10, 2004 and the responses dated February 28, May 18, and June 10, 2005 to PADEP comments received on the draft SCR submitted in June 2004;

ii) the responses and additional evaluations/documents submitted November 22 and December 2, 13, and 16, 2005, January 13 and 27, February 1, July 17, August 23 and September 22, 2006, and July 6, 2007 to PADEP comments received on the revised draft SCR and Baseline Human Health Risk Assessment (HHRA) submitted in July 2005;

iii) the scope of work that was described in the submission to PADEP entitled "Work Plan, Step 3-Problem Formulation, Ecological Risk Assessment" (Step 3 ERA Work Plan), dated October 17, 2005 (revised June 2 and 26, 2006) and approved by PADEP on June 26, 2006; and

iv) the scope of work that was described in the submission to PADEP entitled "Work Plan for SPL on National Transit and Surrounding Properties" (Off-Site SPL Work Plan), dated August 12, 2005 and the discussions held during the on-Site meeting of November 1, 2005 to address the PADEP comments dated October 3, 2005.

This SCR:

i) meets the objective of 25 Pa. Code §245.309 and 25 PA. Code §250.408;

ii) contains the elements set forth in 25 Pa. Code §245.310 and 25 Pa. Code §250.408;

iii) complies with 25 Pa. Code §93.6 and 25 Pa. Code §96.3 relating to the general surface water quality criteria and water quality protection requirements for all areas of the Property;

iv) complies with the applicable provisions of the storage tank regulations (Chapter 245);

v) meets the objectives of the U.S. Environmental Protection Agency's RCRA Corrective Action Environmental Indicator goals at American Refining's EPA sites PAD001604693, PAD000780171, and PAD000651281.

This SCR builds upon the base established by previous studies that have been performed at the Site.

A Screening Level Ecological Risk Assessment (SERA) (CRA, 2007) and Human Health Risk Assessment (HHRA) (CRA, 2007) were performed in support of this SCR. Both of these assessment reports are submitted under separate cover and summarized in this report.

ES1.1 SITE DESCRIPTION

The Site is an active refinery located in the City of Bradford and in Foster Township of McKean County, as shown in Figure ES.1.1. The refinery has been in operation since the 1890s, making it the oldest active refinery in the United States. The Site occupies approximately 131 acres along a 1.5 mile stretch of Tunungwant Creek.

The Site is divided into four major areas (see Figure ES.1.2) which are used to describe the facility throughout this report. These four areas are:

i) Main Refinery (MR);

ii) Crude Tank Farm (CTF);

iii) Foster Brook Facility (FBF); and

iv) Packaging Plant (PP).

The refinery operations consist of five processing units, approximately 375 feedstock and product above ground storage tanks (ASTs), a main office building, a refinery office building, research and control laboratories, warehouse buildings, and maintenance buildings. Products manufactured at the Site include various lubricating oils, specialty products, and gasoline. Currently the Site has a cumulative storage capacity of

approximately 57,000,000 gallons and a crude oil throughput of 10,000 barrels per stream day (BPSD). The Site receives crude oil by truck, railroad, and pipeline from the Pennsylvania grade crude oil region.

ES2.0 SITE DESCRIPTION, OPERATIONS, AND HISTORY

ES2.1 SITE HISTORY AND OPERATIONS

Portions of the Site and surrounding area were used for oil exploration and production, even before the Site was first used as a refinery. Various sections of the Site have been owned and operated as a refinery since the late 1800s.

In 1997, the refinery was sold by Crompton to ARG who still owns and operates the Site. In accordance with the sales agreement with ARG, Crompton has retained the environmental liability for past refining activity impacts to soil and groundwater at the Site.

The Refinery refines crude oil and manufactures, packages, stores, and distributes petroleum products in both bulk and packaged forms. The distribution percentages of the products manufactured and distilled from the processed crude oil are as follows:

i) 20% gasolines;

ii) 30% naphtha distillate solvents and Kensols;

iii) 40% finished lubricating oils; and

iv) 10% waxes and heavy fuel oil.

The operations are typical of a refinery and include atmospheric distillation, fractionation, stripping, purification, hydrotreating, various dewaxing operations, maintenance, research and development, storage, packaging, loading, unloading, and distribution. Typical of refinery operations, numerous kettles, tanks, pumps, compressors, heat exchangers, and ASTs are used.

ES2.2 STORAGE AND USE OF CHEMICALS

The Refinery produces gasoline, fuel oil, solvent naphthas distillate solvents, lubricant base oils, waxes and resins, dust control agents, and a variety of other petroleum specialties including shock fluids, camping fuel, asphalt cut back solvents, well treating solvent, extract blends, and quench oils.

ES2.3 ENVIRONMENTAL PERMITS

Current environmental permits for the Site include the following: AST Registration, NPDES Wastewater Discharge Permit, Industrial Wastewater Discharge Permit, Stormwater Discharge Permits, and Air Quality Control permitting for multiple sources.

ES2.4 STORMWATER DRAINAGE

The Plant Site is serviced with a stormwater collection system which is designed to direct select stormwater flows to the Refinery process sewer/oil recovery system (API separator system). There are three API Separators in the Main Refinery. One is located in each of the MEK Unit, Crude Unit, and Dubbs Area of the Refinery. The API Separators pretreat the water to remove floating oil and grease. The API Separator effluent then goes to the onsite Waste Water Treatment Plant (WWTP) which includes an induced air flotation system, biological treatment, and continuous sand filtration prior to discharge to Tunungwant Creek. In addition to the API Separator system for the Main Refinery, there is an API Separator that collects stormwater from the south portion of the Foster Brook Facility and pretreats the water prior to flowing into the two equalization ponds and then discharging to Tunungwant Creek.

The stormwater collection system includes eight stormwater outfalls. One permitted stormwater outfall (002) receives stormwater and treated wastewater and seven permitted stormwater outfalls (004 through 010) receive stormwater only. All of the outfalls discharge into Tunungwant Creek. Tunungwant Creek has been subject to considerable hydraulic improvement projects; most notably the straightening, channelizing, and provision of flood control walls by the Army Corps of Engineers in 1954. The flood control walls are only present in the Main Refinery section of the Site and do not extend through the Crude Tank Farm and Foster Brook Facility. The straightening and channelization work extended through the entire Site. Any incidental stormwater flow not entering the drainage system remains on or in the immediate proximity of the Site where it evaporates or infiltrates the ground surface.

ARG conducts annual stormwater sampling and inspections for all permitted outfalls, per the Facility's NPDES permit No. 0002674 which became effective November 1, 1999.

ES3.0 INVESTIGATIVE ACTIVITIES

ES3.1 INTRODUCTION

The historical investigations that have been conducted at the Site are extensive and provide a very thorough understanding of the Site conditions and the impact of oil product releases over the years on the local environment. Having supplemented the historic data with the additional data that has been collected during the recent study, it is now believed that the understanding of the Site conditions is suitable for moving into the remediation option assessment phase of the regulatory process.

The investigative activities that have been performed to date at the Site can be summarized as follows:

Main Refinery

	# Soil Samples	*# Boreholes/ Soil Sample Locations(1)*	*# Test Pits/ Holes*	*# Wells/ Piezometers*	*# Groundwater Samples*
Historical	266±	130±	0	210±	190±
Supplemental	3	0	0	30	89
Total	269±	130±	0	240±	279±

Crude Tank Farm

	# Soil Samples	*# Boreholes/ Soil Sample Locations(1)*	*# Test Pits/ Holes*	*# Wells/ Piezometers*	*# Groundwater Samples*
Historical	70±	60±	0	30±	50±
Supplemental	13	7	15	14	46
Total	83±	67±	15	44±	96±

Foster Brook Facility

	# Soil Samples	*# Boreholes/ Soil Sample Locations(1)*	*# Test Pits/ Holes*	*# Wells/ Piezometers*	*# Groundwater Samples*
Historical	260±	270±	4	120±	150±
Supplemental	84	93	0	12	44
Total	344±	363±	4	132±	194±

Packaging Plant

	# Soil Samples	# Boreholes/ Soil Sample Locations(1)	# Test Pits/ Holes	# Wells/ Piezometers	# Groundwater Samples
Historical	11±	3±	0	5	14±
Supplemental	0	0	0	5	10
Total	11±	3±	0	10	24±

Tunungwant Creek and Tributaries

	# Surface Water Samples	# Sediment Samples	# Macroinvertebrate Samples
Historical	46±	46±	9
Supplemental	29	0	27
Total	75±	46±	36

(1) Does not include locations where well/piezometer installed.

In accordance with the SSD Work Plan, the following field activities were performed to complete the site characterization:

i) borehole drilling and soil sample collection and analyses (physical and chemical);

ii) groundwater monitoring well installation (52 wells), development, and up to four rounds of groundwater sampling and analyses (September/October 2002, November/December 2003, February/March 2004, and April 2005);

iii) SPL sample collection and analyses (physical and chemical) from 23 locations;

iv) groundwater level and apparent SPL thickness monitoring;

v) SPL bail-down tests at 10 locations;

vi) vadose zone well installation and soil gas collection and analyses at 9 locations;

vii) indoor air and ambient air sample collection and analysis;

viii) profiling of the horizontal wells;

ix) pumping tests in 3 newly installed vertical wells and 4 existing horizontal wells;

x) surface water sample collection and analyses;

xi) macroinvertebrate survey;

xii) wetland delineation and habitat characterization; and

xiii) abandoned underground pipeline investigation, including the 5-inch diameter crude pipeline running from the vicinity of the Custer City Oil facility to ARG's Crude Tank Farm.

The locations of the investigative activities are shown on Figures ES3.1 through ES3.3.

ES4.0 ENVIRONMENTAL SETTING

The current use of the Site is industrial and is expected to remain industrial in the future. Current land uses adjacent to the Site are:

i) vegetated undeveloped land to the north; and

ii) industrial/commercial/residential properties to the east, south, and west.

The Site is located in the Tunungwant Creek Valley. Tunungwant Creek flows northward and is located east of the south portion of the Site, bisects the middle portion, and is west of the Foster Brook Facility. Four tributaries (Kendall Creek, Bolivar Run, Foster Brook, and an unnamed tributary in the CTF) flow into Tunungwant Creek in the vicinity of the Site.

The City of Bradford experiences a humid continental type climate, characterized by large annual and daily temperature changes. The annual average precipitation as measured at the Bradford Airport is approximately 47 inches.

Regional precipitation runoff data for McKean County suggests that average annual runoff is approximately 20 to 25 inches (USGS, 1997). Evapotranspiration for McKean County in the north-central portion of Pennsylvania, where elevations are higher and temperatures are lower, is estimated to be approximately 15 inches. Therefore, annual regional groundwater recharge is estimated to be approximately 7 to 12 inches.

Within the City of Bradford, urban development including stormwater control, greatly reduces infiltration by increasing runoff. Similar storm water controls are present at the Site, including ditching and catchbasins that collect and direct storm water off Site, reducing local infiltration to the water table.

Potable water for the City of Bradford and Foster Township is provided by three man-made reservoirs located on the West Branch of Tunungwant Creek and the tributaries thereto. A City ordinance controls the use of groundwater for potable supply in the vicinity of the Site. However, unless the City notifies the property owner to connect to the City supply, such connection may not occur. There are no groundwater wells used as a community water supply source near the Site. There are also no Zone-2 wellhead protection areas within 1,000 feet of the Site.

ES5.0 HYDROGEOLOGIC SETTING

There are three separate aquifer units underlying the Site. Each is comprised of coarse-grained alluvial and is separated by clay aquitard units. These hydrogeologic units are, in descending order:

i) Upper aquifer: a water table (unconfined) aquifer comprised of the fill material, upper silty sand alluvial unit, and the upper alluvial unit, extending to the top of the upper clay unit;

ii) Upper clay aquitard: comprised of the upper clay unit and forming a lower boundary to the upper aquifer;

iii) Intermediate (second) aquifer: a confined aquifer comprised of the intermediate alluvial unit;

iv) Lower clay aquitard: comprised of the lower clay unit;

v) Lower (third) aquifer: a confined aquifer comprised of the lower alluvial unit; and

vi) Bedrock: comprised of the shale and sandstone bedrock and acting as a lower aquitard to the lower aquifer, and as lateral aquitards to the intermediate and upper aquifers. Small amounts of groundwater may discharge from the bedrock into the overburden aquifer units.

The hydrogeologic unit impacted by activities related to the Site is the Upper Aquifer, an unconfined aquifer generally on the order of 70 feet thick. This unit is underlain by the upper clay aquitard. Upward vertical gradients are present through the upper clay aquitard to the Upper Aquifer, thus preventing any possible impact upon the groundwater below the upper clay aquitard. Furthermore, the upward gradient tends to keep impacted groundwater near the water table surface.

Groundwater flow in the Upper Aquifer discharges to Tunungwant Creek and its tributaries.

The soil within the Upper Aquifer becomes coarser with depth resulting in higher hydraulic conductivities with depth. The combination of:

i) upward gradient in the Upper Aquifer; and

ii) floating SPL,

results in only the upper 10-foot thickness of groundwater in the Upper Aquifer being impacted by constituents attributable to the Site.

ES5.1 GROUNDWATER LEVEL/SEPARATE PHASE LIQUID APPARENT THICKNESS MONITORING

During the Site Characterization Study, three groundwater and SPL thickness measurement events were performed, on all of the available wells at the Site. The measured groundwater levels were corrected to account for the SPL that floats atop the groundwater. These measurement events occurred in March/early April 2003, April 14 to 15, 2003 and December 17 to 19, 2003 for the entire refinery. The measured groundwater levels for December 2003 are provided on Figures ES5.1a through ES5.1c and the apparent SPL thickness on Figures ES5.2a through ES5.2c.

In addition to the groundwater monitoring events that were performed at the Site, a series of pumping tests were also performed. Three vertical well pumping tests and four horizontal well pumping tests were conducted in September 2003 to assess the effectiveness of vertical and horizontal wells on the containment and removal of SPL. The tests showed that:

i) Pumping in the area of an SPL plume causes a depression in the groundwater table which, in the area of an SPL plume, results in SPL flowing to the well and the accumulation of greater thicknesses of SPL within the depression. The greater SPL thickness results in more effective SPL removal.

ii) The overlapping influences of pumping all of the horizontal wells provides significantly more drawdown than the pumping of an individual well. This results in more effective prevention of SPL and associated impacted groundwater migration to Tunungwant Creek.

ES5.2 PIPELINE INVESTIGATIONS

As part of the Site Characterization Study, the abandoned underground pipelines were investigated to determine their integrity, identify pipeline contents (if any), inspect the adjacent and underlying soils for visual impact, and verify the adequacy of the pipeline abandonment methods used. The investigations showed that:

i) the abandoned underground pipelines, including the Duke Center crude oil pipeline, were structurally in good condition;

ii) the abandoned pipelines on the Site contained clean water. No indication of product was observed in the water samples;

iii) no indication of leakage from the pipelines was observed in the soils at the investigation locations; and

iv) the abandonment techniques were adequate to prevent future releases from the abandoned pipelines.

ES6.0 CHEMICAL SITE CHARACTERIZATION

In order to evaluate the chemical data collected during the Site Characterization Study, the data have been grouped into geographic areas at the Site that match the environmental Exposure Units (EUs) developed for the Site. Each of the environmental Exposure Units has its own unique characteristics and usage patterns which must be taken into consideration in assessing the data.

As appropriate, all of the analytical data have been screened by comparing the measured concentrations to the applicable and appropriate guidance values established by PADEP for the various media. The analytical results for the groundwater and soil media were compared to the most stringent PADEP Chapter 25, Act 2 Statewide Health Standard (SHS) Medium Specific Concentrations (MSCs) for each chemical analyzed. The appropriate SHS MSC for groundwater was selected from PADEP Title 25, Chapter 250, Appendix A, Tables 1 and 2, based on the following:

i) the groundwater underlying the Site was determined to be used;

ii) the groundwater's total dissolved solids concentration is <2,500 mg/L; and

iii) the land use is Non-Residential (NR).

The appropriate SHS MSC for soil was selected from PADEP Title 25, Chapter 250, Appendix A, Tables 3 and 4, based on the following:

i) most stringent MSC for Direct Contact Numeric Values and Soil to Groundwater Numeric Values;

ii) the land use is Non-Residential (NR);

iii) the groundwater underlying the aquifer is used; and

iv) the groundwater's total dissolved solids concentration is <2,500 mg/L.

For soils, the results were segregated into 3 intervals:

i) surface soil (0 to 2 ft bgs);

ii) unsaturated soil (2 ft bgs to the seasonally high groundwater table or a maximum of 15 ft bgs, whichever occurred first); and

iii) saturated soil (from the seasonally high groundwater table to 15 ft bgs).

For saturated soils, the standard used was 1/10th of the generic value for the appropriate parameters.

The appropriate SHS MSC for surface water was selected based on the most stringent of the following:

i) residential groundwater SHS MSC; and

ii) Chapter 16, Table 1, Water Quality Criteria.

For sediment, residential direct contact Act 2 criteria were used.

All of the data collected during the Site Characterization Study were QA/QC validated prior to use and found to be acceptable for almost all uses. To the extent that QA/QC information was available, it was also possible to validate the majority of the historic data. In most cases, the historical data were deemed acceptable. For some of the older reports, the QA/QC information was not available and therefore, a meaningful validation of the data from these reports could not be made. In general, this SCR relies primarily upon the most recent data, all of which has been evaluated for QA/QC. Consequently, the conclusions drawn from the data are valid. The unvalidated historical data has simply been used where necessary to fill minor gaps in the recent data set or to provide an indication of expected trends.

ES6.1 CHEMICAL CHARACTERIZATION SUMMARY

For the discussions provided in the subsequent sections, the following descriptions are used:

i) low level exceedances are ≤5 times the SHS MSC;

ii) moderate exceedances are >5 to ≤50 times the SHS MSC; and

iii) significant exceedances are >50 times the SHS MSC.

Groundwater locations which had exceedances of different levels on different dates were assigned the higher level in the following discussion.

ES6.1.1 ENTIRE SITE

Significant iron and manganese exceedances occur throughout the groundwater underlying and upgradient of the Site. These conditions are believed to be typical for the area although the Site has caused some increase of the iron and manganese concentrations beneath the Site. There are no applicable SHS MSCs for iron or manganese in soil. In general, the concentrations of iron and manganese in groundwater are holding constant or slowly decreasing with time. These two parameters are not further discussed in the following sections.

ES6.1.2 MAIN REFINERY (EXPOSURE UNIT 1)

	Number of Locations with Exceedances (1)			
Media	*Groundwater*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	21 to 87	10 to 12	84 to 98	93 to 112
Non-Chlorinated VOCs	7/10/4	1/0/0	9/1/0	11/3/0
Chlorinated VOCs	3/0/0	0/0/0	0/0/0	0/0/0
PAHs	7/4/4	0/0/0	5/0/0	6/1/0(3)
Arsenic	37/0/0(2)	0/0/0	0/0/0	13/0/0
Other Metals	3/4/2(2)	2/0/0(4)	3/0/0	27/3/0

(1) 7/4/4 = number of locations with low level/moderate/significant exceedances.
(2) Dissolved Metals
(3) Excluding naphthalene which is included in Non-Chlorinated VOCs.
(4) Background concentration for lead greater than on-Site exceedance.

Number of SPL Plumes : 16 (SPL-1 through SPL-15 and SPL-29)
Volume of SPL based on Corrected Thickness : 55,200 gallons

The above shows that much of the groundwater and saturated soil underlying the Main Refinery has been impacted by non-chlorinated VOCs, PAHs, and arsenic. The areas of greatest impact are those beneath or downgradient of SPL plumes. In general, the groundwater PAH concentrations are decreasing with time while the non-chlorinated VOCs are holding constant or decreasing with time.

ES6.1.3 ADMINISTRATION AND RESEARCH AREA (EXPOSURE UNIT 2)

Media	*Number of Locations with Exceedances* (1) *Groundwater*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	8 to 9	3	6	4 to 6
Non-Chlorinated VOCs	1/0/0	0/0/0	0/0/0	0/0/0
Chlorinated VOCs	1/3/2(2)(5)	0/0/0	0/0/0	0/0/0
PAHs	0/0/0	0/0/0	0/0/0	0/0/0
Arsenic	4/0/0(4)	0/0/0	0/0/0	0/0/0
Other Metals	1/0/0(3)(4)	0/0/0	0/0/0	1/0/0

(1) 1/3/2 = number of locations with low level/moderate/significant exceedances.
(2) Not sourced by activities attributable to the Site.
(3) Background concentration for aluminum greater than on-Site exceedance.
(4) Dissolved Metals.
(5) Background concentrations for Cis-1,2-DCE and VCM greater than on-Site exceedances.

Number of SPL Areas : 1, a continuation of SPL-14 from EU-1
Volume of SPL : Included in EU-1

The above shows that the Administration and Research area has been minimally impacted by Site-related activities except for the area adjacent to Kendall Avenue which correlates with the SPL in this area. The only environmental concern is associated with chlorinated VOC concentrations in the groundwater and this situation appears to be decreasing with time and is not related to Site activities.

ES6.1.4 CRUDE TANK FARM (EXPOSURE UNIT 3)

Media	*Number Of Locations With Exceedances (1)*			
	Groundwater	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	13 to 36	17 to 20	33 to 34	11
Non-Chlorinated VOCs	2/0/1	0/1/0	2/0/0	1/0/0
Chlorinated VOCs	0/5/6 (2)(3)	0/0/0	0/0/0	0/0/0
PAHs	0/0/0	0/0/0	0/0/0	0/0/0
Arsenic	3/0/0 (4)	3/0/0	1/0/0	2/0/0
Other Metals	1/0/0 (4)	2/0/0	1/0/0	2/0/0

(1) 0/5/6= number of locations with low level/moderate/significant exceedances.

(2) Not sourced by activities attributable to the Site.

(3) Background concentration(s) greater than on-Site exceedances.

(4) Dissolved Metals.

Number of SPL Areas : 3 (SPL-16 to SPL-18)
Volume of SPL based on Corrected Thickness : 7,500 gallons

The above shows that the Crude Tank Farm has been minimally impacted by Site related activities except for the three areas where SPL is present. No trend with time could be discerned for the non-chlorinated and chlorinated VOC groundwater concentrations.

ES6.1.5 FOSTER BROOK FACILITY SOUTH (EXPOSURE UNIT 4)

	Number Of Locations With Exceedances (1)				
	Groundwater				
Media	*On-Site*	*Downgradient*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	63 to 78	4 to 11	34 to 38	67 to 115	22 to 52
Non-Chlorinated VOCs	8/7/27	1/2/2	3/4/0	4/11/20	6/5/9
Chlorinated VOCs	1/6/0	0/0/0	2/1/0	2/0/0	0/1/0
PAHs	2/3/0 (3)	1/0/0	1/0/0	0/3/0(3)	1/1/0(3)
Arsenic	32/1/0(2)	2/0/0 (2)	0/0/0	1/0/0	3/0/0
Other Metals	11/1/0 (2)	2/0/0 (2)	9/3/0	7/0/0	0/1/0

(1) 8/7/27 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals.

(3) Excluding naphthalene which is included in non-chlorinated VOCs.

Number of SPL Areas : 7 (SPL-22 to SPL-28)

Volume of SPL based on Corrected Thickness : 19,200 gallons

The above shows that much of the groundwater, unsaturated subsurface soil, and saturated soil underlying the Foster Brook Facility South has been significantly impacted by non-chlorinated VOCs. The groundwater also has low-level impacts due to PAHs and metals, primarily arsenic. The areas of greatest impact are the Light End Tank Farm, Garage/Shed Area, and the Former Burn Pit Area. These three areas correlate with areas where SPL is present. On-Site groundwater concentrations for the PAHs and non-chlorinated VOCs appear to be constant or decreasing with time.

Also, two off-Site areas have been impacted. The first is the groundwater downgradient of the Light End Tank Farm which has been moderately to significantly impacted with benzene. The second is the Former Burn Pit Area soil and groundwater west of the Site boundary. These off-Site soils have been significantly impacted principally with naphthalene, 1,2,4-TMB, 1,3,5-TMB, and benzene. The off-Site groundwater has been significantly impacted with benzene.

ES6.1.6 FOSTER BROOK FACILITY NORTH (EXPOSURE UNIT 5)

Media	*Number Of Locations With Exceedances (1)*			
	Groundwater	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	3 to 9	28	19 to 25	9 to 11
Non-Chlorinated VOCs	0/0/0	0/0/0	0/0/0	0/0/0
Chlorinated VOCs	2/1/0	0/0/0	0/0/0	0/0/0
PAHs	0/0/0	0/0/0	0/0/0	0/0/0
Arsenic	0/0/0 (2)	2/0/0	1/0/0	6/0/0
Other Metals	4/0/1 (2)	2/0/0	1/0/0	3/1/0

(1) 2/0/1 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals

Number of SPL Areas : None

The above shows that the Foster Brook Facility North has been minimally impacted by Site related activities.

ES6.1.7 PACKAGING PLANT (EXPOSURE UNIT 6)

Media	*Number Of Locations With Exceedances (1)*			
	Groundwater	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	9	NS	3	NS
Non-Chlorinated VOCs	0/0/0		0/0/0	
Chlorinated VOCs	0/7/0		0/0/0	
PAHs	0/0/0		0/0/0	
Arsenic	0/0/0 (2)		0/0/0	
Other Metals	0/0/0 (2)		0/0/0	

(1) 0/7/0 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals

NS Not Sampled

Number of SPL Areas : 2 (SPL-20 and SPL-21)
Volume of SPL based on Corrected Thickness : 1,300 gallons

The above shows that the groundwater underlying the Packaging Plant has been moderately impacted by chlorinated VOCs. The area of impact correlates with the location of the two SPL plumes. No trend with time could be discerned for the chlorinated VOC groundwater concentrations.

ES6.1.8 TUNUNGWANT CREEK (EXPOSURE UNIT 7)

Number Of Locations With Exceedances (1)

Media	*Surface Water*		*Sediment*
	May 2005	*August 2006*	
Number of Sample Locations	46	29	30 to 38
Non-Chlorinated VOCs	0/0/0	0/0/0	0/0/0
Chlorinated VOCs	5/0/0	4/0/0	0/0/0
PAHs	0/8/0	0/7/0	0/0/0
Arsenic	0/0/0 (2)	0/0/0(2)	24/1/0
Other Metals(3)	7/0/0 (2)	1/0/0(2)	3/0/0

(1) 7/0/0 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals

(3) Not including iron and manganese

The above shows that Tunungwant Creek has been minimally impacted by Site-related activities. This is supported by the results of the macroinvertebrate study which showed that while a slight to moderate impairment is evident, no toxic impact attributable to Site related chemicals was apparent. The major factors causing the impairment are habitat modifications and continuing physical disturbances that have been performed in conjunction with flood control efforts.

ES6.1.9 NATIONAL TRANSIT PROPERTY (EXPOSURE UNIT 8)

Media	*Number Of Locations With Exceedances (1)*			
	Groundwater	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	3 to 53	42 to 52	44 to 47	16 to 35
Non-Chlorinated VOCs	5/28/6	4/1/0	3/0/0	6/0/0
Chlorinated VOCs	2/1/0	0/0/0	0/0/0	0/0/0
PAHs	3/0/0	0/0/0	0/0/0	0/0/0
Arsenic	0/0/0 (2)	0/0/0	0/0/0	0/0/0
Other Metals	1/0/0 (2)	0/0/0	0/0/0	0/0/0

(1) 6/2/0 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals

Number of SPL Areas	: 2 (part of SPL-18 and SPL-19)
Volume of SPL based on Corrected Thickness	: 450 gallons (on-Site)
	: 540 gallons (off-Site)

The above shows that the groundwater and saturated soil underlying the National Transit Property has been significantly and moderately impacted, respectively, by non-chlorinated VOCs. The areas of highest impact correlate with the areas where SPL is present in the eastern one-third of the Property.

ES6.2 SEPARATE PHASE LIQUID

Thirty SPL plumes with a total volume of 85,200 gallons (corrected thickness) currently exist on-Site. The number of plumes and volume (corrected thickness) for each Exposure Unit are:

Exposure Unit	*SPL Plumes*	*Volume (Gallons)*
EU-1	SPL-1 through SPL-15 and SPL-29	55,200
EU-2	continuation of SPL-14	included in EU-1
EU-3	SPL-16 through SPL-18	8,500
EU-4	SPL-22 through SPL-28 and SPL-30	19,200
EU-5	0	0
EU-6	SPL-20 and SPL-21	1,350
EU-8 (on-Site)	SPL-18 and SPL-19	450
EU-8 (off-Site)	SPL-18	540

SPL Plume	*Location*	*Description*	*Specific Gravity*	*Dynamic Viscosity (centipoise)*
SPL-1	MEK Unit	Solvent Distillate	0.84 to 0.86	10.2
SPL-2	MEK Unit	--	0.82	--
SPL-3	MEK Unit	MN (Medium Neutral)	--	--
SPL-4	MEK Unit	--	--	--
SPL-5	ROSE Unit	HN (Heavy Neutral) with MN	0.82 to 0.87	21.6
SPL-6	ROSE Unit	HN	0.79	--
SPL-7	ROSE Unit	HN and MN	0.85 to 0.89	89.0
SPL-8	ROSE Unit	--	--	--
SPL-9	Dubbs Unit	--	--	--
SPL-10	Crude Unit/ Upper Yard	Solvent Distillate with LLN and HN	0.84 to 0.87	4.44
SPL-11	Crude Unit	Solvent Distillate with MN and HN	0.86	12.4
SPL-12	MR Barrel House	MN and HN	0.86	10.3
SPL-13	MR Barrel House	HN, MN and Solvent Distillates	0.83 to 0.88	46.3
SPL-14	MR Barrel House/Adm	HN and Solvent Distillates	0.84	
SPL-15	Erie Wye Unit	Unknown with Solvent Distillate	0.80 to 0.83	2.29
SPL-16	CTF	--	0.82	3.49
SPL-17	CTF	--	0.87	17.5
SPL-18	Independent Production Area South	2001 - Severely Weathered Crude 2003 – Light End Hydrocarbons	0.79 to 0.82	2.23
SPL-19	NT Property	--	--	--
SPL-20	Packaging Plant	--	0.88	91.1
SPL-21	Packaging Plant	--	--	--

SPL Plume	*Location*	*Description Gravity*	*Specific Gravity*	*Dynamic Viscosity (centipoise)*
SPL-22	Bulk Haul/	Gasoline or Diesel based (MW-TF10)	0.84 to 0.87	10.5
	Light End Tank Farm	Gasoline based (MW-TF28)	0.74 to 0.75	0.96
SPL-23	FB Barrel House	--	0.89	35.1
SPL-24	Light End Tank Farm	--	--	--
SPL-25	Former Impoundment Area	--	--	--
SPL-26	Garage/Shed Area	Gasoline Based	0.74 to 1.00	3.25
SPL-27	Bauxite Fill Area	Gasoline Based	0.85 to 1.00	11.3
SPL-28	Former Burn Pit Area	--	0.92	1,140
SPL-29	Platformer Unit	--	--	--
SPL-30	Railway Unloading, Foster Brook	Crude	--	--

In addition, 2 off-site SPL plumes upgradient of the Site have been identified. One is a newly identified SPL plume located on the Buffalo and Pittsburgh railway south of Bolivar Drive (i.e., SPL-31) and the other on the Custer City Oil property north of Bolivar Drive (i.e., SPL-CC01).

ES6.3 CLOSURE EVALUATION - FOSTER BROOK FACILITY

Five areas in the Foster Brook Facility were evaluated to determine if they were properly closed in compliance with Pennsylvania laws and regulations and, if not, what additional measures are needed to achieve proper closure.

ES6.3.1 BAUXITE FILL AREA

The evaluations showed that:

i) the bauxite fill is uncovered and friable and thus subject to erosion;

ii) benzene, ethylbenzene, and naphthalene exceeded SHS MSCs in the unsaturated soil; and

iii) benzene, arsenic, iron, and manganese exceeded SHS MSCs in groundwater.

Therefore, this area will be closed under a combined SHS MSC and SSS.

The above show that an impact to groundwater could have occurred. To properly close the Bauxite Fill Area, the following actions are proposed:

i) regrading to achieve compliance, to the extent practical, with the slope requirements;

ii) placement of a 6-inch thick crushed limestone cover to prevent contact and to reduce infiltration;

iii) implementation of deed restrictions to restrict land and groundwater use and operating procedures to ensure appropriate H&S measures are implemented for subsurface activities; and

iv) inspections, monitoring, and maintenance.

ES6.3.2 FLY ASH AREA

The evaluation showed that:

i) no parameters exceeded SHS MSCs in soil;

ii) no groundwater analytical results are available. However, considering no exceedances of SHS MSCs occurred in the soil, it is unlikely that the groundwater has Site-related exceedances;

iii) the fly ash is covered with a 4 to 6-inch thick layer of clay/slag material with a slope of 1% or less. The cover appears to be controlling infiltration; and

iv) the cover is only partially vegetated and thus some areas are subject to erosion.

Because there are no exceedances of SHS MSCs, this area will be closed under the SHS MSCs.

The above shows that an impact to groundwater is unlikely to be occurring. The existing cover is preventing contact and reducing infiltration. However, to assist in controlling future erosion, it is proposed to:

i) perform minor isolated regrading to enhance precipitation runoff to Foster Brook;

ii) supplement the existing cover with 6 to 8 inches of topsoil (where needed) which will better support vegetation;

iii) revegetate the Fly Ash Area with grasses and herbaceous seed mix to enhance the ecological value of the area; and

iv) inspections and maintenance.

ES6.3.3 FORMER BURN PIT AREA

The evaluations showed that:

i) the area is completely vegetated with only a few small isolated bare spots;

ii) the ground surface is currently sloped at approximately 2% toward Foster Brook and the drainage swale of State Route 219;

iii) PAHs, BTEX, chlorinated VOCs, lead, and selenium were detected in soil at concentrations in exceedance of SHS MSCs;

iv) PAHS, benzene, ethylbenzene, chlorinated VOCs, arsenic, and manganese were detected in groundwater at concentrations in exceedance of SHS MSCs; and

v) most areas are covered with a 2 to 4 foot thick layer of clayey silt.

Because there are exceedances of SHS MSCs, this area will be closed under a combined SHS MSC and SSS.

The above shows a significant impact to groundwater has occurred. To properly close the Former Burn Pit Area, the following actions are proposed:

i) moderate regrading of the existing 2 to 4-foot thick clayey silt cover to enhance precipitation runoff toward Foster Brook and the State Route 219 drainage swale;

ii) placement of an additional 6-inch thick cover of topsoil;

iii) revegetate with grasses and herbaceous seed mix to enhance the ecological value of the area;

iv) implementation of deed restrictions to restrict land and groundwater use and operating procedures to ensure appropriate H&S measures are implemented for subsurface activities; and

v) inspections, monitoring, and maintenance.

ES6.3.4 CONSTRUCTION DEBRIS AREA

The evaluations showed that:

i) the area is partially vegetated (70% coverage);

ii) the fill, where present, is generally exposed at ground surface;

iii) chlorinated VOCs, metals, and benzene were detected in the soil at concentrations in exceedance of SHS MSCs; and

iv) chlorinated VOCs, iron, manganese, nickel, and beryllium were detected in groundwater at concentrations in exceedance of SHS MSCs.

Because there are exceedances of SHS MSCs, this area will be closed under a combined SHS MSC and SSS.

The above shows an impact to groundwater and the potential for erosion and contact with the fill. To properly close the Construction Debris Area, the following actions are proposed:

i) regrading of uneven and open, non-vegetated areas to promote surface water drainage;

ii) cover all exposed wastes and regraded areas with 12 inches of topsoil;

iii) revegetate with grasses and herbaceous seed mix to enhance the ecological value of the area;

iv) implementation of deed restrictions to restrict land and groundwater use and operating procedures to ensure appropriate H&S measures are implemented for subsurface activities; and

v) inspections, monitoring, and maintenance.

ES6.3.5 REFUSE/CONTAINER REMOVAL AREA

The evaluations showed that:

i) the previously completed container removal program has effectively remediated this area;

ii) the container removal area is partially vegetated (70% coverage);

iii) the rest of the area is completely vegetated;

iv) fill is exposed only in a small number of test pits and along a steep drop-off;

v) two locations had arsenic and one location had acetone, lead, and thallium concentrations in soil very slightly in exceedance of SHS MSCs. TPH concentrations ranged from non-detect to a maximum of 37,000 mg/kg except for 3 locations which ranged from 75,000 to 200,000 mg/kg. There is currently no SHS MSC for TPH. Individual compounds included in TPH, which are deemed to be of significant concern (e.g., BTEX), have SHS MSCs. No such compounds exceeded their SHS MSC;

vi) two locations had both arsenic and cobalt concentrations in soil very slightly in exceedance of SHS MSCs; and

vii) one location had beryllium and two locations had nickel in groundwater very slightly in exceedance of SHS MSCs.

Because there are exceedances of SHS MSCs, this area will be closed under a combined SHS MSC and SSS.

Given the low level exceedances and infrequent presence, the metals and acetone are not of environmental concern. Furthermore, because no compounds included in the TPH exceeded their SHS MSC, it is believed that the TPHs are not a significant environmental concern.

Considering that all drummed waste and a considerable amount of other waste and contaminated soil has already been removed from this area and there are few and minimal exceedances of SHS MSCs, the following measures are proposed for the proper closure of this area:

i) minor regrading to improve surface water drainage;

ii) cover all exposed wastes and regraded areas with 12 inches of topsoil;

iii) revegetate the newly covered and regraded areas with grasses and herbaceous seed mix to enhance the ecological value of the area;

iv) implementation of deed restrictions to restrict land and groundwater use and operating procedures to ensure appropriate H&S measures are implemented for subsurface activities; and

v) inspections, monitoring, and maintenance.

ES7.0 FATE AND TRANSPORT EVALUATION

The fate and transport evaluation showed that:

i) the organic chemicals detected in groundwater beneath the Site are primarily related to the SPL present on top of the water table;

ii) the most significant migration pathway for chemicals present in the groundwater to surface water is groundwater discharge to surface water;

iii) the leaching of chemical constituents from the SPL to groundwater is resulting in lower groundwater concentrations than would be calculated using partitioning theory;

iv) only the groundwater flowing through the upper 10 feet or less of the upper aquifer is impacted by Site-related chemicals and contributes chemical loading to the surface water;

v) the total chemical loading from groundwater discharge to surface water results in estimated in-stream concentrations that are below the screening criteria for all detected chemicals except for a few parameters with low level exceedances;

vi) the calculated chemical loadings from the groundwater to surface water are not a significant concern to human health or the ecological aquatic environment;

vii) the surface water analytical results converted to 7Q10 conditions are consistent with the results of the surface water concentrations calculated based on groundwater loading in that only a few parameters with low level exceedances were detected in a few locations sporadically within the Site reaches of Tunungwant Creek and, in the majority of the locations, the concentrations were similar to the upstream concentrations;

viii) the surface water analytical results show that the Site is not adversely impacting the four tributaries;

ix) the calculated chemical loadings from groundwater are conservative and are expected to decrease in the future as the SPL continues to be removed from the subsurface;

x) the mobile SPL in EU-1 is being controlled and its volume reduced by the interim remedial measures being implemented; and

xi) the SPL plumes in EU-3, EU-4, and EU-6 are relatively immobile and the interim remedial measures of source removal which are currently in place will prevent potential migration of these plumes to the surface water.

ES8.0 HUMAN HEALTH RISK ASSESSMENT

The risk characterization integrates the exposure assessment and toxicity assessment to provide a complete evaluation of the potential human health risks associated with exposure to Constituents of Potential Concern (COPCs) at or near the Site. Two levels of exposure were evaluated:

i) the Central Tendency (CT), which utilizes the mean COPC concentrations and approximates the most probable exposure conditions; and

ii) the Reasonable Maximum Exposure (RME), which utilizes the 95 percent upper confidence level of the COPC mean concentrations and approximates maximum exposure conditions.

The estimated cumulative carcinogenic risks resulting from exposure to Site COPCs were compared to a cumulative risk (TCR) of 10^{-4}. Estimated non-carcinogenic hazards were calculated and compared to a Hazard Index (HI) of 1. A summary of the Reasonable Maximum Exposure (RME) cumulative risk results is presented below:

Exposure Unit	*Construction Worker*		*Indoor Worker*		*Outdoor Worker*		*Trespasser*		*Recreational Visitor*		*Resident/Child/ Adults*	
	CR	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*
EU1	1.1E-04	21,000	7.4E-05	6.9	2.2E-06	0.09	2.3E-07	0.023	NA	NA	NA	NA
EU1 Off-Site Hilton Street	–	0.46	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Penn Electric	–	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Mill Street	7.4E-06	6,600	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site B&P Railroad (MEK & Rose)	1.5E-05	7,500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Conrail	9.6E-07	6,600	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site B&P Railroad (Crude Unit)	5.2E-06	14,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Kendall Avenue	2.7E-04	17,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Werzalit	2.2E-06	17,000	2.1E-06	0.12	NA	NA	NA	NA	NA	NA	NA	NA
EU2	1.2E-05	21,000	2.7E-06	0.033	9.9E-07	0.016	1.2E-07	0.005	NA	NA	NA	NA
EU3	7.0E-04	22,000	7.8E-05	1.5	1.7E-05	0.24	2.1E-06	0.071	NA	NA	NA	NA
EU3/EU8 Off-Site B&P Railroad	2.3E-04	21,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU3 Off-Site Conrail	4.0E-04	38,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU4	9.7E-03	130,000	2.5E-03	150	1.4E-05	2.3	1.4E-06	0.24	NA	NA	NA	NA

Exposure Unit	*Construction Worker*		*Indoor Worker*		*Outdoor Worker*		*Trespasser*		*Recreational Visitor*		*Resident/Child/ Adults*	
	CR	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*
EU4 Off-Site PennDOT	9.1E-04	14,000	NA	NA	NA	NA	5.1E-05	0.18	NA	NA	NA	NA
EU4 Off-Site Bolivar Drive	5.7E-07	1,100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU4 Off-Site B&P Railroad	3.5E-04	12,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU5	1.7E-06	10	7.6E-06	0.16	1.8E-05	0.39	2.2E-06	0.39	NA	NA	NA	NA
EU6	2.1E-06	1,000	1.9E-06	0.036	NA	NA	NA	NA	NA	NA	NA	NA
EU6 Off-Site Graham Packaging	1.3E-06	1,000	9.9E-07	0.006	NA	NA	NA	NA	NA	NA	NA	NA
EU7 (Child/Adult)	NA	NA	NA	NA	NA	NA	NA	NA	8.1E-05	0.71/0.12	NA	NA
EU8 Off-Site Residential	2.3E-06	18,000	3.5E-06	0.09	NA	NA	NA	NA	NA	NA	2.5E-05	2.2/0.68

Notes:

NA = Not Applicable

-- = not calculated

The results of the HHRA show that the risks exceeding the cumulative risk of 10^{-4}, were identified for the indoor worker in EU4 (RME=2.5E-03), the on-Site construction worker in EU1 (RME = 1.1E-04), EU3 (RME -= 7.0E-04), EU4 (RME=9.7E-03), and the off-Site construction worker in EU1-Kendall Avenue (RME = 2.7E-04), EU3/EU8-B&P Railroad (RME = 2.3E-04), EU3-Conrail (RME = 4.0E-04), EU4-PennDOT (RME = 9.1E-04), and EU4-B&P Railroad (RME = 3.5E-04). EU Hazard Indices exceeding the target HI of 1 were identified for the indoor worker in EU1 (RME=6.9), EU3 (RME = 1.5), and EU4 (RME = 150), the on-Site construction worker in EU1 (RME=21,000), EU2 (RME=21,000), EU3 (RME=22,000), EU4 (RME=130,000), EU5 (RME=10), and EU6 (RME=1,000). For the off-Site construction worker HIs exceeding 1 were identified in EU1-Mill Street (RME=6,600), EU1-B&P Railroad (MEK/Rose) (RME=7,500), EU1-Conrail (RME=6,600), EU1-B&P Railroad (Crude Unit) (RME=14,000), EU1-Kendall Avenue (RME=17,000), EU1-Werzalit (RME = 17,000), EU3/EU8-B&P Railroad (RME = 21,000), EU3-Conrail (RME = 38,000), EU4-PennDOT (RME = 14,000), EU4-Bolivar Drive (RME = 1,100), EU4-B&P Railroad (RME = 12,000), EU6-Graham Packaging (RME = 1,000), and EU8-Residential (RME = 18,000). For the resident, the results show an HI exceeding 1 for a child in EU8-Residential (RME = 2.2).

It should be noted that these cancer risk and HI exceedances incorporate some highly conservative assumptions. It is improbable that the same person would experience all potential exposures associated with the Site, or that he/she would experience these exposures over the periods of years specified in the individual RME scenarios.

Site-specific standards (SSSs) were developed for each COPC exceeding Statewide Health Standards (SHS) in each media, as outlined in Appendix M of the HHRA. Briefly, the SSSs were developed by conducting the RA process in reverse. In other words, the HQ/HI formula and risk formula are solved for the exposure concentration term by setting the HI or risk to a specified target level. SSSs were developed for a target HI of 1 and target risk of 1E-05. Section 6.0 contains a detailed description of the SSSs for all receptors and exposure pathways.

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU1	Indoor Worker (Current/ Future)	Soil Gas (Indoor Air Inhalation)	1,1,2,2-Tetrachloroethane	µg/m³	4.6E+03	1.4E+02	4.8E+03	6.1
			1,2-Dibromo-3-chloro-propane	µg/m³	4.0E+03	5.8E+01	2.7E+04	
			1,2-Dibromoethane	µg/m³	2.6E+03	3.7E+01	5.5E+03	
			Chloroform	µg/m³	2.5E+03	9.2E+01	3.4E+03	
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Aluminum	mg/kg	5.5E+03	1.9E+05	3.2E+04	6.12
			Chromium	mg/kg	7.3E+01	1.9E+05	1.5E+03	
			Copper	mg/kg	5.4E+03	1.9E+05	5.9E+03	
			Anthracene	mg/kg	1.9E+01	1.9E+05	1.4E+02	
			Benzo(a)pyrene	mg/kg	9.7E+00	1.9E+05	1.0E+02	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	1.8E+02	
			Benzo(k)fluoranthene	mg/kg	8.5E+00	1.9E+05	2.7E+02	
			Fluoranthene	mg/kg	8.5E-01	1.9E+05	3.7E+02	
			Benzene	mg/kg	1.9E-02	2.4E+02	1.1E+01	
			Ethylbenzene	mg/kg	9.2E-01	1.0E+04	6.1E+01	
			Naphthalene	mg/kg	1.7E-02	1.9E+05	9.0E+01	
			Xylene	mg/kg	6.3E-02	1.0E+04	1.8E+02	
		Groundwater (Ingestion Dermal Inhalation)	Antimony	mg/L	4.5E-02	6.0E-03	2.9E-01	6.13
			Benzene	mg/L	2.2E-01	5.0E-03	1.5E+00	
			Naphthalene	mg/L	8.2E-02	1.0E-01	2.7E-01	
			Manganese	mg/L	1.7E+00	3.0E-01	3.9E+01	
			Fluoranthene	mg/L	3.9E-01	2.6E-01	5.0E-01	
			Arsenic	mg/L	6.9E-02	5.0E-02	1.6E-01	
			Iron	mg/L	1.4E+02	3.0E-01	2.0E+02	
			Thallium	mg/L	1.1E-02	2.0E-03	2.0E-02	
			Benzo(a)anthracene	mg/L	2.5E-03	3.6E-03	1.6E-01	
			Benzo(a)pyrene	mg/L	1.7E-04	2.0E-04	2.8E-02	
			Benzo(b)fluoranthene	mg/L	1.7E-03	1.2E-03	1.6E-02	

Exposure Unit	Receptor	Medium (Route)	Chemical of Potential Concern	Units	Cumulative SSS	SHS MSCs	Maximum Detected Concentration	HHRA Table Reference
			Benzo(k)fluoranthene	mg/L	1.9E-02	5.5E-04	3.1E-02	
			Dibenz(a,h)anthracene	mg/L	7.9E-05	3.6E-04	3.0E-03	
			1,2,4-Trimethylbenzene	mg/L	8.2E-02	3.5E-02	1.5E+00	
			1,3,5-Trimethylbenzene	mg/L	8.6E-02	3.5E-02	4.8E-01	
EU1 Off-Site Mill Street	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzo(a)pyrene	mg/kg	6.1E+00	1.9E+05	6.3E+00	6.12
EU1 Off-Site B&P Railroad (MEK Unit)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	1.6E+02	1.9E+05	4.5E+03	6.12
			Chromium	mg/kg	7.3E+01	1.9E+05	1.5E+03	
			Vanadium	mg/kg	2.0E+01	1.9E+05	2.3E+01	
			Benzo(a)pyrene	mg/kg	3.1E+00	1.9E+05	6.3E+00	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	3.9E+01	6.13
EU1 Off-Site Conrail	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Naphthalene	mg/L	2.5E-01	1.0E-01	2.7E-01	6.13
EU1 Off-Site B&P Railroad (Crude Unit)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Naphthalene	mg/kg	3.2E-02	1.9E+05	1.6E+01	6.12
			Aluminum	mg/kg	3.7E+03	1.9E+05	2.3E+04	
			Manganese	mg/kg	5.4E+01	1.9E+05	2.3E+02	
EU1 Off-Site Kendall Avenue	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzene	mg/kg	5.6E-02	2.4E+02	1.1E+01	6.12
			Naphthalene	mg/kg	1.6E-01	1.9E+05	1.3E+01	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	2.3E+01	6.13
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	3.7E-01	
			Arsenic	mg/L	1.4E-01	5.0E-02	1.5E-01	
EU2	Indoor Worker (Current/ Future)	Groundwater (Indoor Air Inhalation)	Vinyl Chloride	mg/L	1.2E-01	3.0E+00	1.5E-01	6.2
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	1.6E+02	1.9E+05	1.1E+03	6.12
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	4.4E+00	3.0E-01	3.2E+01	6.13
EU3	Indoor Worker (Current/ Future)	Groundwater (Indoor Air Inhalation)	Vinyl Chloride	mg/L	1.0E-01	3.0E+00	2.4E-01	6.2

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
		Soil (Indoor Air Inhalation)	Benzene	mg/kg	8.2E-02	6.3E-01	5.5E+00	6.3
EU3 (cont'd)	Indoor Worker (Current/ Future) (cont'd)	Surface Soil (Ingestion Inhalation)	Arsenic	mg/kg	5.9E+01	5.3E+01	9.2E+01	6.4
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	9.2E+01	6.6
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	8.4E+01	1.9E+05	9.4E+01	6.120
			Benzene	mg/kg	1.9E-02	2.4E+02	5.5E+00	
			Benzo(a)pyrene	mg/kg	4.2E+00	1.9E+05	7.1E+00	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	2.2E-01	5.0E-03	6.0E-01	6.13
			cis-1,2-Dichloroethene	mg/L	4.7E-01	7.0E-02	1.3E+00	
			Tetrachloroethene	mg/L	2.5E-01	5.0E-03	4.5E-01	
			Manganese	mg/L	2.9E+00	3.0E-01	1.9E+01	
			Vinyl Chloride	mg/L	1.5E-01	2.0E-03	2.4E-01	
			Arsenic	mg/L	1.4E-01	5.0E-02	1.1E+00	
EU3 Off-Site B&P Railroad	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	1,2,4-Trimethylbenzene	mg/kg	1.0E-02	3.6E+02	5.0E+01	6.12
			1,2-Dibromo-3-chloropropane	mg/kg	2.8E-04	2.0E-02	1.1E+00	
			1,3,5-Trimethylbenzene	mg/kg	4.5E-03	3.6E+02	1.8E+01	
			Benzo(a)pyrene	mg/kg	1.5E+00	4.6E+00	5.8E+00	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.2E+00	3.0E-01	3.8E+00	6.13
			1,2,4-Trimethylbenzene	mg/L	1.0E-01	3.5E-02	9.6E-01	
			1,3,5-Trimethylbenzene	mg/L	1.0E-01	3.5E-02	4.8E-01	
			Benzo(a)anthracene	mg/L	2.9E-04	3.6E-03	3.4E-01	
			Benzo(a)pyrene	mg/L	2.0E-03	2.0E-04	3.0E-01	
			Benzo(b)fluoranthene	mg/L	2.0E-02	1.2E-03	3.6E-01	
			Dibenz(a,h)anthracene	mg/L	2.2E-02	3.6E-04	3.7E-02	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU3 Off-Site Conrail	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	3.3E-01	5.0E-03	6.0E-01	6.13
			Tetrachloroethene	mg/L	3.0E-01	5.0E-03	3.3E-01	
EU4	Indoor Worker (Current/ Future)	Soil Gas (Indoor Air Inhalation)	1,1,2,2-Tetrachloroethane	µg/m³	2.5E+02	1.4E+02	8.0E+04	6.1
			1,1,2-Trichloroethane	µg/m³	1.2E+04	5.1E+02	6.5E+04	
			1,2-Dibromo-3-chloropropane	µg/m³	2.6E+02	5.8E+01	4.6E+05	
			1,2-Dibromoethane	µg/m³	1.7E+02	3.7E+01	9.0E+04	
			1,2-Dichloroethane	µg/m³	4.4E+02	3.1E+02	4.8E+04	
			1,2-Dichloropropane	µg/m³	1.3E+03	7.9E+02	5.5E+04	
			1,3-Dichlorobenzene	µg/m³	2.8E+04	1.1E+03	7.0E+04	
			1,4-Dichlorobenzene	µg/m³	2.4E+03	1.3E+03	7.0E+04	
			Benzene	µg/m³	1.7E+03	1.1E+03	1.8E+06	
			Bromodichloromethane	µg/m³	7.6E+02	2.2E+02	8.0E+04	
			Bromomethane	µg/m³	6.9E+03	1.4E+03	4.6E+04	
			Carbon tetrachloride	µg/m³	9.2E+02	5.5E+02	7.5E+04	
			Chloroform	µg/m³	1.3E+02	9.2E+01	5.5E+04	
			Chloromethane	µg/m³	4.0E+04	4.5E+03	9.5E+04	
			cis-1,3-Dichloropropene	µg/m³	3.9E+03	2.0E+03	5.5E+04	
			Dibromochloromethane	µg/m³	1.5E+03	3.0E+02	1.0E+05	
			Ethylbenzene	µg/m³	5.9E+04	7.3E+03	2.2E+05	
			m&p-Xylene	µg/m³	7.1E+05	3.0E+04	9.2E+05	
			Trans-1,3-Dichloropropene	µg/m³	3.9E+03	2.0E+03	5.5E+04	
			Vinyl Chloride	µg/m³	1.3E+03	9.5E+02	3.0E+04	
			1,2,4-Trimethylbenzene	µg/m³	2.4E+04	1.7E+03	7.9+04	
		Surface Soil (Ingestion Inhalation)	Antimony	mg/kg	2.0E+02	1.1E+03	5.6E+02	6.4
		Soil (Inhalation)	Benzene	mg/kg	5.9E+01	2.4E+02	1.5E+02	6.5
			Naphthalene	mg/kg	3.9E+02	1.9E+05	7.6E+02	
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	3.5E+01	6.6
			Antimony	mg/kg	2.0E+02	1.1E+03	5.6E+02	
		Soil (Inhalation)	Benzene	mg/kg	2.2E+01	2.4E+02	1.5E+02	6.7
			Naphthalene	mg/kg	1.5E+02	1.9E+05	7.6E+02	
			Xylene	mg/kg	5.2E+02	1.0E+04	1.0E+03	
			1,2,4-Trimethylbenzene	mg/kg	6.7E+01	3.6E+02	1.5E+02	
			1,3,5-Trimethylbenzene	mg/kg	5.8E+01	3.6E+02	1.4E+02	

Exposure Unit	Receptor	Medium (Route)	Chemical of Potential Concern	Units	Cumulative SSS	SHS MSCs	Maximum Detected Concentration	HHRA Table Reference
EU4 (cont'd)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Antimony	mg/kg	2.4E+01	1.9E+05	5.6E+02	6.12
			Benzene	mg/kg	1.9E-02	2.4E+02	1.5E+02	
			Naphthalene	mg/kg	5.8E-02	1.9E+05	7.6E+02	
			Xylene	mg/kg	4.4E-01	1.0E+04	1.0E+03	
			Aluminum	mg/kg	2.8E+03	1.9E+05	6.2E+04	
			Mercury	mg/kg	1.7E+01	1.9E+05	3.3E+01	
			Fluoranthene	mg/kg	6.4E-01	1.9E+05	3.9E+02	
			Pyrene	mg/kg	3.9E+01	1.9E+05	3.5E+02	
			Ethylbenzene	mg/kg	9.3E-01	1.0E+04	1.6E+02	
			Toluene	mg/kg	3.0E+00	1.0E+04	4.1E+02	
			Arsenic	mg/kg	8.4E+01	1.9E+05	2.3E+02	
			Chromium	mg/kg	7.3E+01	1.9E+05	8.8E+01	
			Anthracene	mg/kg	1.9E+01	1.9E+05	7.2E+01	
			Benzo(a) pyrene	mg/kg	1.3E+01	1.9E+05	5.2E+01	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	9.0E+01	
			Benzo(k)fluoranthene	mg/kg	8.5E+00	1.9E+05	1.1E+02	
			1,1-Dichloroethane	mg/kg	6.5E-01	1.2E+03	7.6E+00	
			1,2,4-Trimethylbenzene	mg/kg	3.6E-02	3.6E+02	1.5E+02	
			1,3,5-Trimethylbenzene	mg/kg	1.0E-02	3.6E+02	1.4E+02	
			Chloromethane	mg/kg	1.7E-01	1.0E+03	1.4E+00	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	2.2E-01	5.0E-03	2.2E+01	6.13
			Naphthalene	mg/L	1.2E-01	1.0E-01	3.3E-01	
			Xylene	mg/L	2.8E+00	1.0E+01	1.2E+01	
			Manganese	mg/L	4.4E+00	3.0E-01	2.8E+01	
			Toluene	mg/L	4.1E+00	1.0E+00	2.1E+01	
			Arsenic	mg/L	1.4E-01	5.0E-02	2.6E-01	
			Iron	mg/L	1.4E+02	3.0E-01	2.0E+02	
			Benzo(a) pyrene	mg/L	2.0E-03	2.0E-04	3.3E-03	
			Dibenz(a,h)anthracene	mg/L	9.4E-04	3.6E-04	7.2E-03	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU4 Off-Site PennDOT	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzene	mg/kg	2.8E-02	2.4E+02	1.6E+01	6.12
			Naphthalene	mg/kg	8.6E-02	1.9E+05	1.1E+02	
			Xylene	mg/kg	7.0E-01	1.0E+04	5.3E+02	
			Ethylbenzene	mg/kg	1.3E+00	1.0E+04	1.1E+02	
			Lead (1)	mg/kg	1.2E+02	1.9E+05	1.4E+02	
			Anthracene	mg/kg	1.9E+01	1.9E+05	3.6E+01	
			Benzo(a) pyrene	mg/kg	8.4E+00	1.9E+05	2.3E+01	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	3.0E+01	
			1,1,1-Trichloroethane	mg/kg	4.0E+00	1.0E+04	3.5E+01	
			1,1-Dichloroethane	mg/kg	6.5E-01	1.2E+03	3.0E+01	
			1,2,4-Trimethylbenzene	mg/kg	6.7E-02	3.6E+02	2.0E+02	
			1,2-Dichloroethane	mg/kg	1.0E-01	7.3E+01	4.8E+00	
			1,3,5-Trimethylbenzene	mg/kg	2.1E-02	3.6E+02	9.2E+01	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	3.3E-01	5.0E-03	2.8E+00	6.13
			Naphthalene	mg/L	1.2E-01	1.0E-01	4.3E-01	
			Xylene	mg/L	2.8E+00	1.0E+01	1.5E+01	
			Manganese	mg/L	4.4E+00	3.0E-01	2.0E+01	
			Iron	mg/L	1.4E+02	3.0E-01	1.9E+02	
EU4 Off-Site Bolivar Drive	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	1,2,4-Trimethylbenzene	mg/kg	4.8E-02	3.6E+02	5.0E+01	6.12
			1,3,5-Trimethylbenzene	mg/kg	1.5E-02	3.6E+02	1.8E+01	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	4.7E+00	6.13
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	9.1E-01	
			1,3,5-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	2.4E-01	
EU4 Off-Site B&P Railroad	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Mercury	mg/kg	3.0E-01	1.9E+05	3.3E+01	6.12
			Lead	mg/kg	8.7E+01	1.9E+05	9.0E+01	
		Groundwater (Ingestion Dermal Inhalation)	Benzo(a)anthracene	mg/L	2.9E-02	3.6E-03	9.9E-02	6.13
			Benzo(a)pyrene	mg/L	2.0E-03	2.0E-04	8.7E-02	
			Benzo(b)fluoranthene	mg/L	2.0E-02	1.2E-03	1.1E-01	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU5	Indoor Worker (Current/ Future)	Surface Soil (Ingestion Inhalation)	Arsenic	mg/kg	5.3E+01	5.3E+01	8.4E+01	6.4
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	8.4E+01	6.6
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	8.1E+01	1.9E+05	2.3E+03	6.12
			Thallium	mg/kg	2.0E+01	1.9E+05	2.1E+01	
			Arsenic	mg/kg	4.0E+01	1.9E+05	8.4E+01	
			Barium	mg/kg	6.0E+02	1.9E+05	1.1E+03	
			Iron	mg/kg	8.4E+04	1.9E+05	1.5E+05	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	4.4E+00	3.0E-01	2.7E+01	6.13
EU6	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Aluminum	mg/kg	1.1E+04	1.9E+05	2.2E+04	6.12
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	8.7E+00	3.0E-01	3.0E+01	6.13
EU6 Off-Site Graham Packaging	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	8.7E+00	3.0E-01	2.2E+01	6.13
EU7	Recreational Visitor (Current/ Future)	Surface Water (Fish Ingestion)	Hexachlorobenzene	mg/L	9.6E-06	7.5E-07	2.3E-05	6.15
			Benzo(a)anthracene	mg/L	2.4E-05	4.4E-06	7.3E-05	
			Benzo(b)fluoranthene	mg/L	2.3E-05	4.4E-06	4.8E-05	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU8 Residential (R&S)	Resident (Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	7.2E+00	1.2E+01	2.2E+01	6.10
		Soil (Inhalation)	1,2,4-Trimethylbenzene	mg/kg	8.3E+00	1.1E+02	5.6E+01	6.11
			1,3,5-Trimethylbenzene	mg/kg	7.2E+00	1.1E+02	3.9E+01	
			1,2-Dibromo-3-chloropropane	mg/kg	1.0E+00	3.8E+00	1.1E+00	
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Xylene	mg/kg	1.9E-01	1.0E+04	5.9E+01	6.12
			1,2,4-Trimethylbenzene	mg/kg	1.6E-02	3.6E+02	5.6E+01	
			1,3,5-Trimethylbenzene	mg/kg	1.2E-02	3.6E+02	3.9E+01	
			Ethylbenzene	mg/kg	1.9E+00	1.0E+04	8.3E+00	
			1,2-Dibromo-3-chloropropane	mg/kg	7.9E-04	1.2E+01	1.1E+00	
		Groundwater (Ingestion Dermal Inhalation)	Naphthalene	mg/L	8.2E-02	1.0E-01	1.0E+00	6.13
			Xylene	mg/L	1.9E+00	1.0E+01	1.5E+01	
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	1.6E-02	5.9E+00	
			1,3,5-Trimethylbenzene	mg/L	1.4E-01	1.6E-02	1.9E+00	

Note:

(1) Lead SSS calculated using the Adult Lead Model and compared to the medium arithmetic mean rather than maximum detected concentration.

ES9.0 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

The Screening Level Ecological Risk Assessment that was performed for the Site included the following three components in support of the Assessment:

i) A Wetlands Delineation;

ii) A Habitat Characterization Study; and

iii) A Benthic Macroinvertebrate Study.

The conclusions formulated for each of these components of the Ecological Risk Assessment are as follows:

Wetlands Delineation

i) There are no "Exceptional Value" wetlands on the Site.

ii) All of the wetlands present on the Site are classified as "Other" wetlands on the basis of criteria identified in Pennsylvania Chapter 105.17.

iii) The types of wetlands and aquatic habitats encountered on the Site include:

- Riverine open water upper perennial;
- Riverine open water intermittent;
- Palustrine emergent wetland;
- Palustrine scrub-shrub wetland;
- Palustrine forested wetland; and
- Palustrine open water

Habitat Characterization Study

i) There are 10 general types of terrestrial habitats and cover types on the Site and in the surrounding area including:

- Developed
  - Industrial
  - Residential
  - Commercial
- Herbaceous Vegetation
  - Mowed lawn

    - Field
    - Old field
  - Scrub-Shrub Uplands
    - Early successional
    - Late successional
  - Early Successional Deciduous Forest
  - Mature Secondary Growth Deciduous Forest

ii) The identified Species of Concern for the Site are the American brook lamprey and the Ohio lamprey although there is no suitable habitat at the Site to support these two species.

iii) Two other Species of Concern potentially inhabiting the area are the American bittern and the osprey. However, there is no suitable habitat for either species present on or in the vicinity of the Site.

iv) All of the wetlands on the Site are identified as Habitats of Concern because they provide identified function and value. However, none are identified as "Exceptional Value".

Benthic Macroinvertebrate Study

i) Although some impairment of the aquatic community adjacent to the Site was noted (compared to the upstream control area), not all of the impairment is related to the refinery.

ii) No toxic response was indicated by the data.

iii) Petroleum was not noted to be present in the water column or the sediment of the Tunungwant Creek or its Tributaries.

iv) Habitat modifications and continuing habitat disturbances are concluded to be major factors limiting the distribution of Species of Concern and the quality of the stream as a Habitat of Concern.

v) Habitats of Concern and Species of Concern have not been significantly impacted by refinery operations.

vi) Kendall Creek and Bolivar Run were determined to be non-impaired.

vii) Foster Brook was determined to be moderately impaired but this is based upon a lack of suitable habitat; not as a result of impact from the Site.

viii) The benthic invertebrate community has improved or recovered since the PADEP survey conducted in 2000.

Screening Level Ecological Assessment – Steps 1 and 2

The SERA evaluated risk to ecological receptors posed by chemical constituents in the various areas of the Site. Some of the risk to ecological receptors posed by chemical constituents at the Site were in excess of the various ecological screening values for surface water, sediment, and surface soils. Consequently, it was necessary to continue to Step 3 of the USEPA's 8-Step ecological evaluation process. Many of the constituents carried forward to Step 3 did not exceed the ecological screening values, but simply had elevated detection levels (even though they were not detected). These constituents were carried forward to Step-3 as a precautionary measure. In Step-3, more Site specific characteristics were taken into consideration in the evaluation process. The constituents carried forward to Step 3 of the USEPA's 8-Step process are described below.

Surface Water

For the surface water of Tunungwant Creek, Kendall Creek, Bolivar Run, the Crude Tank Farm Tributary, and Foster Brook (Exposure Unit-7), Continuous Concentrations Criteria (CCC) for the protection of fish and aquatic life as published in *Chapter 16. Water Quality Toxics Management Strategy – Statements of Policy* (or other appropriate reference documents) were used as ecological screening values (ESVs) for surface water. Based on the available data:

i) aluminum is the only constituent detected in the surface water of Tunungwant Creek that exceeded the ESV;

ii) selenium and silver are the only constituents detected in Foster Brook that exceeded their ESVs;

iii) twelve organic constituents, including six polycyclic aromatic hydrocarbons (PAHs), and one metal were not detected in surface water, but were carried forward as a precautionary measure because their limits of detection exceeded their ESVs; and

iv) cis-1,2-dichloroethene was carried forward because an ESV was not available.

In summary, a total of 17 surface water chemical constituents will be carried forward to Step 3.

Sediment

For sediment, Probable Effects Concentrations (PEC) identified by MacDonald et al. (2000) were used as ESVs. If a PEC was not available, a Threshold Effects Concentration (TEC), also from MacDonald et al. (2000) or other appropriate reference documents were used. Based on the available data:

i) for Tunungwant Creek, 1,2,4-TMB, acetone, acrylonitrile, benzene, ethylbenzene, toluene, xylene, antimony, beryllium, iron, and manganese are the constituents detected in the sediments that exceeded their ESVs;

ii) five constituents were carried forward because an ESV was not available;

iii) 83 other constituents were carried forward because, although not detected in the sediments, their limits of detection exceeded their screening levels;

iv) for Foster Brook, acetone, vinyl acetate, beryllium, and iron, are the four constituents detected in the sediments that exceeded their ESVs; and

v) fifteen organic constituents, including chlorinated organic constituents, were carried forward because, although not detected in sediments, these compounds have limits of detection that exceeded their screening values.

In summary, a total of 100 sediment chemical constituents were carried forward to Step 3.

Surface Soil

For surface soils, separate analyses were conducted for the Main Refinery (Exposure Unit 1), Crude Tank Farm (Exposure Unit 3), Foster Brook Facility South (Exposure Unit 4), Foster Brook Facility North (Exposure Unit 5), and the Tunungwant Creek - Foster Brook Corridor (Exposure Unit 7). Ecological soil screening levels (ECO-SSL), and other pertinent criteria, were used as ESVs for soil. The detected parameters that exceeded their ESV are:

i)	Main Refinery:	benzene	iron
		fluoranthene	lead
		phenanthrene	mercury
		chromium	vanadium

ii)	Crude Tank Farm:	benzene	naphthalene
		phenanthrene	pyrene
		chromium	iron
		lead	mercury
		selenium	vanadium
		zinc	hexachlorobutadiene
iii)	Foster Brook Facility South:	1,1,1-trichloroethane	1,1-dichloroethane
		1,2-dibromomethane	1,2-dichloromethane
		bis(2-ethylhexyl)phthalate	benzene
		ethylbenzene	xylene
		2-methylnaphthalene	anthracene
		benzo(a)anthracene	benzo(a)pyrene
		benzo(k)fluoranthene	fluoranthene
		chrysene	phenanthrene
		naphthalene	antimony
		pyrene	copper
		chromium	lead
		iron	selenium
		mercury	zinc
		vanadium	
iv)	Foster Brook Facility North:	bis(2-ethylhexyl)phthalate	benzo(a)pyrene
		chrysene	fluoranthene
		naphthalene	phenanthrene
		pyrene	chromium
		iron	copper
		vanadium	lead
		mercury	selenium
		thallium	zinc
v)	Tunungwant Creek - Foster Brook corridor:	anthracene	benzo(a)pyrene
		fluoranthene	naphthalene
		phenanthrene	pyrene
		chromium	iron
		mercury	vanadium

In summary, a total of 168 soil chemical constituents were carried forward to Step 3.

STEP 3 ECOLOGICAL RISK ASSESSMENT

In Steps 1 and 2, the most conservative ecological benchmark concentrations were identified as the Ecological Screening Value (ESV) against which to assess each chemical constituent in each media (soil, sediment, and surface water). In the first phase of Step 3, ecological benchmark concentrations that are more appropriate for site-specific conditions (refinement benchmarks) are identified. Factors such as site-specific background concentrations (for metals) and surrogate chemical concentrations (for chemicals that do not have ESV or other ecological benchmark concentrations) are also identified. Then the maximum and mean concentrations of the COPECs at the Site are compared to the refinement benchmark concentrations. For those constituents retained in the first phase of Step 3 as COPECs that exceed the refinement benchmark concentrations, simple food chain models were then used to evaluate potential risk for various trophic guilds.

The evaluation performed in the first refinement phase of Step 3 identified five chemical constituents that were retained as COPECs in soil:

- 1,2,4-trimethylbenzene;
- 1,3,5-trimethylbenzene;
- bis(2-ethylhexyl)phthalate;
- 2-methylnaphthalene; and
- copper.

There were no chemical constituents that were identified as COPECs for either the sediment or for the surface water media.

These five chemical constituents were then further evaluated in the second phase of Step 3 using simple food chain models and wildlife indicator species to evaluate risk to various trophic guilds of ecological receptors. Short-tailed shrew and American woodcock were used to evaluate risk to mammalian insectivores and avian insectivores, respectively. The deer mouse was used to evaluate risk to mammalian herbivores. The red fox and red-tailed hawk were used to evaluate risk to mammalian carnivores and avian carnivores, respectively. Each analysis evaluated a range of exposure scenarios (maximum, mean, and 95 percent upper confidence level concentrations) to determine whether these five chemical constituents would result in an observable adverse effect in these wildlife indicator species.

Results of the food chain analyses show that the potential for risk is within acceptable limits for the wildlife indicator species exposed to the COPECs in the soil in the Foster Brook Facility and Tunungwant Creek-Foster Brook Corridor. Scenarios based on the mean and 95 percent upper confidence level concentration and Lowest Observable Adverse Effects Level generally produced a Hazard Quotient less than one indicating that the risk levels are within acceptable limits. Because conservative assumptions were used for area use (i.e., 100 percent area use) and exposure (e.g., 100 percent bioavailability), Hazard Quotients slightly greater than one were interpreted to be within the limits of acceptable potential for risk. When more realistic assumptions of area use are considered, the Hazard Quotients for all scenarios are generally less than one. Use of more realistic bioavailability assumptions would further reduce the Hazard Quotients.

Because no constituents were identified as COPECs for either surface water or sediment, food chain analyses were not used to evaluate the potential for risk to semi-aquatic wildlife that forage on fish or other aquatic organisms. This has been identified and included as a source of uncertainty in the Step 3 evaluation of risk.

One additional issue that was evaluated during the ecological risk assessment involved the observations of iron staining in the sediment of Tunungwant Creek. PADEP was concerned that the iron staining could be a source of concern for potential risk to ecological receptors in the water column and sediment of Tunungwant Creek. The results of the assessment performed show that the iron staining may cause an adverse impact on the aesthetics of Tunungwant Creek. However, the potential for risk to ecological receptors due to iron in surface water and sediment was found to be within acceptable limits. Furthermore, the macroinvertebrate survey conducted as part of the SERA did not identify any impacts to the benthic community that could be attributed to iron or any other COPEC.

Based on the results of the refinement process and food chain analyses, it can be concluded that the potential for risk to ecological receptors is within acceptable limits in all surface water, sediment, and soil media in all assessment areas at the ARG Facility. Consequently, there is neither need nor justification for a baseline risk assessment and the ecological risk assessment process can be exited at Step 3.

Given the absence of any identified unacceptable risk in any of the media, the ecological risk assessment for the ARG Facility is complete.

ES10.0 IMPLEMENTED REMEDIAL ACTIONS

i) The completed container removal program in the Refuse/Container Removal Area has effectively remediated this area.

ii) The pumping of the horizontal wells, supplemented by select vertical wells is effectively preventing the discharge of SPL and significantly reducing the flux of Site-impacted groundwater to Tunungwant Creek. This conclusion is based on the fact that between May 2003 and the end of March 2005, approximately 33,875,000 gallons of groundwater and 13,600 gallons of SPL was collected from these pumping systems. This conclusion is further supported by the minimal observed occurrences of seeps to the Creek via the flood control wall weep holes in the last year compared to previous years.

iii) Construction of the new groundwater treatment facility which is successfully operating and is fully capable of meeting the PADEP permit discharge limits.

iv) A program of manual SPL recovery has been implemented at the Site and has significantly reduced the thickness and volume of SPL underlying the Site. Approximately 27,200 gallons of SPL have been recovered from the manual SPL Recovery Program to March 31, 2007.

v) Implementation of an IRM beneath the Foster Brook Facility attendant's station to ensure that the air space beneath the building will be the same as the ambient outdoor air and eliminate the soil gas to indoor air pathway. (Fig. 9.5)

The locations of the implemented remedial actions are shown on Figures ES10.1 and ES10.2.

ES11.0 PLANNED REMEDIAL ACTIONS

ES11.1 SITE

The remedial actions planned to be implemented for the Site include the following:

i) continued operation of the horizontal and vertical collection wells;

ii) continued operation of the groundwater treatment system;

iii) continued implementation of the manual SPL recovery program;

iv) inspection and reporting of the Creek bank conditions, including mapping of the iron stained areas on an annual basis;

v) implementation of corrective actions to address any observed SPL or sheens noted during the Creek bank inspection; and

vi) closure and monitoring of the five specific areas in the Foster Brook Facility.

In addition, a macroinvertebrate study and surface water sampling will be performed every two years, which started in 2006, until such study/sampling can be stopped in accordance with the conditions provided in Section 3.c of the COA. It is noted that the surface water sampling is to be performed when flow conditions are equal to or less than 7Q10 or when conditions acceptable to PADEP exist.

The recommended technologies for SPL-1, SPL-4, SPL-9, SPL-20, SPL-21, SPL-27, and SPL-30 are:

i) manual SPL/groundwater recovery;

ii) natural attenuation; and

iii) institutional controls.

The recommended technologies for SPL-2/3 and SPL-18 are:

i) manual SPL/recovery;

ii) manual SPL/groundwater recovery;

iii) natural attenuation; and

iv) institutional controls.

The recommended remedial technologies for SPL-16 are:

i) excavation;
ii) natural attenuation; and
iii) institutional controls.

The recommended technologies for SPL-23 are:

i) manual SPL recovery;
ii) in-situ remediation;
iii) natural attenuation; and
iv) institutional controls.

The recommended technologies for SPL-17, SPL-25, SPL-28, and SPL-29 are:

i) natural attenuation; and
ii) institutional controls.

The recommended technologies for SPL-10 are:

i) manual SPL/recovery;
ii) vertical SPL extraction wells;
iii) horizontal collection wells;
iv) natural attenuation; and
v) institutional controls.

The recommended technologies for SPL-5, SPL-6, SPL-7, SPL-8, SPL-11, SPL-12/13, SPL-14, and SPL-15 are:

i) manual SPL recovery;
ii) horizontal collection wells;
iii) natural attenuation; and
iv) institutional controls.

The recommended technologies for SPL-22, SPL-24, and SPL-26 are:

i) manual SPL recovery;

ii) AS/SVE;

iii) natural attenuation; and

iv) institutional controls.

An expanded description of these planned remedial actions is provided in Appendices AN and AR. Draft language for the deed restrictions and operating procedures for on-Site areas are provided in Appendices AO and AP, respectively.

ES11.2 OFF-SITE AREAS

This section summarizes the planned remedial actions for the off-site properties adjacent to and/or downgradient of the Site.

In summary, natural attenuation and institutional controls were recommended for all off-Site properties, except for two areas; the portion of the B&P Railroad south of Kendall Avenue where manual SPL/groundwater recovery and the portion of the B&P Railroad adjacent to EU3/EU8 where manual SPL recovery were also recommended.

Furthermore, the recommended technologies for SPL-31 also include manual SPL recovery and dual phase extraction.

With regard to the protection of the construction worker in implementing the planned remedial actions, procedures will be put in place to ensure that appropriate health and safety measures are implemented.

For the off-site private properties, deed restrictions will need to be in place to preclude the use of groundwater, other than that needed for monitoring and remedial purposes.

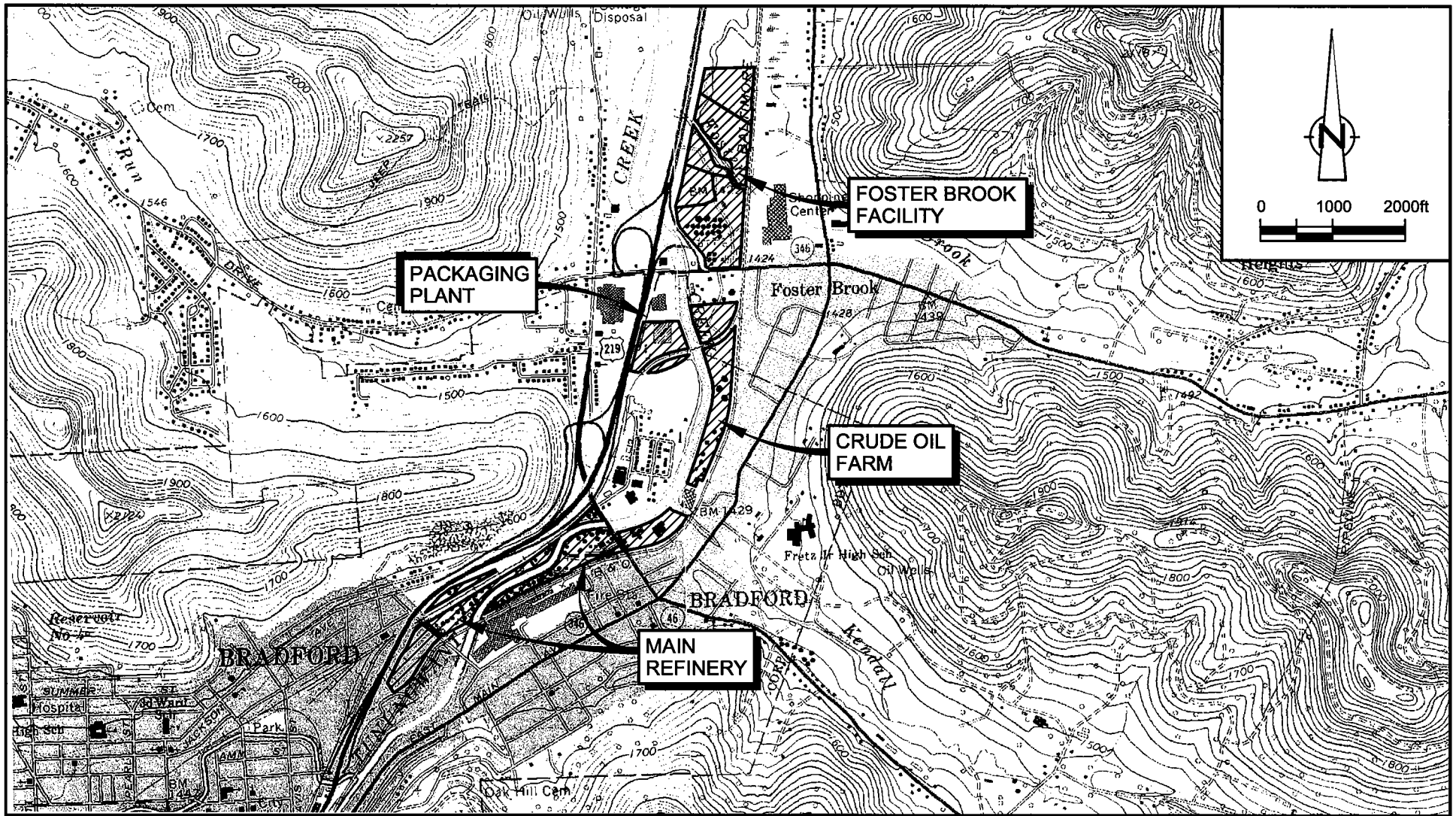
For the properties that are under the control of public entities (e.g., City of Bradford) or utility companies (e.g., railroads), deed restrictions will not be implemented. Rather, procedures will be in place to ensure that ARG/Chemtura are notified of any subsurface activities that are planned and that an appropriate health and safety plan is available for and used for the activity.

Draft language for the procedures to put the deed restrictions in place and to ensure appropriate H&S measures are implemented are provided in Appendices AS and AT, respectively.

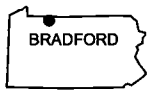
ES12.0 SUMMARY

This SCR fulfills the requirements of the applicable provisions of Chapter 245 (Storage Tank Regulations), Chapter 93 and 96 (Surface Water Quality and Water Quality Protection) and Chapter 250 (Pennsylvania Land Recycling Program), and of the Consent Order and Agreement dated June 4, 2004, which has been executed between PADEP, Chemtura, and ARG.

The information presented in this SCR provides a thorough understanding of the Site conditions and this understanding is sufficient to progress to the next step; the development of the Site Cleanup Plan in accordance with §250.410.



SOURCE: USGS QUADRANGLE MAP;
BRADFORD, PENNSYLVANIA
1969, PHOTOREVISED 1977, REVISED 1981
DERRICK CITY, PENNSYLVANIA
1969, PHOTOREVISED 1983, REVISED 1986



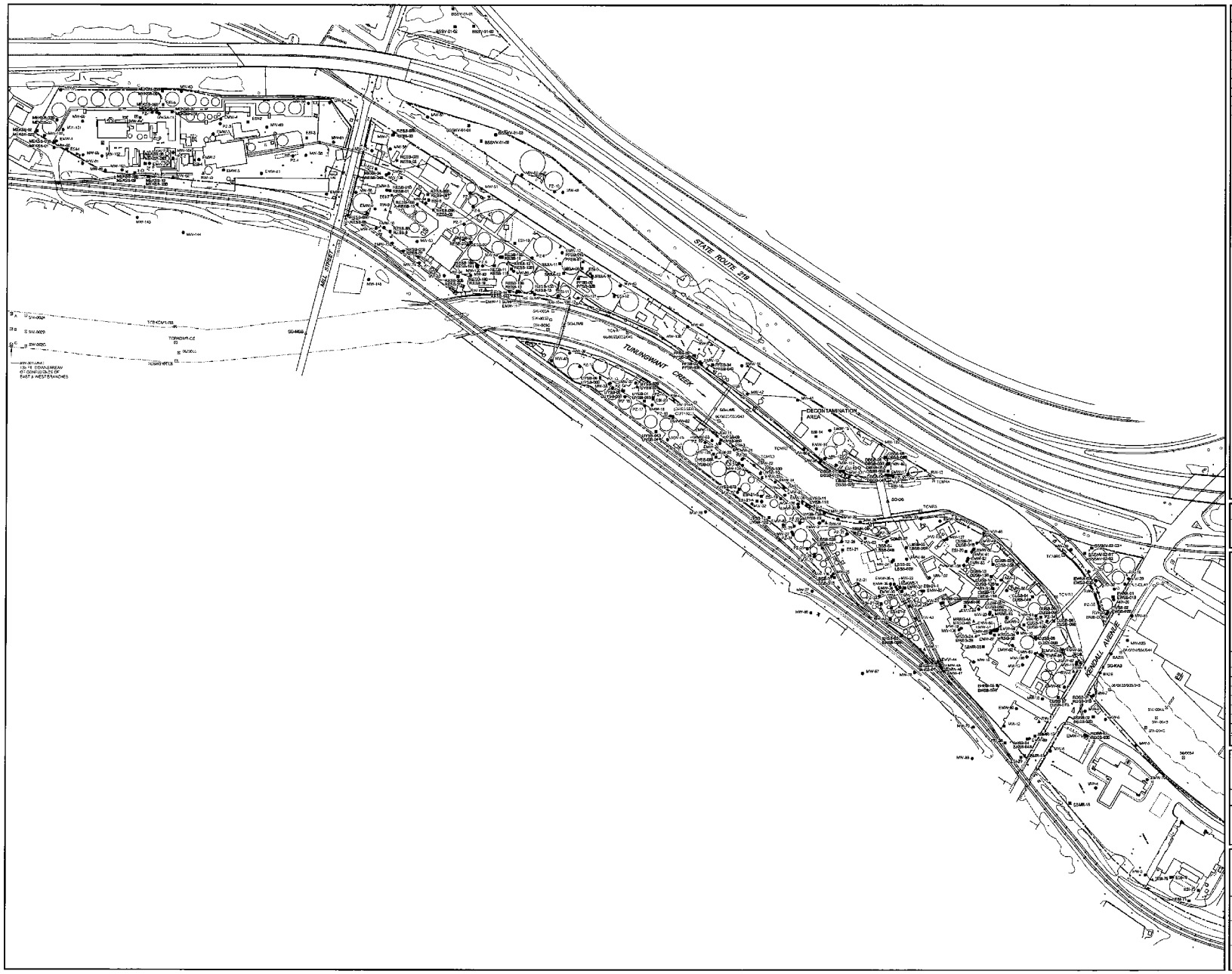
PENNSYLVANIA

figure ES1.1

SITE LOCATION

ARG Refinery, Bradford, Pennsylvania

30984-27(006)GN-WA083 JUN 09/2004



NO	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- MW-RA04 MONITORING WELL/PIEZOMETER LOCATION
- RW-147 RECOVERY WELL LOCATION
- 22 SOIL BORING LOCATION
- TRENCH1 EXCAVATION/TRENCH LOCATION
- CDSS-04 SOIL SAMPLE LOCATION
- A-PB02D SEDIMENT/SURFACE WATER SAMPLE LOCATION
- SG-48MS8 STAFF GAUGE LOCATION
- OIL OIL WELL LOCATION
- TP-1 TEST PIT LOCATION
- MRSG-01 SOIL GAS PROBE LOCATION

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

MAIN REFINERY

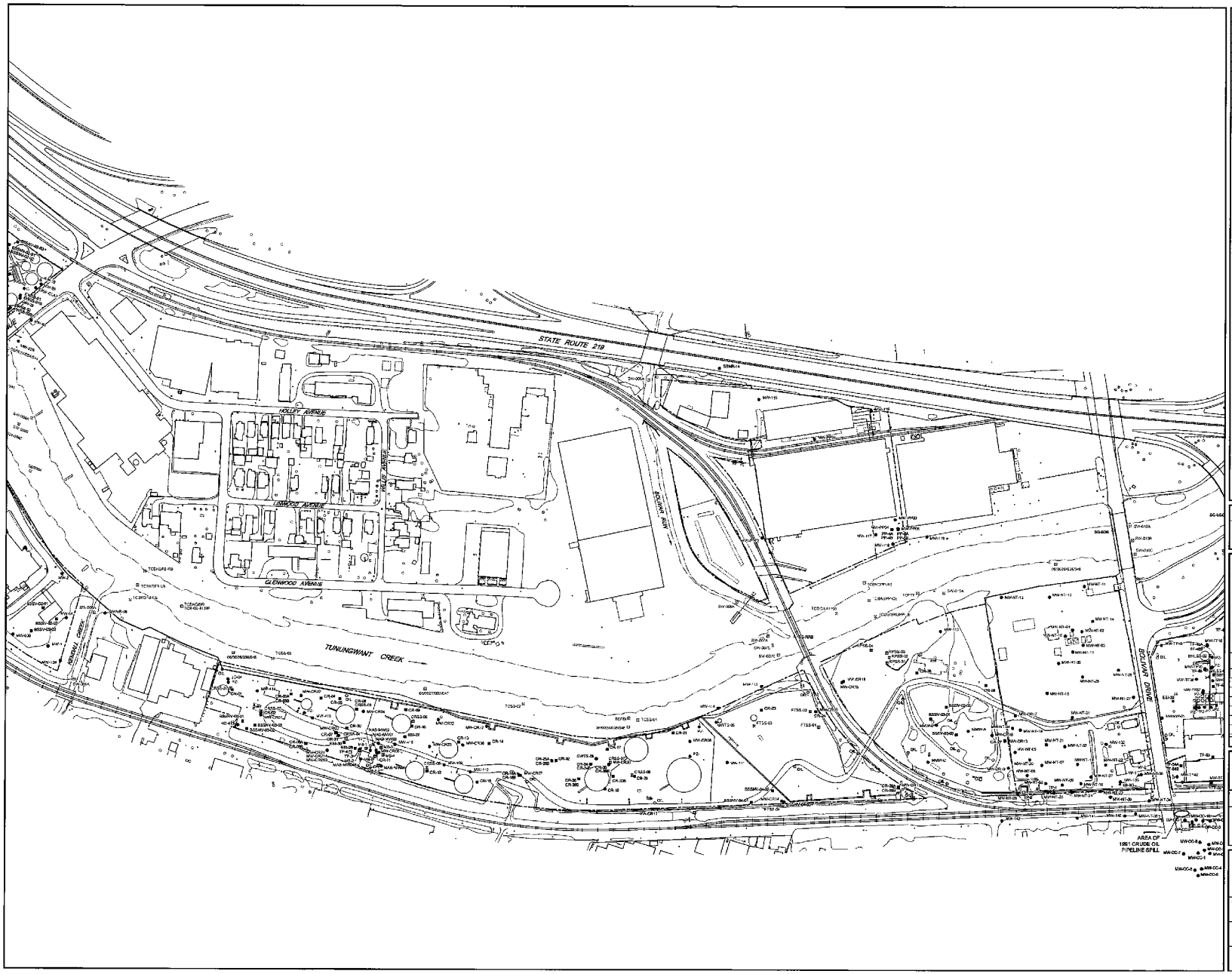
SITE PLAN AND
SAMPLING LOCATIONS

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C., BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	K. SCHMIDTKE	APRIL 2004	
Scale: AS SHOWN	Project N°: 30984-27	Report N°: 006	Drawing N°: fig ES3.1

30984-27(006)GN-WA065 JUL 01/2005



NO.	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- MONITORING WELL/PIEZOMETER LOCATION
- RECOVERY WELL LOCATION
- SOIL BORING LOCATION
- EXCAVATION/TRENCH LOCATION
- SOIL SAMPLE LOCATION
- SEDIMENT/SURFACE WATER SAMPLE LOCATION
- STAFF GAUGE LOCATION
- OIL WELL LOCATION
- TEST PIT LOCATION
- SOIL GAS PROBE LOCATION

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

CRUDE TANK FARM & PACKAGING PLANT

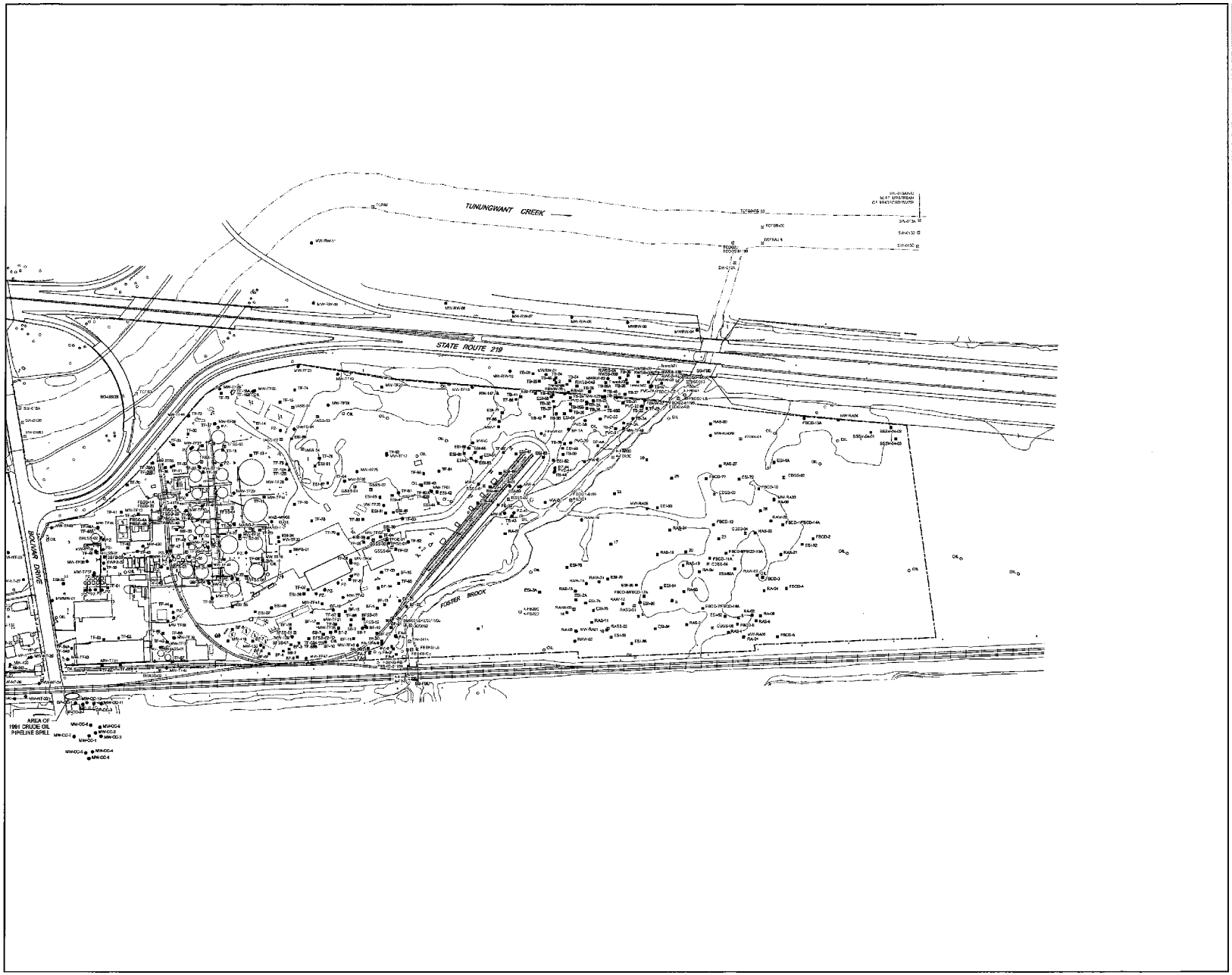
SITE PLAN AND
SAMPLING LOCATIONS

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C. BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	K. SCHMIDTKE	APRIL 2004	
Scale:	Project N#:	Report N#:	Drawing N#:
AS SHOWN	30984-27	006	fig ES3.2

30984-27(006)GN-WA055 JUL 01/2005



Nº	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- MW-RA04 MONITORING WELL/PIEZOMETER LOCATION
- RW-147 RECOVERY WELL LOCATION
- ZP SOIL BORING LOCATION
- TRENCH EXCAVATION/TRENCH LOCATION
- CDSS-04 SOIL SAMPLE LOCATION
- SEDIMENT/SURFACE WATER SAMPLE LOCATION
- SG4/SG5 STAFF GAUGE LOCATION
- OIL OIL WELL LOCATION
- TP-1 TEST PIT LOCATION
- MASS-01 SOIL GAS PROBE LOCATION

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

FOSTER BROOK FACILITY

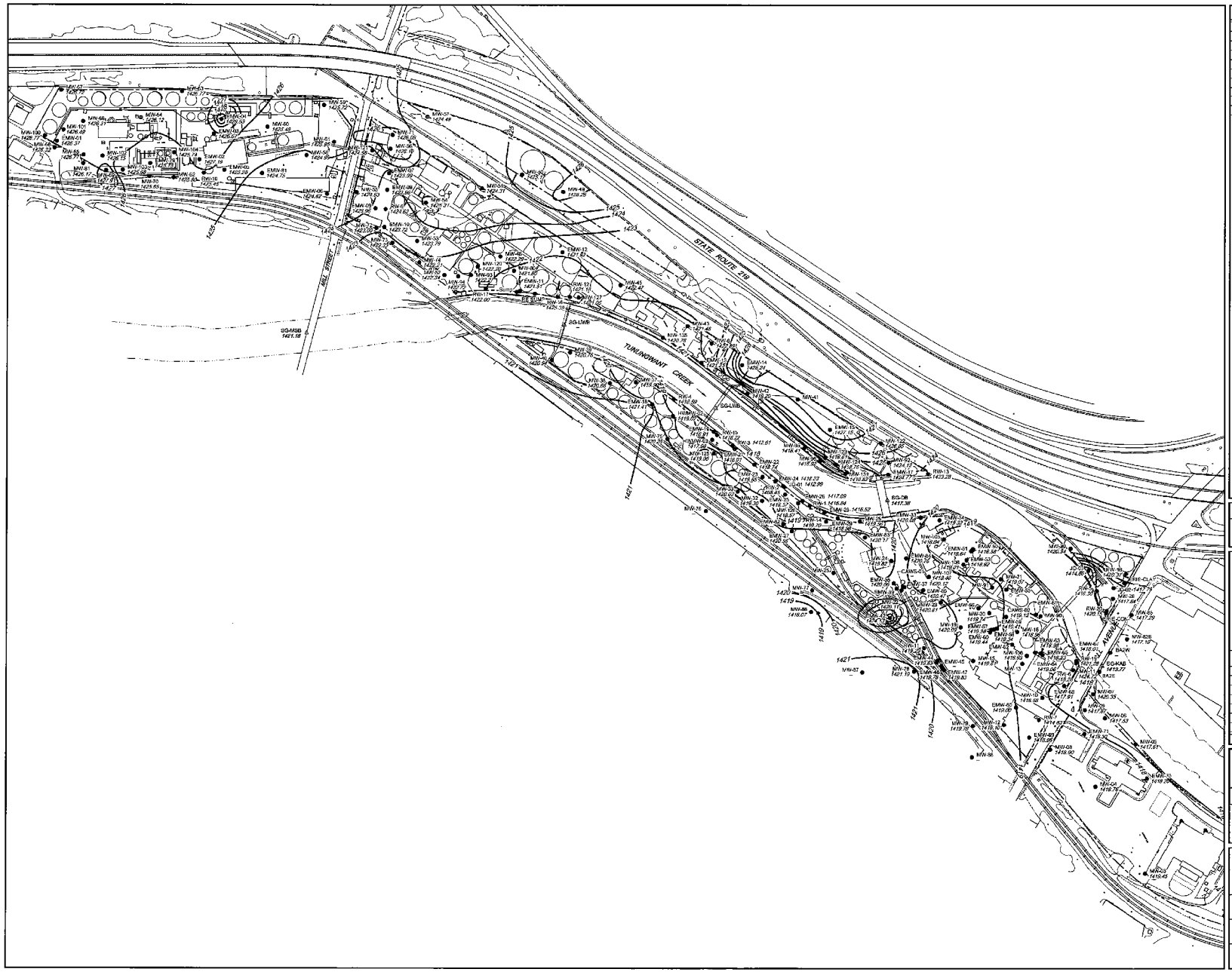
SITE PLAN AND
SAMPLING LOCATIONS

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C., BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	K. SCHMIDTKE	APRIL 2004	
Scale: AS SHOWN	Project Nº: 30984-27	Report Nº: 006	Drawing Nº: fig ES3.3

30984-27(006)GN-WA003 JUL 01/2005



NR	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- 1414 GROUNDWATER CONTOUR
- MW-95 1416.19 MONITORING WELL/PIEZOMETER LOCATION AND GROUNDWATER ELEVATION (ft.)
- SG-KSB 1418.72 STAFF GAUGE LOCATION AND SURFACE WATER ELEVATION (ft.)
- – / – NOT MEASURED

NOTES:

1. MONITORING WELLS EMW-67 (MAIN REFINERY) AND BW-416 (FOSTER BROOK) ARE DEEP WELLS. GROUNDWATER ELEVATIONS IN THESE WELLS MAY NOT REFLECT WATER TABLE AQUIFER CONDITIONS.
2. WATER ELEVATIONS HAVE BEEN CORRECTED TO ACCOUNT FOR SPL PRESENCE, WHERE APPLICABLE.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

MAIN REFINERY

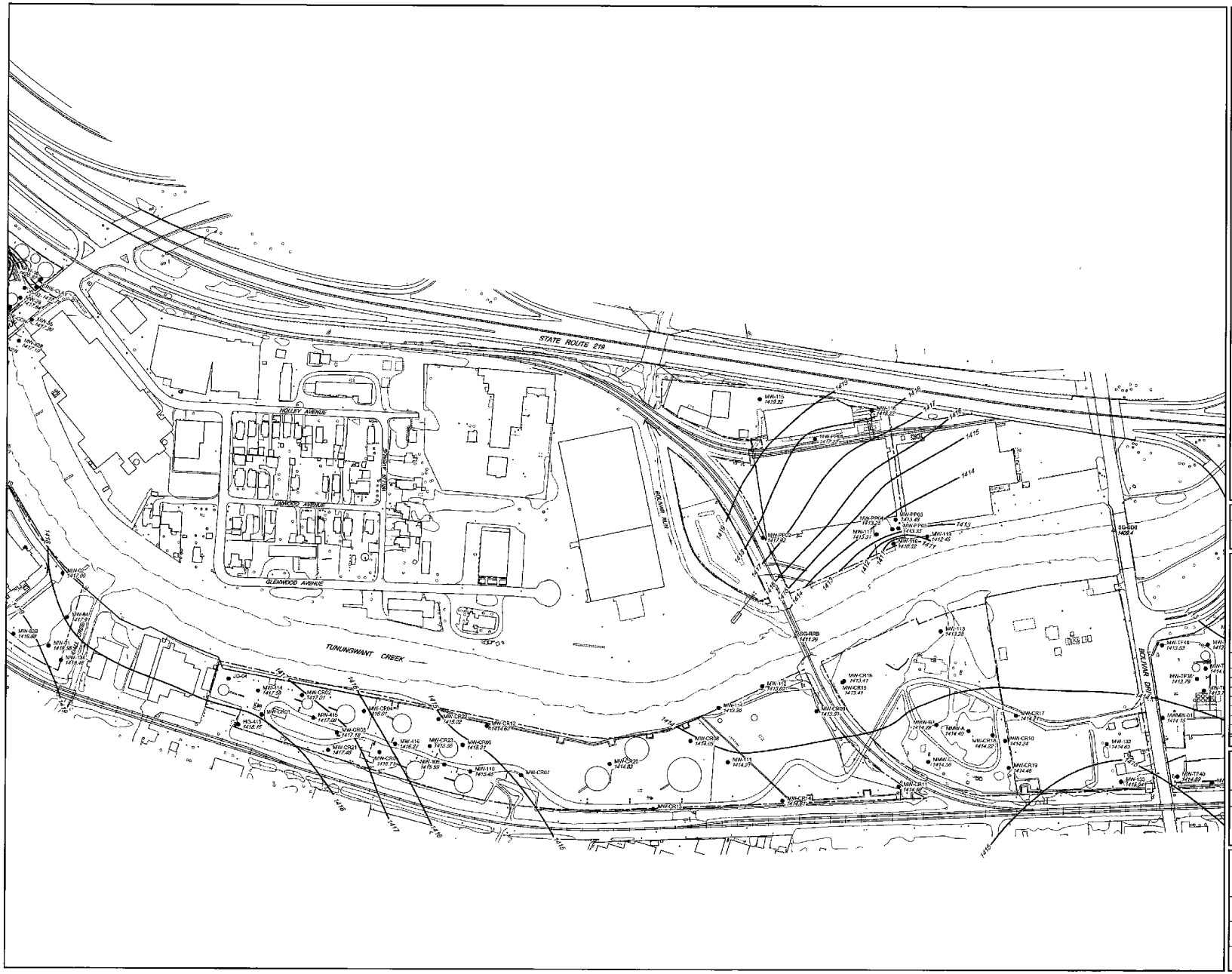
CORRECTED GROUNDWATER ELEVATIONS
DECEMBER 17-19, 2003

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C. BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	B. TRYTTEN	JUNE 2004	
Scale:	Project NR:	Report NR:	Drawing NR:
AS SHOWN	30984-27	006	fig ES5.1a

30984-27(006)GN-WA085 JUL 01/2005



No	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- 1414 — GROUNDWATER CONTOUR
- MW-35 1419.15 — MONITORING WELL/PIEZOMETER LOCATION AND GROUNDWATER ELEVATION (ft.)
- SG-KAB 1415.72 — STAFF GAUGE LOCATION AND SURFACE WATER ELEVATION (ft.)
- – / – — NOT MEASURED

NOTES:

1. MONITORING WELLS EMW-67 (MAIN REFINERY) AND BW-418 (FOSTER BROOK) ARE DEEP WELLS. GROUNDWATER ELEVATIONS IN THESE WELLS MAY NOT REFLECT WATER TABLE AQUIFER CONDITIONS.
2. WATER ELEVATIONS HAVE BEEN CORRECTED TO ACCOUNT FOR SPL PRESENCE, WHERE APPLICABLE.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

CRUDE TANK FARM

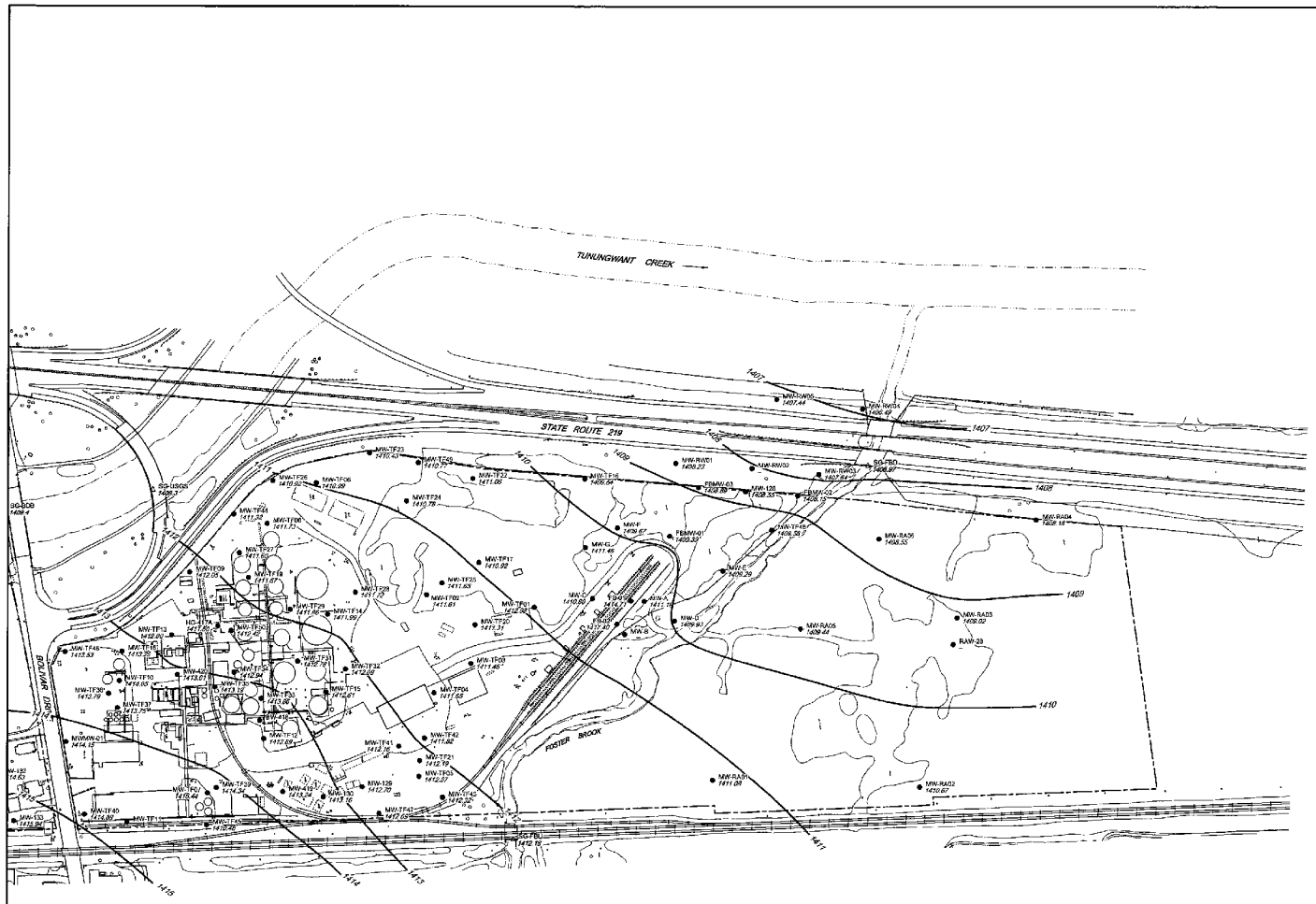
CORRECTED GROUNDWATER ELEVATIONS
DECEMBER 17-19, 2003

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C. BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	B. TRYTTEN	JUNE 2004	
Scale:	Project N#:	Report N#:	Drawing N#:
AS SHOWN	30984-27	006	fig ES5.1b

30984-27(006)GN-WA036 JUL 01/2005



NO	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- 1414 GROUNDWATER CONTOUR
- MW-RG 1419.16 MONITORING WELL/PIEZOMETER LOCATION AND GROUNDWATER ELEVATION (ft.)
- SG-HOAB 1415.72 STAFF GAUGE LOCATION AND SURFACE WATER ELEVATION (ft.)
- -- / -- NOT MEASURED

NOTES:

1. MONITORING WELLS EMW-07 (MAIN REFINERY) AND BW-419 (FOSTER BROOK) ARE DEEP WELLS. GROUNDWATER ELEVATIONS IN THESE WELLS MAY NOT REFLECT WATER TABLE AQUIFER CONDITIONS.
2. WATER ELEVATIONS HAVE BEEN CORRECTED TO ACCOUNT FOR SPL PRESENCE, WHERE APPLICABLE.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

FOSTER BROOK FACILITY

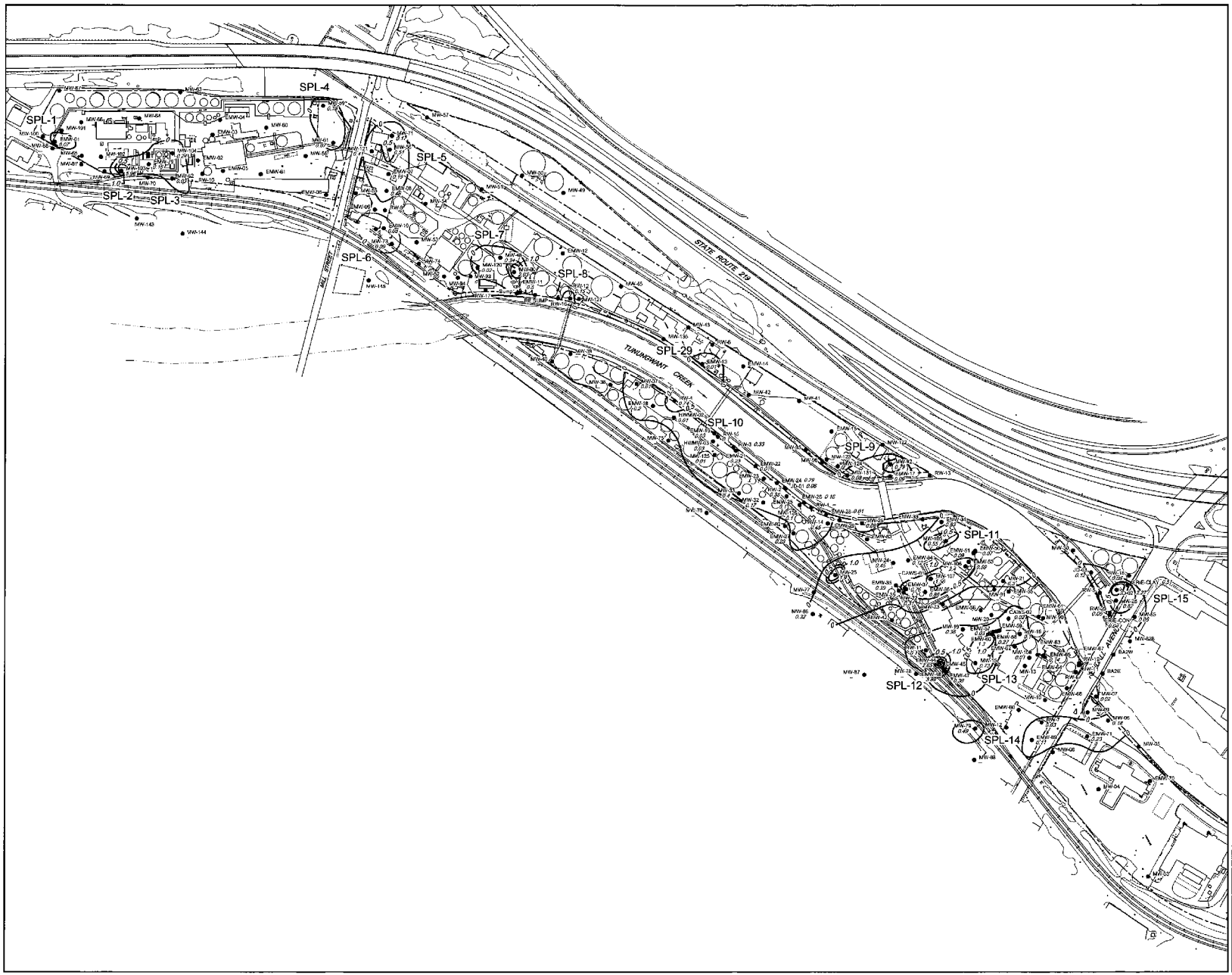
CORRECTED GROUNDWATER ELEVATIONS
DECEMBER 17-19, 2003

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C. BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager	Reviewed By	Date	
J. KAY	B. TRYTTEIN	JUNE 2004	
Scale: AS SHOWN	Project NR: 30984-27	Report NR: 006	Drawing NR: fig ES5.1c

30984-27(006)GN-WA036 JUL 01/2005



NO	Revision	Date	Initial

0 50 150ft

LEGEND

PROPERTY BOUNDARY

0 THICKNESS CONTOUR

MW-12 0.26 MONITORING WELL/PIEZOMETER LOCATION AND APPARENT SPL THICKNESS (ft.)

SPL-1 SPL AREA DESIGNATION

NOTES:

CONTOURS AT 0, 0.5, 1.0, 2.0, 3.0, 4.0 FEET APPARENT THICKNESS

WELLS MW-143, MW-144, AND MW-145 INSTALLED IN APRIL 2005

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

MAIN REFINERY

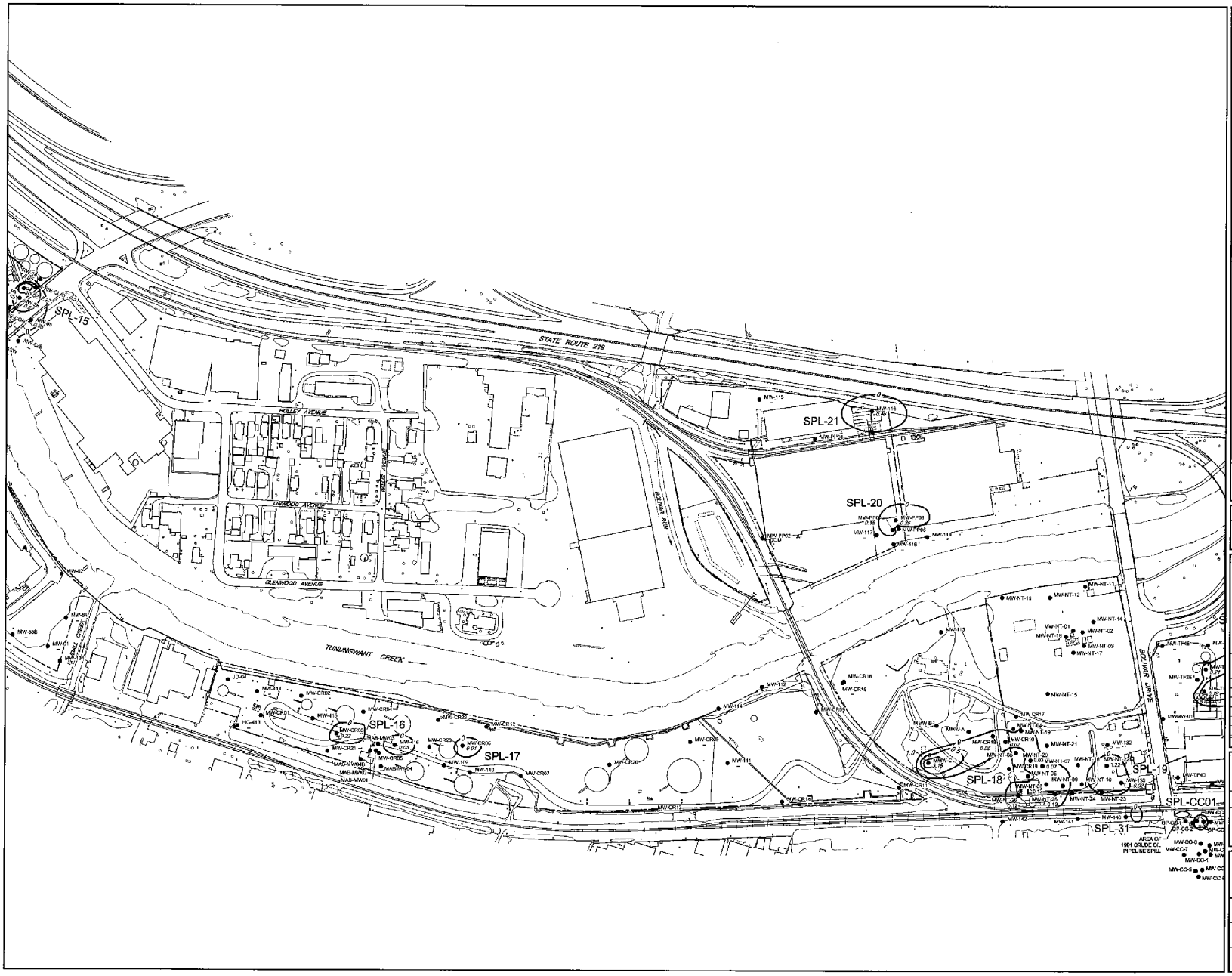
APPARENT SPL THICKNESS
DECEMBER 17-19, 2003

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C., BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 18, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	B. TRYTTEN	APRIL 2004	
Scale:	Project NR:	Report NR:	Drawing NR:
AS SHOWN	30984-27	006	fig ES5.2a

30984-27(006)GN-WA087 APR 24/2007



NO	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- 0 THICKNESS CONTOUR
- MW-12 0.06 MONITORING WELL/PIEZOMETER LOCATION AND APPARENT SPL THICKNESS (ft.)
- SPL-1 SPL AREA DESIGNATION
- EXTENT OF SPL-18 PRIOR TO DIESEL PIPELINE RELEASE REPORTED IN MAY 2004

NOTES:

CONTOURS AT 0, 0.5, 1.0, 2.0, 3.0, 4.0 FEET APPARENT THICKNESS.
SPL-KTB1 ADDED AND SPL-19 REVISED AS PER MARCH 2005 SHELL SCR.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

CRUDE TANK FARM & PACKAGING PLANT

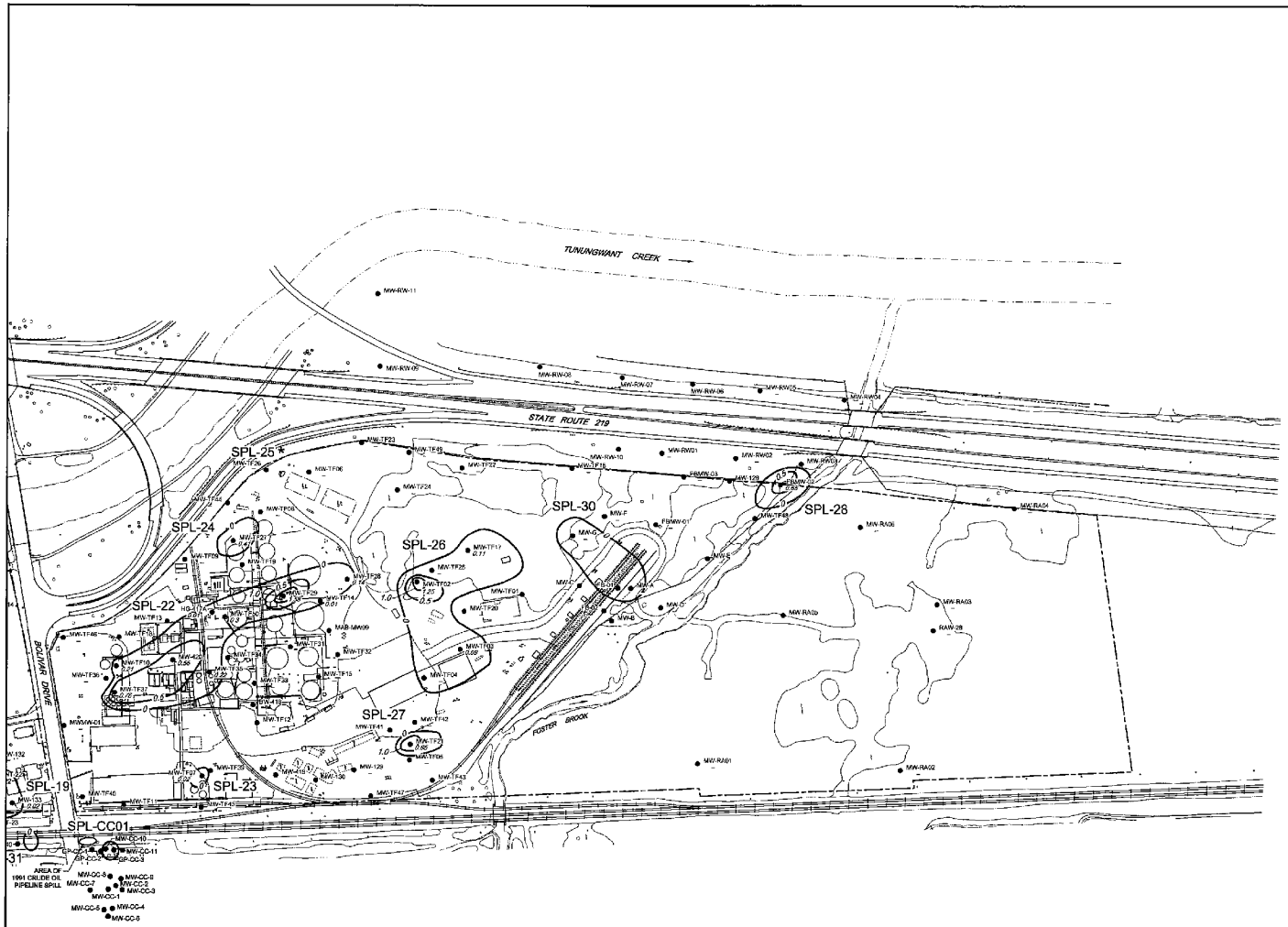
APPARENT SPL THICKNESS
DECEMBER 17-19, 2003

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C. BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	B. TRYTTEN	APRIL 2004	
Scale: AS SHOWN	Project NR: 30984-27	Report NR: 006	Drawing NR: fig ES5.2b

30984-27(006)GN-WA087 JJ1 04/2007



NO	Revision	Date	Initial

0 50 150ft

LEGEND

PROPERTY BOUNDARY

0 THICKNESS CONTOUR

MW-12 0.06 MONITORING WELL/PIEZOMETER LOCATION AND APPARENT SPL THICKNESS (ft.)

SPL-1 SPL AREA DESIGNATION

NOTES:
CONTOURS AT 0, 0.5, 1.0, 2.0, 3.0, 4.0 FEET APPARENT THICKNESS.
* SPL NOT PRESENT IN DECEMBER 2003.
SPL-NT01 ADDED AND SPL-19 REVISED AS PER MARCH 2006 SHELL SCR.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

FOSTER BROOK FACILITY

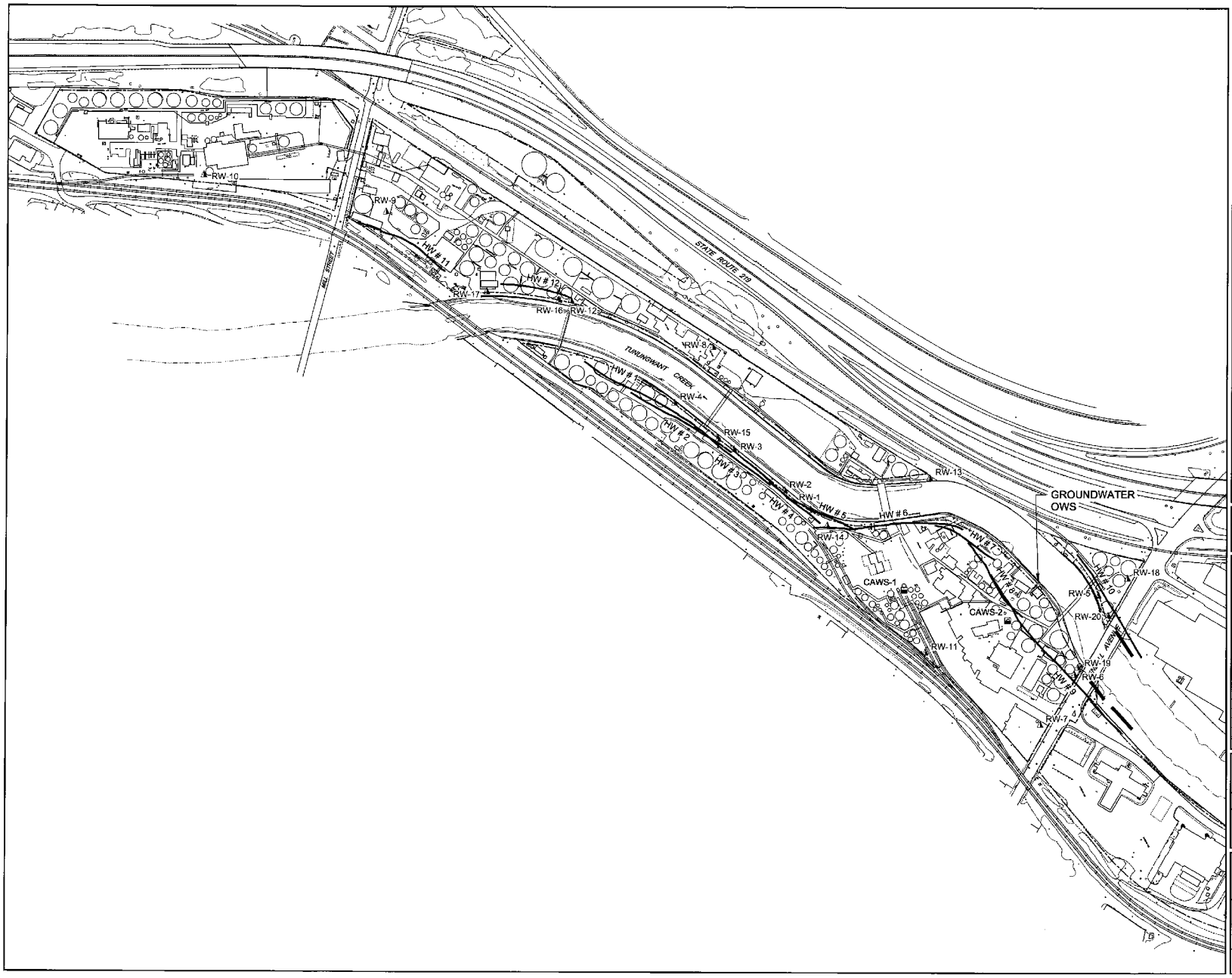
APPARENT SPL THICKNESS
DECEMBER 17-19, 2003

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C. BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	B. TRYTTEN	APRIL 2004	
Scale:	Project Nº:	Report Nº:	Drawing Nº:
AS SHOWN	30984-27	006	fig ES5.2c

30984-27(006)G4-WA087 APR 25/2007



NO	Revision	Date	Initial

0 50 150ft

LEGEND

- PROPERTY BOUNDARY
- RW-16 SPL RECOVERY WELL LOCATION
- CAWS-1 CAISSON ANGLE WELL SYSTEM LOCATION
- HORIZONTAL WELL LOCATION
- KENDALL AVENUE BRIDGE TRENCH

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

MAIN REFINERY

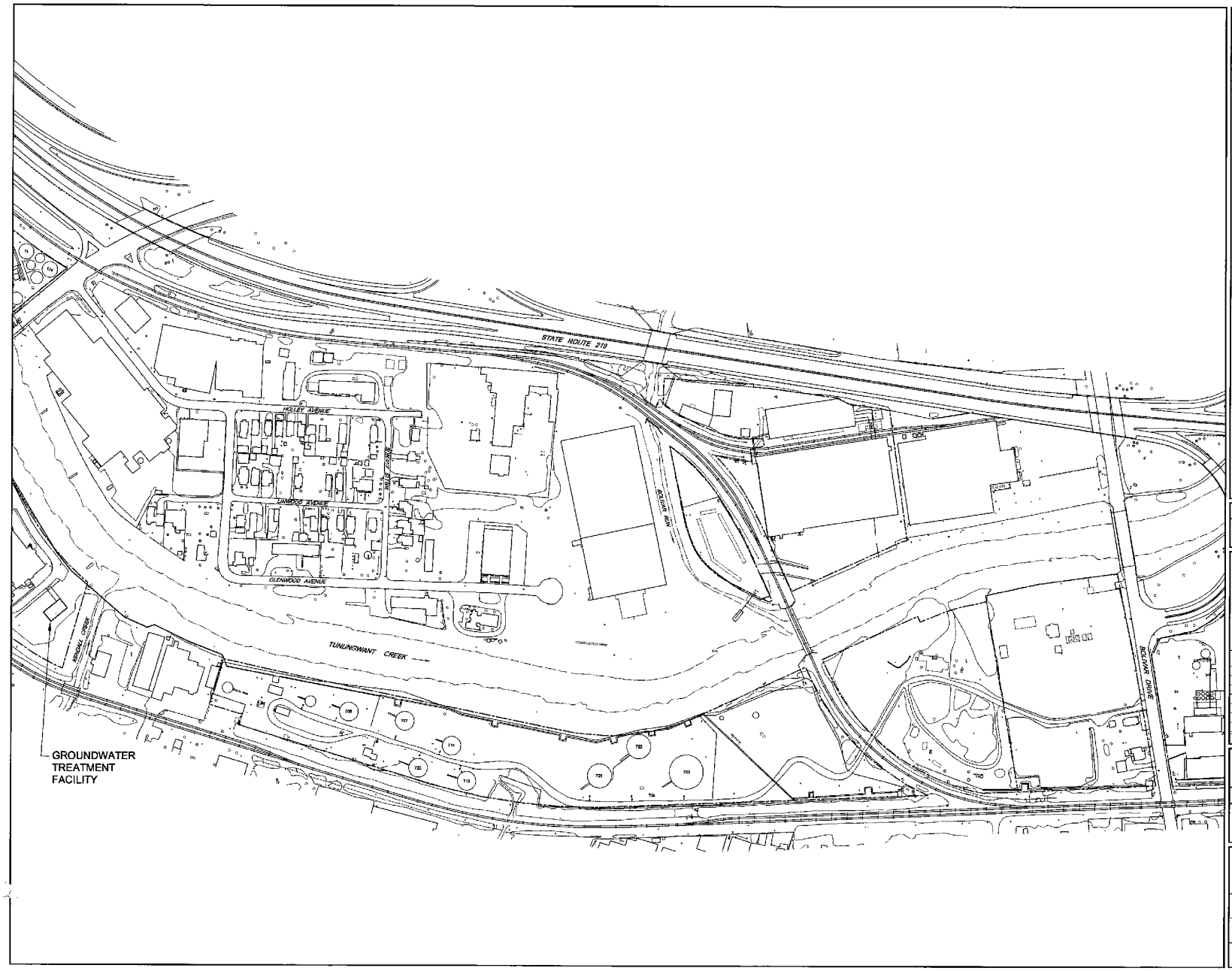
SPL AND GROUNDWATER RECOVERY IRM COMPONENTS

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C. BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 16, 2003

Project Manager:	Reviewed By:	Date:	
J. KAY	K. SCHMIDTKE	JUNE 2004	
Scale:	Project N#:	Report N#:	Drawing N#:
AS SHOWN	30984-27	006	fig ES10.1

30984-27(006)GN-WA086 JUL 01/2005



Nº	Revision	Date	Initial

0 50 100ft

LEGEND

PROPERTY BOUNDARY

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

ARG REFINERY
Bradford, Pennsylvania

CRUDE TANK FARM & PACKAGING PLANT

SPL AND GROUNDWATER
RECOVERY IRM COMPONENTS

CONESTOGA-ROVERS & ASSOCIATES

Source Reference: E & M ENGINEERS AND SURVEYORS, P.C.
BASED ON AERIAL PHOTOGRAPHY DATED SEPT. 18, 2003

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J. KAY	K. SCHMIDTKE	JUNE 2005	
Scale:	Project Nº:	Report Nº:	Drawing Nº:
AS SHOWN	30984-27	006	fig ES10.2

30984-27(006)GN-WA114 JUL 01/2005

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AMSL	Above Mean Sea Level
ARG	American Refinery Group
AST	Aboveground Storage Tank
B&R Railroad	Buffalo & Pittsburgh Railroad
bgs	below ground surface
BMP	Best Management Practice
BPSD	Barrels per Steam Day
cfs	cubic feet per second
COC	Constituent of Concern
Corps	United States Army Corps of Engineers
CRA	Conestoga-Rovers & Associates
CTF	Crude Tank Farm
DEHP	Bis(2-ethylhexyl)phthalate
D&D	Dewaxing and Deresining
DOT	Department of Transportation
EDR	Environmental Data Resources
EHB	Environmental Hearing Board
ERA	Ecological Risk Assessment
ESI	Enviro-Sciences, Inc.
EU	Exposure Unit
FBF	Foster Brook Facility
HHRA	Human Health Risk Assessment
HNE	Heavy Neutral Extract
HNSW	Heavy Neutral Slack Wax
IAF	Induced Air Flotation
ICP	Integrated Contingency Plan
K	Kensol®
LLNSW	Light Lube Neutral Slack Wax
LNE	Light Neutral Extract
LSR	Light Straight Run
MEK	Methyl Ethyl Ketone
MNE	Medium Neutral Extract
MNSW	Medium Neutral Slack Wax

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MSC	Medium Specific Concentration
MSDS	Material Safety Data Sheets
NIR	Notice of Intent to Remediate
NMP	N-methyl-2-pyrrolidone
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
NR	Non-Residential
NTC	National Transit Company
nka	Now Known As
OWS	Oil-Water Separator
PAH	Polycyclic Aromatic Hydrocarbons
PADEP	Pennsylvania Department of Environmental Protection
PennDOT	Pennsylvania Department of Transportation
PID	Photoionization Detector
PPC Plan	Site Preparedness, Prevention, and Contingency Plan
ppm	parts per million
PQS	Pennzoil-Quaker State Company
PVC	Polyvinyl Chloride
RCRA	Resource Conservation and Recovery Act
R&D	Administration/Research and Development
RI	Remedial Investigation
ROSE®	Residual Oil Supercritical Extraction
SCR	Site Characterization Report
SERA	Screening Level Ecological Risk Assessment
SHS	Statewide Health Standard
Site	ARG Bradford Refinery
SPL	Separate Phase Liquid
SPR	Spill Prevention Response
SSD Work Plan	Supplemental Site Delineation Work Plan
SSS	Site-Specific Standard
STL	Severn Trent Laboratories
SVOC	Semi-Volatile Organic Compound
TDS	Total Dissolved Solids

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USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VI	Viscosity Index
VOC	Volatile Organic Compound
Witco	Witco Corporation
WQM	Water Quality Management
WWTP	Wastewater Treatment Plant

1.0 INTRODUCTION

On behalf of Crompton Corporation, Conestoga-Rovers & Associates (CRA) has prepared this Site Characterization Report (SCR) for the American Refining Group (ARG) Refinery facility (formerly owned by Crompton-Witco Corporation) in Bradford, Pennsylvania. The report has been prepared in response to the Consent Order and Agreement dated June 8, 2004, which has been executed between the Commonwealth of Pennsylvania Department of Environmental Protection (PADEP), Crompton Corporation, and ARG. It is noted that on July 1, 2005, Crompton Corporation changed its name to Chemtura Corporation.

This Site Characterization Report has been prepared in accordance with:

i) the outline that was described in the submission to PADEP entitled "Pennsylvania Land Recycling Program – Supplemental Site Delineation Work Plan" (SSD Work Plan) dated September 2003 (revised January 15 and February 19, 2004) and approved by PADEP on June 10, 2004;

ii) the responses dated February 28, May 18, and June 10, 2005 to PADEP comments received on the draft SCR submitted in June 2004;

iii) the responses and additional evaluations/documents submitted November 22 and December 2, 13, and 16, 2005, January 13 and 27, February 1, July 17, August 23, and September 22, 2006, and July 6, 2007 to PADEP comments received on the revised draft SCR and Baseline Human Health Risk Assessment (HHRA) submitted in July 2005;

iv) the scope of work that was described in the submission to PADEP entitled "Work Plan, Step 3-Problem Formulation, Ecological Risk Assessment" (Step 3 ERA Work Plan), dated October 17, 2005 (revised June 2 and 26, 2006) and approved by PADEP on June 26, 2006; and

v) the scope of work that was described in the submission to PADEP entitled "Work Plan for SPL on National Transit and Surrounding Properties" (Off-Site SPL Work Plan), dated August 12, 2005 and the discussions held during the on-Site meeting of November 1, 2005 to address the PADEP comments dated October 3, 2005.

This SCR:

i) meets the objective of 25 Pa. Code §245.309 and 25 PA. Code §250.408;

ii) contains the elements set forth in 25 Pa. Code §245.310 and 25 Pa. Code §250.408;

iii) complies with 25 Pa. Code §93.6 and 25 Pa. Code §96.3 relating to the general surface water quality criteria and water quality protection requirements for all areas of the Property;

iv) complies with the applicable provisions of the storage tank regulations (Chapter 245);

v) meets the objectives of the U.S. Environmental Protection Agency's RCRA Corrective Action Environmental Indicator goals at American Refining's EPA sites PAD001604693, PAD000780171, and PAD000651281.

This Site Characterization Report builds upon the base established by previous studies that have been performed at the Site. The results of previous investigative activities and evaluations of the results have been presented in many documents, the most recent of which are:

i) Draft Final Report, Act 2 Compliance Evaluation for the Former Witco Corporation Bradford Refinery, dated July 1997 (1997 Compliance Report);

ii) PADEP Act 2 Facility Characterization Report, Former Witco Chemical Corporation, Bradford Refinery - Foster Brook Facility, dated July 1999 (July 1999 Characterization Report); and

iii) Crude Tank Farm Remedial Investigation Report, Bradford Refinery, dated December 2001 (December 2001 RI Report).

The 1997 Compliance Report provided information on the entire Refinery whereas the 1999 Characterization Report focussed on the Crude Tank Farm and Foster Brook Facility. The December 2001 RI Report was further focussed such that it only reported upon the Crude Tank Farm. Pursuant to discussions with PADEP, this Site Characterization Report characterizes the entire Refinery. Thus, the results of the historical investigations and those recently performed as part of the supplemental activities described in the SSD Work Plan and responses to PADEP comments on the draft SCR dated June 2004 and the draft SCR dated July 2005 are presented herein in a Refinery-wide SCR which incorporates the results of all of the previous investigations.

The Site is an active refinery located in the City of Bradford, in Foster Township of McKean County, as shown in Figure 1.1. The refinery has been in operation since the 1890s, making it the oldest active refinery in the United States. The Site occupies 131 acres along a 1.5 mile stretch of Tunungwant Creek, which flows from south to north through the middle of the Site. The Site is divided into four major areas (see Figure 1.2) which are used to describe the facility throughout this report. These four areas are:

i) Main Refinery;

ii) Crude Tank Farm (CTF);

iii) Foster Brook Facility (FBF); and

iv) Packaging Plant.

The investigations that have been performed cover all four areas of the Site and include Tunungwant Creek and its tributaries. This SCR presents all of the available data covering all aspects of these areas of the Site. The SCR has been organized as follows:

- **Section 2.0 - Site History and Operations.** Describes the facility location and layout; the history of production activities; the history of spills, emissions, waste production and disposal at the facility; and the history of ownership.
- **Section 3.0 – Investigative Activities.** Presents a summary of the historical studies that have been conducted at the Site; and presents the methodology and work performed as part of this current supplemental study involving surface water, sediment, surface soils, deep soils, soil gas, groundwater, Separate Phase Liquids (SPL), and pipelines.
- **Section 4.0 - Site Characteristics - Geology, Hydrology, and Hydrogeology.** Characterizes the regional and local setting including current land use, climate, geology, hydrogeology, groundwater usage, and surface water bodies; presents a description of surface soil conditions and surface characteristics.
- **Section 5.0 - Chemical Characterization.** Presents the chemical concentrations identified to be present in each of the investigated media including the Site soils, groundwater, surface water, sediment, and soil gas; the concentrations are compared to State and Federal criteria to determine whether they have any potential for impact to human health and the environment.
- **Section 6.0 - Fate and Transport Evaluation.** Presents the short and long-term impacts resulting from the presence of chemicals in the surface soils, subsurface soils, groundwater, and surface water; an evaluation of their presence in soil gases; the impact of chemical presence in surface soils is assessed for the former disposal areas of Foster Brook; and the impact of the presence of SPL on the various media is assessed along with its migration potential.
- **Section 7.0 - Human Health Risk Assessment (HHRA).** Evaluates all the routes of potential exposure for Site chemicals; assesses the completeness of the pathways of exposure; determines their impacts upon human health. (The SCR only presents a

summary of the HHRA report which is to be submitted to PADEP as a separate report.)

- **Section 8.0 - Ecological Risk Assessment (ERA).** Evaluates all of the chemicals present in the context of their impact or potential impact on the ecological environment on and around the Site; delineation of wetlands; impact on endangered species, if any; and impacts to receiving bodies such as the flora, fauna, and aquatic organisms. (The SCR only presents a summary of the Screening Level Ecological Risk Assessment (SERA) reports which are to be submitted to PADEP as three separate reports; two reports for Steps 1 and 2 and one report for Step 3 of the USEPA 8-step process.)
- **Section 9.0 - Completed Remedial Actions.** Discusses the remedial efforts that have been implemented at the Site to date; a summary of their effectiveness is also presented.
- **Section 10.0 - Conclusions.** Presents all of the Conclusions arrived at as a result of this study.
- **Section 11.0 – Public Involvement.** Presents documentation relative to the Public Involvement Plan.

2.0 SITE DESCRIPTION, OPERATIONS, AND HISTORY

2.1 SITE DESCRIPTION

The American Refining Group (ARG), Inc. Bradford refinery (Site) occupies approximately 131 acres and is located at 77 North Kendall Avenue. The property is split in that part of the facility is located in the City of Bradford and the remainder is in Foster Township. Both parts are in McKean County, Pennsylvania. The location of the Site is shown on Figure 1.1.

The elevation of the Bradford refinery is approximately 1,500 feet above mean sea level (MSL) and is situated in the Tunungwant Creek basin. The Site occupies the area immediately adjacent to the Creek and is surrounded by rolling hills on either side. The Site is approximately 1.5 miles in length (north to south) and 500 feet wide at its widest point (east to west). The property is designated as City Index No. 712-101, according to the City Treasurer and Tax Collector of Bradford, Pennsylvania.

The Bradford refinery is located in an area that includes industrial, commercial, and residential properties. The Site is adjoined by the following properties:

i) Tunungwant Creek (also known as Tuna Creek), U.S. Route 219 and the Erie Railroad to the west (at the extreme southern end of the Main Refinery, Tunungwant Creek is actually on the east side of the Site);

ii) Dresser Industries, Inc., an oil field pipe and fittings manufacturer to the south;

iii) East Main Street and the Buffalo and Pittsburgh Railroad to the east; and

iv) Vacant land to the north.

The Bradford refinery is divided into four main parts as shown on Figure 1.2:

i) Main Refinery (MR);

ii) Crude Tank Farm (CTF);

iii) Packaging Plant (PP); and

iv) and the Foster Brook Facility (FBF).

The operations are spread along Tunungwant Creek and consist of five processing units, approximately 375 feedstock and product above ground storage tanks (ASTs), a main office building, a refinery office building, research and control laboratories, warehouse buildings, and maintenance buildings. Products manufactured at the Site include

various lubricating oils, specialty products, and gasoline. Currently the Site has a cumulative storage capacity of approximately 57,000,000 gallons and a crude oil throughput of 10,000 barrels per stream day (BPSD). The largest aboveground storage tank has a capacity of approximately 2,524,000 gallons.

The Site receives crude oil by truck, railroad, and pipeline from the Pennsylvania grade crude oil region that comprises approximately 35,000 square miles, covering a geographic area running from southwestern New York, through western Pennsylvania, and into eastern Ohio and West Virginia. Portions of the Site have been operated by various owners as a refinery since at least 1890. It is currently owned and has been operated by ARG since 1997.

To supplement the understanding of the operational history of the Site, historical aerial photographs of the Site and adjoining properties were acquired and reviewed for the years 1956, 1969, 1983, 1993, and 2001. Consultations with current and former refinery employees have helped to refine the Site's operating history. The historical aerial photographs are provided in Appendix A.

2.2 SITE HISTORY AND OPERATIONS

Portions of the Site and surrounding area were used for oil exploration and production, even before the Site was first used as a refinery. Various sections of the Site have been owned and operated as a refinery since the late 1800s by the following:

i) Emery Oil Company built the Refinery in 1881. The Foster Brook Facility was the former All-Penn refinery, operating since the 1890s.

ii) The City of Bradford purchased the Site in the early 1900s from Emery Oil Company and operated the Site through to 1950;

iii) From 1950 through to 1966, the Site was owned and operated as the Kendall Oil Company (Kendall). The Packaging Plant was a baseball park prior to Kendall's purchase;

iv) Witco Corporation (Witco) acquired Kendall Refining in 1966. From 1966 through to 1997, the Site was owned and operated under Witco. In 1969, Witco built the methyl ethyl ketone (MEK) unit which is located south of Mill Street. Prior to this time, this area was a separate oil refinery that had been owned and operated by Pennzoil Company from the 1890s to the 1940s;

v) In 1997, the refinery was sold by Witco to ARG who still owns and operates the Site;

vi) In 1999, Crompton Manufacturing Company (Crompton) merged with Witco; and

vii) On July 1, 2005 Crompton Corporation changed its name to Chemtura Corporation.

As part of the review of historical operations at the Site, the Sanborn Fire Insurance Maps were checked by Environmental Data Resources, Inc. (EDR) in 1995 and a report was prepared (September 25, 1995). This report commented on the maps for the Bradford Refinery and adjacent properties for the years 1890, 1895, 1911, 1931, 1949, and 1968. The complete Fire Insurance Map Abstract prepared by EDR is provided in Appendix B. The abstract notes that refinery structures suggesting oil drilling and refining processes (e.g., oil derrick with well, engine house, and tank house) were present on-Site as far back as 1890. The railroad tracks were also present at that time. The 1905 map identifies the presence of distillation tanks and more refinery features. By 1911, the oil derrick had been removed. By 1925, the Snodgrass Cracking Plant had become part of the Site. This was later renamed the Dubbs Cracking Plant on the 1931 map. By 1968, refinery facilities are present on both sides of Tunungwant Creek.

The Refinery refines crude oil and manufactures, packages, stores, and distributes petroleum products in both bulk and packaged forms. The distribution percentages of the products manufactured and distilled from the processed crude oil are as follows:

i) 20% gasolines;

ii) 30% naphtha distillate solvents and Kensols;

iii) 40% finished lubricating oils; and

iv) 10% waxes and heavy fuel oil.

The operations are typical of a refinery; including atmospheric distillation, fractionation, stripping, purification, hydrotreating, various dewaxing operations, maintenance, research and development, storage, packaging, loading, unloading, and distribution. Typical of refinery operations, numerous kettles, tanks, pumps, compressors, heat exchangers, and ASTs are used.

A brief description of the four main sections of the refinery are presented in the following subsections.

2.2.1 MAIN REFINERY

The Main Refinery is a thin, rectangular parcel of land that is approximately 28 acres in size. The Main Refinery is bordered by Route 219 to the west and by the Buffalo and Pittsburgh Railroad lines to the east. Kendall Creek forms the northern boundary of the Main Refinery and the southern boundary is approximately 900 feet south of Mill Street. The Main Refinery north of Mill Street is bisected from the south to the north by Tunungwant Creek. The Creek banks in the Main Refinery area are protected with either steel sheet pile or concrete walls, as a result of a US Army Corps of Engineers (Corps) flood control project. The project was initiated in 1954. Details of the flood control walls are provided in Appendix C.

The Main Refinery's operations can be divided into the following processing units (see Figure 2.1):

i) the Crude Unit;

ii) the Erie Wye Unit;

iii) the Platformer Unit and Isomerization Unit;

iv) the Residual Oil Supercritical Extraction (ROSE®) Unit;

v) the N-methyl-2-pyrrolidone (NMP) Solvent Extraction Unit; and

vi) the MEK Unit.

The Crude Unit processes Pennsylvania grade crude oil through atmospheric distillation at a rate of up to 10,000 BPSD and makes fuel gas, naphtha, lube and waxy neutrals, and cylinder stock. The Erie Wye Unit includes six ASTs for the storage of No. 1 and 2 fuel oil. The Platformer Unit operations include the production of naphtha, straight run gasoline, and fuel gas. The Isomerization Unit makes high octane gasoline. The ROSE® Unit makes deresined cylinder stock and resins. The MEK Unit removes wax to make neutral slack waxes, and the NMP Extraction Unit treats the lubestock by removing aromatic compounds to make base oils and extracts. Process flow diagrams and process descriptions are provided in Appendix D. The Main Refinery area also includes the Administrative Office Building and the Research & Development Laboratory Building.

2.2.1.1 PROCESS UNITS

The Crude Unit is made up of the following four process units: the Crude Unit, the Crude Unit Barrel House (Barrel House), the Crude Unit Loading Rack (Loading Rack), and the Upper Yard (see Figure 2.1). The Crude Unit is bounded to the north by Kendall Avenue, to the south by the Upper Yard, to the east by the Barrel House, and to the west by Tunungwant Creek. The Crude Unit was built in 1985 and has a capacity of 10,000 BPSD. This Unit uses an atmospheric distillation process that fractionates crude oil into eight liquid streams and one fuel gas stream. The distillation process consists of a main fractionator tower, six side stream strippers, three pump arounds, and an overhead condenser. The Crude Unit yields the following products: fuel gas, heavy Naphtha, Kensol® (48, 50, 51, 53, and 61), waxy light lube neutral, waxy medium neutral, waxy heavy neutral, and Kendex® 0842 (Cylinder Stock). The Crude Unit contains approximately 24 ASTs with volumes ranging from 10,364 to 634,561 gallons. The products within the ASTs include Nos. 1, 2, and 6 fuel oil; crude oil; blended lube oils, lube base stocks, and lube oil additives; and neutrals. The type of product stored within each of the ASTs in the Main Refinery is shown on the drawing included in Appendix E. The Barrel House is an oil handling facility for railroad tank cars and commercial trucks that is bounded to the north by Kendall Avenue, to the south by the Loading Rack, to the east by the Buffalo and Pittsburgh Railroad lines, and to the west by the Crude Unit Area. The railroad tank car oil loading and unloading occurs along the east side of the Barrel House, and there are three loading and unloading bays along the west side for commercial trucks. There are approximately 110 ASTs associated with the Barrel House, with volumes ranging from 1,763 to 518,959 gallons. The Loading Rack is a four-bay loading rack for commercial trucks. The Loading Rack is bounded to the north by the Barrel House, to the south by the Upper Yard, to the east by the Buffalo and Pittsburgh Railroad lines, and to the west by the Crude Unit Area. The Upper Yard is a tank farm that has approximately 35 ASTs, with volumes ranging from 11,476 to 518,959 gallons. The Upper Yard is bounded to the north by the Loading Rack, to the south and west by Tunungwant Creek, and to the east by the Buffalo and Pittsburgh Railroad lines. The Upper Yard ASTs are associated with products from the Crude Unit and Barrel House.

The Erie Wye Unit (Erie Wye) is approximately 0.63 acres and contains six ASTs for the storage of No. 1 and 2 fuel oil with volumes ranging from 127,600 to 525,129 gallons. The area is bounded to the north by Kendall Avenue, to the south and east by Tunungwant Creek, and to the west by the Buffalo and Pittsburgh Railroad. An aboveground pipeline transfers fuel oil from the Main Refinery to Erie Wye where it is then distributed to the various storage tanks.

The Platformer Unit is approximately 3.2 acres and is located to the north of the ROSE® Unit, to the south of the Dubbs Unit, to the east of Tunungwant Creek with Route 219 to the west. The Platformer Unit was constructed in 1951 to process the naphtha distilled from crude oil at the Crude Unit. The original Platformer had two reciprocating hydrogen recycle compressors. An oxygen stripper was installed in 1953 to improve on stream time. In 1956, a third recycle compressor was installed to improve cycle lengths between catalyst regeneration and a catalytic hydrodesulfurization unit was added to remove the sulfur from the naphtha. A later improvement included upgrading the catalyst technology to a bimetallic (low sulfur tolerance) that improved yields of gasoline and permitted longer cycles on the catalyst. A Naphtha Fractionator was installed in 1991 to optimize the production of naphtha solvents and minimize the production of gasoline. The Platformer Unit is currently a combination of three separate units: the Unifier, the Naphtha Fractionator, and the Platformer Unit. The Unifier is a naphtha catalytic hydrodesulfurization unit that removes contaminants in the naphtha in order to produce sulfur free products. The Unifier converts the sulfur that naturally exists in naphtha to hydrogen sulfide. The naphtha fractionator is a distillation tower that provides a couple of key services to the Platformer Unit. First, it removes hydrogen sulfide by distillation from the naphtha. Secondly, it produces three narrower distillation range specialty cuts from the naphtha: Kensol® 30 (K-30; mineral spirits type product), Kensol® 17 (K-17; lighter naphtha solvent sold to the asphalt paving industry) or K-80, and Light Straight Run (LSR – a low octane natural gasoline blending component). Liquid products from the bottom of the main naphtha fractionator tower and the bottom side stream stripper are used to charge the Platformer. There are 5 ASTs associated with the Platformer Unit, with volumes ranging from 79,532 to 1,381,933 gallons. The products within the ASTs include naphtha and bright stock.

The Isomerization Unit was constructed in 2003 and is adjacent to the Platformer Unit. The Isomerization Unit is bordered by the Dubbs Unit to the north, the Platformer Unit to the south, Tunungwant Creek to the east, and by Route 219 to the west. The Unit has a throughput capacity of 650 BPSD. The Unit is used to upgrade the Refinery's current low octane LSR gasoline blending component to a higher octane material. This process rearranges the molecular structure of normal paraffins to their higher octane isomers. Yields from the Platformer Unit include the following: Platformate (high octane gasoline blending stock), K-30, K-17, LSR, and fuel gas (hydrocarbon gas that is burned in process heaters and boilers).

The ROSE® Unit is approximately 6.3 acres and is bordered by the Platformer Unit to the north, Tunungwant Creek to the east, Route 219 to the west, and Mill Street to the south. The ROSE® Unit was constructed in 1986 to modify the Dewaxing and Deresining (D&D) Unit to accomplish the deresining of cylinder stock. The dewaxing

section of the D&D Plant was in operation until 1988 and was then decommissioned. The ROSE® Unit uses liquid propane to remove resins from the charge oil. The ROSE® Unit is designed to effect the finished oil's color and viscosity, and the viscosity of the heavy resins. Products produced at the ROSE® Unit include the following: Kendex® 0846 (Deresined Cylinder Stock [D-Stock]), Kendex® 0897 (Light Resins), and Kendex® 0834 (Heavy Resins). There are 10 ASTs associated with the ROSE® Unit, with volumes ranging from 4,116 to 740,321 gallons.

The NMP Extraction Unit (NMP Unit) is located adjacent to the ROSE® Unit. The NMP Unit is the "finishing" unit for lube base stocks. It was designed to selectively remove aromatics from the feedstock. This process improves the quality of the lube stock by improving its Viscosity Index (VI), color, and oxidation stability. The Extraction Unit was built in the 1930s as a lube base oil solvent extraction unit that used phenol as a solvent. Bright stock and resins were originally processed in this unit. The Unit was upgraded to an NMP solvent extraction process in 1981. Beginning in 1988, resins were no longer processed in the NMP Extraction Unit because of the conversion to the ROSE® technology. At that time, all of the lubrication base oils produced at the refinery were processed at the NMP Extraction Unit. Base oils and extracts from the NMP Extraction Unit include the following: Kendex® 0060 (60 SUS) and Kendex® 0150 (150 SUS), Kendex® 0750 (750 SUS), Kendex® 0847, Kendex® 0866 (Bright Stock Extract), Kendex®MNE (Medium Neutral Extract), Kendex®HNE (Heavy Neutral Extract), and Kendex®LNE (Light Neutral Extract). There are approximately 30 ASTs associated with the NMP Unit, with volumes ranging from 317 to 740,321 gallons.

The MEK Dewaxing Unit (MEK Unit) is approximately 6.1 acres and is located south of Mill Street, and bordered to the east by the Buffalo and Pittsburgh Railroad lines and to the west by Route 219. Tunungwant Creek is located approximately 400 feet east of the Railroad. The MEK Unit was built in 1969 to allow the refinery to shut down the Wax Plant that used filter presses to remove wax. The MEK Unit removes wax from heavy products that were historically being dewaxed at the D&D Unit. This is accomplished by chilling solvent (Toluene and MEK) and charge stock to a desired filter feed temperature. The solvent is removed from the wax and oil by distillation, using steam stripping to remove the last traces of solvent. Improvements to this dewaxing unit were made in 1974, 1985, 1987, and 1995. In 1974, a surface heat exchanger (chiller) and a third filter were installed to increase throughput. Throughput was further increased in 1985 through the installation of an upgraded compressor and turbine, the installation of incremental dilution to the chilling train, and redesigned piping to the third filter for repulp operation. In addition to increased throughputs, these modifications allowed for the processing of deresined cylinder stock at the MEK Unit and allowed for the decommissioning of the dewaxing section of the former D&D Unit. A solvent splitter

was built in 1987 to increase the efficiency of the MEK Unit. A fourth filter was added in 1995, further increasing the capacity of the Unit. Products from the MEK Unit include the following: Light Lube Neutral Slack Wax (LLNSW), Medium Neutral Slack Wax (MNSW), Heavy Neutral Slack Wax (HNSW), and Petrolatum (Kendex® 0111). There are approximately 30 ASTs associated with the MEK Unit, with volumes ranging from 7,060 to 1,682,761 gallons.

In addition to the noted processes, the Main Refinery is also the location of the boiler plant. The Site has four coal-fired boilers, all located at the Mill Street Boiler Plant. These boilers are an integral part of the Refinery steam generating system that provides process steam and space heating. The water supply for the steam generating system comes from the Bradford Water Authority which also supplies the potable water for the entire Site. According to the water authority, it is believed that service to the Site began before 1900.

There is one additional unit that was historically located within the Main Refinery at the Site. A former specialty chemical area operated between the early 1950s and the late 1970s. Refinery personnel referred to this area as the Dowtherm Area and it was located in the southwest corner of the Barrel House. This specialty chemical area used Dowtherm heat transfer fluids.

2.2.1.2 PIPELINES

All of the liquids that are processed in the Main Refinery enter, exit, and are transferred around the area via pipelines. Some of the pipelines are aboveground and some are below. Aboveground piping from the Crude Tank Farm to the Main Refinery is of single wall construction. As the various materials transfer around the Main Refinery, the pipelines carrying these products sometimes cross property not owned by the Refinery. For example, the Mill Street pipe rack crosses Mill Street between the MEK Unit and the ROSE® Unit. In addition, the pipe racks on the Main Refinery drive bridge, the Erie Loading Area pipe bridge, and the two Platformer pipe bridges cross over Tunungwant Creek. The locations of the Main Refinery pipelines are shown on Figure 2.2.

Most of the pipelines throughout the Site are aboveground, although two underground pipelines remain active, transferring blended products from the Barrel House at the Main Refinery to the Packaging Plant. Both of these underground pipelines are four-inch lines. Products transferred through these two lines are gauged before and after transfers to guard against potential pipeline breaks.

2.2.1.3 DUBBS UNIT

The Dubbs Unit is a triangular parcel of property that is approximately 0.90 acres in size. The Dubbs Unit is located to the west of Tunungwant Creek, north of the Platformer Unit, and east of the Buffalo and Pittsburgh Railroad and Route 219 (see Figure 2.1).

The Dubbs Unit is the Main Refinery's wastewater treatment plant (WWTP) that consists of oil/water separators (one at the MEK Unit and one at the Main Refinery), induced air floatation (IAF), two 423,041-gallon equalization tanks, two 23,869-gallon bio-towers, and a sand filtration unit. The maximum capacity of this wastewater treatment system is approximately 400,000 gallons per day. The skimmings (EPA F-038 waste) gathered in the IAF are sent off-Site for disposal, and the effluent from the bio-towers flows through the sand filtration unit, and is discharged to Tunungwant Creek through Outfall 002 under National Pollutant Discharge Elimination System (NPDES) Permit No. 0002674. The WWTP flow diagram for the Main Refinery is provided on Figure 2.3.

The Dubbs Unit also includes four ASTs with volumes ranging from 79,532 to 509,264 gallons. The products within the ASTs include No. 1 fuel oil and naphtha, and are associated with the Crude and Platformer Units.

2.2.1.4 ADMINISTRATION/RESEARCH AND DEVELOPMENT AREA

The Administration/Research and Development (R & D) Area is approximately 5.8 acres in size. The R&D Area is bordered by Kendall Creek to the north, Kendall Avenue to the south, Tunungwant Creek to the west, and by the Buffalo and Pittsburgh Railroad lines to the east (see Figure 2.1).

The Administration Building is adjacent to the south side of the Research and Development Laboratory Building. The building is a two-story, brick and steel shell, and is used for administrative office space. The remainder of this area is covered with parking lots and grass areas.

The R&D Building is a single-story, brick and steel shell. The R&D Building includes product research laboratories, offices, and a less than 90-day RCRA-designated hazardous waste storage area along the east side of the building. The remainder of this area is covered with parking lots and grass areas.

The new groundwater treatment system is located in the northern portion of the R&D Area. The facility is contained within a 38 foot by 68 foot prefab single storey building. The system was installed for the removal of oils and iron from groundwater to meet NPDES permit No. PA0222151 requirements. Groundwater first enters an existing oil/water separator located in the Crude Unit of the Main Refinery for the removal of free oils before being transferred to the new treatment building via a 1300' above ground force main. In the new treatment building the water enters an aerated pH adjustment tank and then gravity flows to a Dissolved Air Flotation (DAF) clarifier. The precipitation of iron and separation of oil from the groundwater is improved by the addition of a coagulant. The sludge that forms is skimmed off and collected in a sludge holding tank for eventual off-Site disposal. The DAF effluent flows to surface water outfall 001. The flow diagram for the groundwater WWTP is provided on Figure 2.4.

2.2.1.5 OIL PRODUCTION WELLS

There are no active oil production wells within the Main Refinery. A summary of the oil production wells is provided in Table 2.1.

2.2.2 CRUDE TANK FARM AREA

2.2.2.1 SITE DESCRIPTION

The Crude Oil Storage Tank Farm Area (Crude Tank Farm) is approximately 17.9 acres in size and contains approximately ten crude oil ASTs with volumes ranging from 215,927 to 2,523,848 gallons. The area is bounded to the south by Kendall Creek and the Futures Rehabilitation Center, National Transit Property (Foster Brook Station) to the north, Tunungwant Creek to the west, and the Buffalo and Pittsburgh Railroad to the east (see Figure 2.5). An aboveground pipeline transfers crude oil from the southern portion of the Foster Brook Facility to the Storage Tank Area where it is then distributed to the various storage tanks. Crude oil is then transferred from the various tanks to the Main Refinery by aboveground pipelines to feed the refining processes. The Crude Tank Farm Area also includes the Fire Training Area, the Former Rendering Plant, and the Independent Production Area that is south of the National Transit Property.

The Fire Training Area is located immediately north of the crude oil storage tanks. Current and historical use has been to serve as a training area for fire emergency and response drills by past and current refinery operators. Controlled fire emergency scenarios are staged in this area and extinguished. Materials that are currently used for

fire extinguishing training include fuel for fires (Kensol 30) and extinguishing materials (Purple-K, Foray, and Plus-Fifty C). Material Safety Data Sheets (MSDSs) for materials used in the Fire Training Area are provided in Appendix F.

Purple K is a dry chemical extinguishing agent containing muscovite mica, magnesium aluminum silicate (attapulgite clay), potassium bicarbonate, methyl hydrogen polysiloxane, and purple pigment. Plus-Fifty C is a dry chemical extinguishing agent containing talc, magnesium aluminum silicate (attapulgite clay), sodium bicarbonate, methyl hydrogen polysiloxane, and blue pigment. FORAY is a dry chemical extinguishing agent containing muscovite mica, magnesium aluminum silicate (attapulgite clay), monoammonium phosphate, ammonium sulfate, methyl hydrogen polysiloxane, and yellow pigment.

The primary constituents for the 3 agents are mica and attapulgite clay, naturally occurring substances unlikely to leach to the environment. Discussion regarding the impact of these agents on the soil and groundwater are provided in Section 5.3.

The Former Rendering Plant is approximately 3.2 acres in size, and is bounded to the north by the National Transit Property, to the south by the Buffalo and Pittsburgh Railroad lines and the Fire Training Area, to the east by the Independent Production Area South, and to the west by Tunungwant Creek. The Former Rendering Area was historically used for the rendering of animal byproducts. The area is relatively flat, vacant land that is covered with vegetation.

The Independent Production Area South is approximately 2.3 acres in size, and is bounded to the north by the National Transit property, to the south by the Buffalo and Pittsburgh Railroad lines and the Fire Training Area, to the east by the Buffalo and Pittsburgh Railroad lines, and to the west by the Former Rendering Plant Area. This area's name was derived from the oil production wells that are located on this parcel of property. There are six active production wells in this area. The majority of this area is flat, vacant land that is covered with vegetation.

2.2.2.2 PROCESS UNITS

There are no current or historical process units associated with the Crude Tank Farm Area.

2.2.2.3 PIPELINES

The pipelines bringing product into the Crude Tank Farm from the Foster Brook Facility and transferring it to the Main Refinery Area are all aboveground pipelines with one exception. There is a 5-inch diameter underground pipe line that formerly fed the Tank Farm from Duke Center which is located approximately 8 miles from the Site. The Duke Center line follows along the east side of the Buffalo and Pittsburgh Railroad lines to a point opposite Tank 708 where it crosses beneath the railroad tracks and enters the Crude Tank Farm. Figure 2.6 presents the locations of the major pipelines in the Crude Tank Farm area. As previously noted, all aboveground piping is of single wall construction.

2.2.2.4 OIL PRODUCTION WELLS

According to ARG personnel, there are currently 10 oil production wells located on the Crude Tank Farm Area that are still in use. All of these production wells are privately owned and operated. The wells are located in the following areas:

i) 6 in the Independent Production Area South;

ii) 3 in the Fire Training area; and

iii) 1 in the Crude Tank Farm area.

A summary of the oil production wells is provided in Table 2.1.

2.2.3 NATIONAL TRANSIT PROPERTY

The National Transit Property is not part of the Site, but is included as part of the study area due to its proximity to the Site. The property, located at 93 Bolivar Drive, has an area of approximately 6.7 acres and is located north of the Former Rendering Area and the Independent Production Area South (described in Section 2.2.2), to the south of Bolivar Drive and the Foster Brook Facility, east of Tunungwant Creek, and west of the Buffalo and Pittsburgh Railroad (see Figure 2.5). Two privately owned parcels of property occupying a total of 0.53 acres separate the eastern half of the National Transit Property from Bolivar Drive. The eastern portion of the property is separated from the western portion by an easement that is oriented in a north/south direction. A dirt access road is built along the easement that allows for vehicle access to the ARG Fire Training Area and Crude Tank Farm Area located to the south of the Property.

The National Transit Property is an inactive crude oil pipeline pumping and storage facility. The first industrial/commercial use of the property was made by Tidewater Pipeline Company (Tidewater). Tidewater and South Penn Oil Company formed a joint venture known as the Bradford Transit Company who acquired the property from Tidewater (date unknown). In the 1960s, Bradford Transit Company and National Transit Company (NTC) merged and continued operating the property as a crude oil storage facility. The collection of crude oil via pipelines was terminated at this property around 1988. The property continued to be used as a trucking terminal and crude oil storage facility by Pennzoil – Quaker State Company (PQS), then known as Pennzoil Products Company, until it ceased operations in 1997. NTC, a wholly owned subsidiary of PQS (now Shell Lubricants), currently owns the property. The property is currently inactive. All structures at the property have been removed or razed. The former office, shop, and shed located along the property's west side were wood frame and wood-sided structures. The former machine shop, maintenance garage, and the pump sheds were wood frame, metal-sided buildings. The former warehouse was a steel frame metal-sided structure. According to the Site Characterization Report of the Shell Lubricants (Foster Brook Station) prepared by ATC Associates Inc. (March 2005), an oil/water separator was located on the east side of the machine shop concrete pad. NTC reported that the oil/water separator discharge pipe might have been excavated along with piping used for transferring petroleum to and from the concrete loading pad. Also, it is reported that all ASTs, associated buried pipe, and trunk line pumps have been removed from the NTC property. The one registered underground storage tank (UST) (which stored gasoline) was located adjacent to and east of the Property's Bolivar drive entrance. This 550-gallon UST was abandoned in place and filled with inert material in 1989, and the dispenser has been removed. The March 2005 SCR indicates that no records are available regarding spillage or leaks from this UST.

2.2.4 FOSTER BROOK FACILITY

The Foster Brook Facility (see Figure 2.7) is approximately 49.7 acres in size and bisected from east to west by Foster Brook, a tributary of Tunungwant Creek. The area south of Foster Brook encompasses 28.6 acres while 21.1 acres is north of Foster Brook. The Foster Brook Facility is bounded to the south by Bolivar Drive, immediately north of the National Transit Property. It is bounded to the west by both Tunungwant Creek and Route 219 and to the east by the Buffalo and Pittsburgh Railroad. The northern boundary of the Facility is located approximately 700 feet north of Foster Brook where it flows under Route 219.

The Foster Brook Facility was the former All-Penn refinery, which began operating in the 1890s. Currently, the Foster Brook Facility is used for specialty product processing, blending, and shipping. The Foster Brook Facility is subdivided into the areas known as the Barrel House Area, the Light End Product Petroleum Storage Tanks/Crude Oil Truck Unloading Transfer Tanks Area (Light End Tank Farm), Bulk Haul Loading Area, Garage/Shed Area, Former Impoundment Area, Independent Crude Production Area North, Former Burn Pit Area, Crude Rail Unloading Area, Former Construction Debris Area, the Former Refuse Area, the Fly Ash Area, the former Container Disposal Area, and the Bauxite Fill Area. Each of these areas are briefly described in the following subsections. Figure 2.7 presents the location of each of these areas.

2.2.4.1 BARREL HOUSE AREA

The Barrel House Area is located just east of the entrance to the Foster Brook Facility and includes the barrel house, rail siding, and three ASTs immediately north of the barrel house. Historical use of this area included the packaging and storage of petroleum products for shipping. Currently the area is used as a warehouse storage facility for petroleum product packaging containers.

2.2.4.2 LIGHT END TANK FARM

The Light End Tank Farm area contains approximately 30 ASTs with volumes ranging from 28,203 to 1,429,877 gallons and is located in the center of the Foster Brook Facility. Historic and current use of the Light End Tank Farm area includes storage, loading, and unloading of refined petroleum products and crude oil.

2.2.4.3 BULK HAUL LOADING AREA

The Bulk Haul Loading Area is located immediately south of the Light End Tank Farm. Current and historical use has been as a loading area of petroleum products for distribution by commercial trucking companies.

2.2.4.4 GARAGE/SHED AREA

The Garage/Shed Area is located northeast of the Light End Tank Farm. Current and historical use has been for the maintenance of company vehicles and other machinery

used within the Facility. Also, there is one inactive oil production well located in this area.

2.2.4.5 FORMER IMPOUNDMENT AREA

The Former Impoundment Area was comprised of up to six shallow basins of varying size, and were bordered to the east by the Light End Tank Farm and to the west by Route 219. The Former Impoundment Area was historically used as storage for Refinery related waste waters/fluids. According to ARG personnel, the identification of the Former Impoundment Area was based on a review of aerial photographs between 1968 and 1976 that showed six surficial water bodies, which were rectangular in shape. These six impoundments were relocated to the current wastewater settling ponds area as part of the Route 219 construction project (circa 1974). Currently, one dual-sectioned, lined lagoon is used to process treated wastewater from the API Separator and stormwater from the Foster Brook Facility. Effluent from the lagoon is discharged to Tunungwant Creek under an NPDES permit (see Section 2.4.3).

2.2.4.6 CRUDE OIL RAIL CAR UNLOADING AREA

The Crude Oil Rail Car Unloading Area is located northeast of the Garage/Shed Area and is adjacent to Foster Brook. Current and historical use has been for unloading of crude oil from railroad tank cars for several decades. Crude oil is unloaded and transferred to the Crude Oil Storage Tank Area via aboveground pipelines. The transfer facility consists of two railway sidings, oil transfer systems (both underground and overhead piping), and related support apparatus. A concrete containment wall (approximately two feet above grade and extending three feet below grade) is located along the eastern edge of the railway. The rail lines are typical in construction, including wooden cross ties and stone ballast. The rail lines are on an area extensively disturbed by earthmoving and fill placement. Foster Brook is approximately 125 feet to the east of the crude oil transfer area.

2.2.4.7 FORMER BURN PIT AREA

The Former Burn Pit Area is located west of the Crude Rail Unloading Area and is bordered to the west by Route 219. The burn pit area was historically used from the mid 1950s until 1971 for the thermal treatment of various types of hydrocarbon waste material. The area is divided into two distinct areas: the Burn Pit and the Burn Pile.

The Burn Pit was the northernmost feature and measured approximately 150 feet by 50 feet and several feet deep. The Burn Pile was located immediately south of the Burn Pit and was approximately 200 feet in diameter. Reports indicated that the Burn Pile was not below surface grade and that it was used as an area to incinerate wood and related material such as shipping pallets, cardboard, etc. Use of the burn area was discontinued when Pennsylvania Department of Transportation (PennDOT) began construction of Route 219 (circa 1974).

2.2.4.8 FORMER FLY ASH AREA

The Former Fly Ash Area is approximately 0.75 acres and is located between the Bauxite Fill Area and Foster Brook and had been used as a disposal site for fly ash from the coal-fired burner of the Boiler Plant. Based on inquiries of refinery personnel, it is believed that this practice was discontinued prior to 1980. Fly ash and residue from the bottom of the coal-fired burner is currently sent to an approved off-Site landfill for disposal.

2.2.4.9 FORMER CONTAINER DISPOSAL AREA

The Former Container Disposal Area was approximately 3.2 acres and occupied the northern portion of the Former Refuse Area and was reportedly used to dispose of demolition debris and miscellaneous products and materials in metal containers, including petroleum-containing solids, semisolids, tar, oil, and soil. The details of container and debris disposal practices are not well documented. Disposal activities ceased in the early 1970s. A voluntary removal action was performed in 1996, as described in Section 9.3, in which all of the containers were excavated and shipped off-Site for disposal at a licensed waste facility.

2.2.4.10 FORMER CONSTRUCTION DEBRIS AREA

The Former Construction Debris Area is located in the northern most portion of the Site along Route 219, north of Foster Brook. The formerly used Construction Debris Area is approximately 14 acres in size. The area is a remote and undeveloped portion of the refinery. Historically, the area was used for the disposal of construction and refuse debris, including metal containers, concrete, brick, hose, wood, railroad ties, and metal pipe. Debris was disposed in naturally occurring topographic depressions. The Construction Debris Area runs parallel to and borders undeveloped land owned by

others to the north, Route 219 to the west, the Buffalo and Pittsburgh Railroad and Bradford Mall to the east, and Foster Brook to the south. The Area is relatively level and low-lying. Reports from current and former Facility employees indicate that minimal numbers of disposal trenches were actually excavated for disposal purposes. No trenching is apparent in the northern portion of the area. Disposal appears to have consisted of surface dumping which resulted in continual raising of the ground surface with construction debris. Use of the Construction Debris Area was discontinued in the 1970s. Woodland and other vegetation currently cover the landscape.

2.2.4.11 FORMER BAUXITE FILL AREA

The former Bauxite Fill Area is approximately 2.3 acres in size and is located adjacent to the Buffalo and Pittsburgh Railroad. Bauxite (Fuller's Earth), used to filter aromatics and color bodies from the filtering process, was historically disposed in this area. These filtering processes were located in the area where the Crude Unit Loading Rack currently is located. This disposal practice was discontinued prior to 1980.

2.2.4.12 PROCESS UNITS

The are currently no process units within the Foster Brook Facility. Historically, the Foster Brook reactor, which is located south of the Light End Tank Farm, was a batch process used to increase the viscosity of oils. Oil was circulated from the reactor through the furnace and back to the reactor. The circulating process was continued until product specifications were met. This process was discontinued in July 2002.

2.2.4.13 PIPELINES

Pipelines in this area of the Site are primarily positioned on the pipe rack located along the east side of the Foster Brook Facility and the Buffalo and Pittsburgh Railroad, and runs between the Foster Brook Facility and the Main Refinery. Aboveground piping from the Foster Brook Facility to the Crude Tank Farm is of single wall construction.

ARG has a total of six active pipelines that run parallel to the east side of the National Transit Property and the Buffalo and Pittsburgh Railroad. Four of these pipelines are three-inch aboveground pipelines that carry platformate, Light Straight Run, K-17, K-80, and diesel. One of the pipelines is a six-inch aboveground pipeline that carries steam. The sixth pipeline is an eight-inch underground pipeline that transports crude oil. Based

on the information provided by ARG, the six pipelines have been hydrotested in October 2002 and passed. The locations of the Foster Brook pipelines are shown on Figure 2.8.

2.2.4.14 OIL PRODUCTION WELLS

There are three private oil production wells in the Independent Crude Production Area North and one in the Garage/Shed Area. These four production wells are privately owned and are currently not in operation.

There are also three oil production wells in the Construction Debris Area. Currently, none of these production wells are operating. According to discussions with the owner's family, two of these production wells are planned to be abandoned and the remaining one will be brought back into operation. A summary of the oil production wells is provided in Table 2.1.

2.2.5 PACKAGING & BLENDING PLANT AREA

The Packaging and Blending Plant (Packaging Plant) is located west of Tunungwant Creek, bordered to the west by Route 219, to the south by a spur line of the Buffalo and Pittsburgh Railroad, and to the north by privately owned industrial property (i.e., Graham Packaging) (see Figure 2.9). The Packaging Plant is approximately 8.1 acres in size and provides custom batch blending, bulk product loading, multicontainer-filling capabilities, and mixed truckloads and mixed pallet loads. The Packaging Plant has two 800-gallon kettles, two 7,000-gallon ASTs used for a variety of motor and hydraulic oils, and 16 blend-in-storage ASTs capable of blending at speeds up to 900 gallons per minute. The total storage of the 36 ASTs on the Packaging Plant area (3,700,000 gallons) is devoted to blending and packaging finished lubricants. The Packaging Plant has two high-speed (360 bottles per minute) quart filling lines, a specialty bottle filling line capable of handling containers ranging in size from eight ounces to two and one-half gallons, a drum line (1,800 drums per day), a pail filling line (15,000 pails per day), and a 16 gallon/120 pound keg filling line (1,200 kegs per day).

The Packaging Plant has an AST facility that is bounded to the north and west by Route 219, to the south by two miscellaneous storage buildings, and is adjacent to the east side of the Packaging Plant. The AST facility is a steel structure, steel-sided building and contains approximately 36 blended lube oil ASTs with volumes ranging from 1,880 to 105,760 gallons. The remaining ASTs are located within the Main Plant

building. An aboveground pipeline transfers base oil from the Main Refinery to the Packaging Plant AST facility where it is then distributed to the various storage ASTs for blending.

Two underground pipelines remain active, transferring blended products from the Barrel House at the Main Refinery to the Packaging Plant. Both of these underground pipelines are four-inch lines. Products transferred through these two lines are gauged before and after transfers to guard against potential pipeline breaks.

Two storage buildings are located in the southwest corner of the Packaging Plant. The two storage buildings are steel shell and contain refinery-related piping and equipment.

2.3 STORAGE TANKS

2.3.1 UNDERGROUND STORAGE TANKS

According to ARG Site personnel, there are presently no USTs on-Site. Based on the Environmental Indicator Inspection Report (Corps, July 2001), nine USTs, that included eight 1,000-gallon gasoline USTs and one 1,000-gallon diesel UST, have been removed. Six of these USTs were located behind the research laboratory and were removed in November 1989. Two of the USTs were located next to the stock room in the Main Refinery and were removed in October 1989. There is no documentation as to the condition of any of the tanks upon removal nor of any spills or leaks.

2.3.2 ABOVEGROUND STORAGE TANKS

Currently the Site has approximately 375 ASTs of which approximately 70% are currently in use as part of the manufacturing process at the Refinery. The majority of the tanks are without secondary containment and are built on unpaved surfaces. Appendix E provides a list of the tanks along with their approximate storage capacities.

Equipment has been installed at the Refinery to both prevent releases from the ASTs that detect and contain them at a very early stage. Fifteen tanks are installed horizontally on saddles, which gives a full view of each tank and provides a means of early leak detection. On-Site vertical tanks are regulated in accordance with the technical and inspection requirements of 25 PA Code chapter 245, subchapters F and G. Recently upgraded vertical tanks have synthetic liners with leak detection equipment (under the tank bottoms) and high liquid level alarms.

In addition, ARG has implemented an AST Compliance Action Plan at the Refinery. The overall purpose of the plan is to evaluate tank integrity through a series of out of service and in service tank inspections, repairs, and hydrostatic pressure tests. Brown and Caldwell prepared a Tank Investigation Report for the Bradford Refinery Site in 1998 to determine the probable tank integrity of selected ASTs at the Site. The current Storage Tanks Spill Prevention Response (SPR) Plan/Integrated Contingency Plan (ICP) was approved by PADEP in January 2003. ARG has implemented an AST floor replacement program since their ownership of the Site began. The testing results and status for the ASTs from the 2002 and 2003 Action Plan and a list of AST floor replacements are provided in Appendix G.

2.4 FACILITY DRAINAGE

In general, precipitation falling within the main facility areas of the Refinery are controlled and released through a series of outfall sewers. Precipitation falling on the unoccupied areas of the Plant (e.g., the northern areas of the Foster Brook Facility) follow whatever surface water features are available to reach on adjacent surface water body (e.g., Foster Brook or Tunungwant Creek). The following sections detail the stormwater drainage systems in place at the Refinery.

2.4.1 STORMWATER DRAINAGE

The Plant Site is serviced with a stormwater collection system which is designed to direct select stormwater flows to the Refinery process sewer/oil recovery system (API separator system). The stormwater collection system includes eight stormwater outfalls, the locations of which are shown on Figure 2.10. One permitted stormwater outfall (002) receives stormwater and treated wastewater and six permitted stormwater outfalls (005 through 010) receive stormwater only. Appendix H provides the NPDES permitted outfalls, maps depicting the stormwater outfall, locations (including latitude and longitude coordinates), receiving water, total acreage drained, type of area drained (i.e., pervious and/or impervious drainage area), and the volume of stormwater from various sized storm events. The stormwater outfall pipes range in size from 12 to 48 inches in diameter. All discharges are monitored per NPDES permit requirements. Any incidental stormwater flow not entering the drainage system remains on or in the immediate proximity of the Site where it evaporates or infiltrates the ground surface. Industrial wastewater collection systems convey precipitation contacting sensitive areas of the Refinery to the on-site WWTP.

The Refinery employs the following Best Management Practices (BMPs) to control stormwater runoff:

i) Dikes;

ii) Berms;

iii) Drip pans;

iv) Retaining walls;

v) Surface contouring; and

vi) Two lined equalization ponds (located in the Foster Brook Facility).

The Refinery consists mainly of buildings, asphalt, and gravel areas, and does not present significant potential for surficial soil erosion and sedimentation.

2.4.2 API SEPARATORS

There are three API Separators in the Main Refinery. One is located in each of the MEK Unit, Crude Unit, and Dubbs WWTP areas of the Refinery. The three API Separators are connected by a series of pipe systems that collect process and stormwater from all process/AST areas of the Site and pretreats the water to remove floating oil and grease. The API Separator effluent then goes to the onsite WWTP which includes IAF, biological treatment, and continuous sand filtration prior to discharge to Tunungwant Creek. In addition to the API Separator system for the Main Refinery, there is an API Separator that collects stormwater from the south portion of the Foster Brook Facility and pretreats the water prior to flowing into the two equalization ponds and then discharging to Tunungwant Creek. The API Separator in the Foster Brook Facility is located south of the Light End Tank Farm and southwest of the two equalization ponds.

There are catch basins in each of the loading and unloading areas, as well as process and storage areas, which direct water and/or potentially spilled product to one of the four API Separators. Each API Separator has a concrete wall/curb ranging from four inches to two feet above ground surface to prevent overflow. Influent and effluent weirs, baffle plates, and valves prevent washing of oil into the Creek during floods. According to ARG's ICP, all API separator units are inspected every two hours. Catch basins and pans at the Main Refinery and Foster Brook Facility are intended to collect spills and convey them through the drain system to the API separators for treatment. The MEK Unit and Crude Unit process areas transfer materials (water and/or product) from their

respective API separators to the Dubbs separator main chamber, the IAF separator, and through a system of WWTP equalization tanks where water and/or product can be stored for treatment. This drain system also collects rainfall for treatment by the API separators prior to discharge to the Creek. The drainpipes are sized to adequately carry the runoff from these sections of the Refinery and range from eight to twelve inches in diameter.

2.4.3 NPDES OUTFALLS

The Refinery has six stormwater-only outfalls (outfalls 005 to 010) presently permitted under the NPDES program. One additional NPDES-permitted outfall (outfall 002) discharges both stormwater and wastewater that have been treated at the Facility's WWTP. No diversions or stormwater detention structures exist within the Refinery (i.e., stormwater basins, diversions, grass strips, and waterways). The majority of fueling stations; vehicle and equipment maintenance and cleaning areas; loading and unloading areas; treatment, storage, and disposal of waste areas; liquid storage tanks; and other processing areas drain to surface inlets leading to the Refinery WWTP. Appendix I includes a portion of ARG's ICP that includes the outfall number, drainage area for each stormwater outfall, outfall receiving waters, plant activities in the different drainage areas, and a description of each outfall drainage area (i.e., number of catchbasins and what is within the drainage area).

ARG conducts annual stormwater sampling and inspections for all permitted outfalls, per the Facility's NPDES Permit No. 0002674 which became effective November 1, 1999.

2.4.4 EPCRA SECTION 313 FACILITY STORMWATER REQUIREMENTS

The stormwater controls implemented in areas where Section 313 water priority chemicals are stored, processed, or handled consist of dikes, retaining walls, surface inlets, storm drains that outlet to stormwater treatment systems, and ground surface contouring and diversion. Stormwater controls including curbing, culverts, gutters, and industrial sewers are used to prevent or minimize the potential for stormwater run-on to come in contact with chemical process and storage areas. Storage of Section 313 water priority chemicals at the Refinery consists of enclosed tanks and storage areas within buildings. Truck and railcar loading and unloading areas for Section 313 water priority chemicals are protected by drip pans, ground surface contouring, and surface water inlets to the industrial wastewater treatment system.

2.5 TUNUNGWANT CREEK FLOOD CONTROL STRUCTURES

Tunungwant Creek is a small stream that traverses the Site on a general north/south axis. The Creek flows from south to north through the Site and continues northward into New York State before flowing into the Allegheny River. The Creek is more than 100 feet across at the Refinery and is generally 1 to 2 feet deep. The Creek bed is approximately 8 to 10 feet below the elevation of the surrounding ground elevation at the Refinery. On occasion, under peak flows, the Creek elevation has risen almost to the height of the Refinery's general surface elevation. In order to limit flooding, the Corps initiated hydraulic improvements to the Creek in 1954. These hydraulic improvements included the straightening of the channel in which the Creek resides and many areas of bank stabilization. The methods used to stabilize the banks included sloped concrete flood walls and vertical sheet pile walls. These forms of slope protection are present through most of the Main Refinery and provide storm protection for the heavily industrialized portion of the Site. The section of the Creek that traverses the downstream Crude Tank Farm and Foster Brook Facility areas of the Site have had channelization improvements but no bank stabilization measures.

Although the improvements were designed and constructed by the Corps, their maintenance and operation is now controlled by the Bradford Flood Control Authority. The Bradford Flood Control Authority has provided construction details of the flood control structures installed along the Main Refinery section of the creek. These construction details are provided in Appendix C.

2.6 ENVIRONMENTAL PERMITS

A list of current environmental permits is provided in Appendix J. Environmental permits for the Site includes the following: AST Registration, NPDES Wastewater Discharge Permit, Industrial Wastewater Discharge Permit, Stormwater Discharge Permits, and Air Quality Control permitting for multiple sources.

2.7 STORAGE AND USE OF CHEMICALS

The Refinery produces gasoline, fuel oil, solvent naphthas distillate solvents, lubricant base oils, waxes and resins, dust control agents, and a variety of other petroleum specialties including shock fluids, camping fuel, asphalt cut back solvents, well treating

solvent, extract blends, and quench oils. A list of products and chemicals stored and used at the Site is provided in Appendix K.

This SCR does not contain a collection of the Refinery MSDS sheets due to the numerous MSDS sheets that apply to the Site. Refer to the Bradford Refinery master set of MSDS binder volumes, located in the Environmental Department Conference Room, for a comprehensive collection of MSDS sheets.

2.8 HISTORIC SPILLS AND RELEASES

As evidenced by the presence of SPL on the groundwater surface beneath various areas of the Site, there have been historic spills and releases of oil products from the facility. Information regarding spills and releases from the distant past is minimal. However, in compliance with the ever-evolving environmental awareness and regulations, spills and releases from the more recent past are well documented. A summary of the known spills and releases on the Site is provided in Appendix L. The main information was obtained from the following documents:

i) Site Preparedness, Prevention and Integrated Contingency Plan (PPC Plan/ICP, September 2004 revision);

ii) Environmental Indicator Inspection Report (July 2001); and

iii) Multiple Release Reports (prepared by MACTEC).

In the event of a spill, the affected materials (i.e., recovered products, contaminated soils, absorbents, and spent chemicals) are analyzed prior to disposal. These materials are transported to licensed treatment/disposal facilities on an as needed basis or are recycled, when possible.

One spill that PADEP specifically requested more information for was the 1991 crude oil pipeline release in a ditch in the northeast corner of the Bolivar Drive railroad crossing (see Figure 3.3). Documentation regarding this spill is provided in Appendix L. In summary, the release was discovered on April 2, 1991 and the source of the release was an abandoned 5-inch diameter pipeline which had been used to transfer crude oil from the Duke Center production field to the refinery's crude oil tank farm. The pipeline was abandoned in either 1988 or 1989.

According to the records, an estimated one barrel of crude oil was recovered using the refinery's vacuum truck and a temporary well was installed to collect product from the

subsurface. In May 1991 a refinery crew "pigged" and water flushed the 5-inch line to a tank battery several miles from the release point and the line was pressure tested to confirm no other leaks were present. Thereafter, the line was blanked from all systems to prevent any further reoccurrence. The flushing of the lines with water was confirmed by the release of water observed during the tapping of the line in 2004, as described in Section 3.2.15.

As shown on Figure 3.3, the area in the vicinity of the 1991 pipeline has a large number of monitoring wells. Thus, it is believed no additional wells need to be installed to characterize the 1991 release.

As described in the July 2002 SCR prepared for the Custer City Oil Site, a representative SPL sample was collected in May 2001 from Custer City Oil well MW-CC-10 and submitted to Worldwide Geosciences, Inc. of Houston, Texas. The analyses indicated the SPL was a mixture of approximately 55% crude oil and 45% lubricant and that the crude oil portion was severely biodegraded with an exposure time of twenty years or more. This supports that the 1991 pipeline crude oil release has not contributed to the SPL observed beneath the Custer City Oil property.

Furthermore, as described in the March 2005 SCR prepared by Pennzoil-Quaker State Company (PQS) for the National Transit Property, SPL was observed at well MW-NT-33 which was installed in September 2004. This well is located in close proximity to the area of the 1991 pipeline release. The SPL in the area of MW-NT-33 was refined product. Given the close proximity of MW-NT-33 to the location of the 1991 pipeline crude oil release and that no crude oil component was present in the SPL from MW-NT-33, this supports that the pipeline release has not contributed to the SPL in MW-NT-33.

Taking into consideration:

i) the large number of monitoring wells in close proximity to the area of the 1991 pipeline release;

ii) that the 1991 release has not contributed SPL in SPL-CC01;

iii) that the 1991 release has not contributed to the SPL in MW-NT-33;

iv) the remedial actions implemented shortly after the spill occurred adequately addressed the release;

v) the results of the 2004 pipeline investigation confirmed the pipeline no longer contained crude oil; and

vi) the results of the 2005/2006 test pits in which no SPL was observed;

this release has been adequately characterized. Based upon the fact that the samples from each well location essentially are comprised of a different product or mix of products, it is evident that the SPL found along the railroad property is sourced by a number of small spills, rather than from one large spill. The SPLs in these areas are being included in Chemtura's manual SPL recovery program. Further evaluation of the 1991 crude oil pipeline spill area is presented in Section 3.15.

2.9 WASTE MANAGEMENT

The majority of wastes generated at the Refinery are either API separator sludge or crude oil tank bottoms. Lesser quantities of the other wastes are generated on a less frequent basis.

The following list details the wastes generated at the Site:

i) API Separator Sludge: approximately 150 tons per year from the oil water separators at the Main Refinery and Foster Brook Facility;

ii) Crude Oil Tank Bottoms: approximately 20 tons per year from the Main Refinery and Crude Oil Tank Farm;

iii) IAF sludge: approximately 10 tons per year from the Main Refinery WWTP;

iv) Non-hazardous biosolids filter cake: approximately 300 tons per year from the Main Refinery WWTP;

v) Waste Solvent Mix (VM&P Naphtha, Pentane, Kerosene): approximately 500 gallons per year of waste solvent mixture are generated by the Site laboratories;

vi) Heat Exchanger Sludge: approximately 1,000 pounds per year from the Main Refinery;

vii) Chloroform/Phenol: approximately 10 gallons per year of these solvents are generated by the Site laboratories; and

viii) Flammable Liquid, N.O.S., Karl Fisher Reagent: approximately 6 gallons per year are generated by the Site laboratories.

2.9.1 NON-HAZARDOUS SOLID WASTE

According to ARG personnel, no solid waste is currently disposed of on-Site. Waste products that cannot be recycled are transported to licensed treatment/disposal facilities on an as needed basis.

2.9.2 TREATED WASTEWATER DISCHARGES

There are three wastewater treatment systems at the Site. One serves the Main Refinery and a second serves the Foster Brook Facility. A third wastewater treatment system, designed to address groundwater remediation activities, exists at the Site. This system is not associated with Plant production wastewater. Consequently, this third wastewater treatment facility is not further discussed in this section.

The Dubbs Unit is the Main Refinery's WWTP. The wastewater treatment system is described in Sections 2.2.1.3 and 2.4.1. A process flow diagram for the Main Refinery wastewater treatment system is provided on Figure 2.3.

The wastewater treatment system in operation at the Foster Brook Facility consists of an API separator and a dual-cell lined equalization pond system. The API Separator collects stormwater from areas of the Foster Brook Facility south of Foster Brook and pretreats the water prior to flowing into the two equalization ponds. The effluent then discharges to Tunungwant Creek (outfall 004). According to ARG personnel, sediment has not been removed from the equalization ponds in approximately 10 years.

The municipal sewer authority handles all of the Plant's sanitary wastewater. All of the occupied areas of the Plant are serviced with sanitary sewers that connect to the City of Bradford's sanitary sewer system along the city streets that intersect the Plant. The Bradford wastewater treatment facility is a typical municipal treatment system equipped with primary and secondary treatment capabilities. It is located approximately two miles downstream of the Site along Tunungwant Creek. According to Site personnel, there are no septic systems on Site.

2.9.3 HAZARDOUS WASTE MANAGEMENT

Information regarding historic hazardous waste management is limited but the ever-evolving environmental awareness and regulations make information regarding more recent management practices available. In a September 1998 Hazardous Waste

Inspection Report, the hazardous wastes that were reported for the Site included: crude oil desalter sludge, petroleum refinery primary separation sludge, petroleum refinery secondary separation sludge, API separator sludge, spent solvents from Laboratories, and lab pack chemicals.

The majority of wastes currently generated at the Site are either API separator sludge or crude oil tank bottoms. Lead paint wastes are also produced when tanks are repaired although this volume is fairly limited. Hazardous wastes are stored for less than 90-days in RCRA-designated locations at the Main Refinery and at the research laboratory. These materials are transported to licensed treatment/disposal facilities on an as needed basis.

2.10 REFINERY IMPROVEMENTS

A summary of the improvements made to the Refinery for the time period January 2003 to March 2004 is presented in Table 2.2. As shown in Table 2.2, the principal improvements were:

i) cleaning of ASTs;

ii) demolition of tanks, including removal of any underlying impacted soil; and

iii) epoxy coating and hydro testing of ASTs.

These improvements are typical of those implemented by ARG on an ongoing basis.

2.11 REGULATORY HISTORY

Since the mid-1980s, investigative activities have been performed at the Site. The most significant of the Site investigations have all been submitted to the regulatory agencies, most notably to PADEP, as described in Section 3.1.

Through the Environmental Indicator Inspection Report dated April 27, 2002, the United States Environmental Protection Agency (USEPA) determined that the Refinery did not meet the criteria under the Federal Resource Conservation and Recovery Act (RCRA) that would allow Chemtura or ARG to cease implementing corrective actions based on the risk of human exposure to petroleum, and based on the fact that the groundwater has been contaminated by petroleum. Accordingly, the USEPA recommended that ARG participate in a voluntary USEPA program under RCRA known as the "Facility Lead

Program" to ensure that ARG complies with corrective action goals under RCRA. In a letter to the USEPA dated May 22, 2002, ARG declined to participate in the Facility Lead Program because ARG believed that the contamination at the facility is being remediated under Pennsylvania's Land Recycling Act.

While Crompton owned the Site, Crompton installed several groundwater wells to recover and treat groundwater. The contaminated groundwater was treated through an oil/water separator. Crompton discharged the treated groundwater into Tunungwant Creek via Outfall 001. On February 6, 1997, PADEP issued NPDES Permit No. PA0222151 to regulate the allowable discharges from the oil/water separator.

Based on PADEP's observations of iron precipitate in Tunungwant Creek, PADEP amended NPDES Permit No. PA0222151 on September 8, 1999, to include Total Iron effluent limits of 12.5 mg/L on an interim basis, and a final compliance effluent limit of 3.5 mg/L from Outfall 001. Also, on September 9, 1999, PADEP sent Crompton a letter requesting that it submit an application for a permit known as a Water Quality Management Permit to authorize Crompton to construct a new wastewater treatment plant to adequately treat the groundwater to meet its final effluent limitations. On October 8, 1999, Crompton filed a Notice of Appeal before the Environmental Hearing Board (EHB) and challenged PADEP's Permit Amendment and the letter dated September 9, 1999.

While the appeal was pending before the EHB, Crompton completed the installation of 12 horizontal wells (identified as HW-1 through HW-12) in July 2000 which are located between the Main Refinery and the banks of Tunungwant Creek. Crompton proposed to use the horizontal wells to pump contaminated groundwater beneath the Main Refinery to ARG's WWTP.

To resolve Crompton's Appeal, PADEP and Crompton agreed to certain terms under NPDES Permit No. PA0222151.

To facilitate Crompton's use of the horizontal wells and the treatment of the groundwater through ARG's WWTP, ARG agreed to allow Crompton to pump groundwater from the horizontal wells to ARG's WWTP at a rate of 30 gpm. Contemporaneously, PADEP amended NPDES Permit No. PA0222151 issued to ARG on October 25, 1999, to discharge effluent from the treated groundwater. Subsequently, ARG authorized Crompton to increase the pumping rate of the horizontal wells from 30 gpm to 66 gpm. Since all of the collected groundwater was being treated and discharged through ARG's wastewater treatment system in the Dubbs Unit, Crompton

did not discharge any treated groundwater through its Outfall 001 between July 2000 and April 2005.

On October 2, 2001, Crompton submitted an application to renew NPDES Permit No. PA0222151 and an application for a Water Quality Management Permit, which was amended on April 1, 2002.

On May 2, 2002, the Department renewed NPDES Permit No. PA0222151 and issued a Water Quality Management Permit No. WQM 4201201 to Crompton to construct a new wastewater treatment facility to address the groundwater collected under the remediation program. This permit expired on May 1, 2004. An application to renew WQM 4201201 was submitted to PADEP by Crompton on February 27, 2004 and an extension of WQM 4201201 was issued by PADEP on April 30, 2004. The extension provided Crompton until May 1, 2005 to complete the construction of a new separate wastewater treatment plant. Construction of the wastewater treatment plant was completed on or about April 11, 2005 and the plant was fully operational by April 18, 2005. In conjunction with the start up of the new groundwater treatment facility, use of Outfall 001 resumed. Figure 2.4 provides a schematic diagram illustrating the components of the new groundwater WWTP.

It is noted that the option of discharge to ARG's WWTP after treatment through Crompton's OWS still exists for those time periods when the groundwater WWTP is non-operational (e.g., for maintenance).

On August 30, 2002, PADEP issued Crompton and ARG a Notice of Violation ("August 2002 NOV"). This NOV was based on PADEP's observations of iron precipitate and petroleum sheens in Tunungwant Creek during the Spring and Summer of 2002.

The NOV also required the removal of SPL from the groundwater flow regime to the extent practical as an interim remedy. Removal of the SPL commenced in September 2002 and is ongoing. The removal has been highly successful in preventing SPL discharge to Tunungwant Creek.

On March 18, 2001, Crompton submitted Notices of Intent to Remediate (NIRs) under the Lands Recycling Act for three major Refinery areas as follows:

i) Main Refinery;

ii) Crude Tank Farm; and

iii) Foster Brook Facility.

A revised NIR was submitted to PADEP on May 3, 2004 to replace the three previous NIRs with one new NIR. The new NIR includes the three areas previously covered plus the Packaging Plant area. The new NIR covers the entire Site.

Based on the June 8, 2004 Consent Order and Agreement (COA), PADEP, Crompton, and ARG have agreed to address remediation at the facility under and in accordance with Act 2 and the PA. Storage Tank Act. Upon successful completion of the COA work, it is anticipated that the facility will qualify for the benefits under the One Cleanup Program Memorandum of Agreement between PADEP and Region III of the USEPA.

3.0 INVESTIGATIVE ACTIVITIES

3.1 HISTORICAL INVESTIGATIONS

Over the years, there have been a number of studies performed at the Site to investigate various aspects of the Site conditions. Some of the investigations were prompted by inspections and assessments performed by PADEP (preliminary assessment of the Main Refinery and Foster Brook Facility in 1985) and by the USEPA (site inspection of the Main Refinery and Foster Brook Facility in June 1988). Others were initiated by Witco themselves. The earliest of these investigations were undertaken in the mid 1980s and were performed by various consultants for Witco to develop a preliminary understanding of the Site conditions. These early studies identified that there were impacted soils and groundwater beneath the Site and that SPL was present floating on the groundwater. In 1989, NUS Corporation prepared the first comprehensive Site Investigation of the conditions in the Main Refinery and Foster Brook Facility. The results of this investigation were submitted to the USEPA's Hazardous Site Control Division. As with many of the studies that have been performed over the years, this initial report covered only a portion or portions of the Plant Site or investigated a single aspect of one area of the Site such as the release from a particular tank. This Site Characterization Report is intended to present an overall assessment of the entire Plant Site and relies upon the data collected over the course of the past 20 years to provide an accurate description of all of the Site conditions concerning all of the Site media including surface soils, subsurface soils, groundwater, surface water, and sediment.

The most significant of the Site investigations have all been submitted to the regulatory agencies, most notably to PADEP. The reports documenting the most significant Site investigations and those that have been most heavily relied upon in the preparation of this Site Characterization Report include the following:

- R.E. Wright Associates, Inc. *Site Remediation and Risk Assessment Evaluation for the Barrel House Site in Bradford, Pennsylvania,* January 1993.
- R.E. Wright Associates, Inc. *The Barrel House Steam Extraction Pilot Test,* March 1994.
- Enviro-Sciences, Inc. *Phase I Environmental Site Assessment,* December 1995.
- Enviro-Sciences, Inc. *Phase II Environmental Site Assessment,* January 1996.
- R.E. Wright Associates, Inc. *Phase III Remedial Activities at the Witco Corporation Bradford Refinery, Bradford, Pennsylvania,* April 1996.
- R.E. Wright Associates, Inc. *Remediation Options Assessment and Preliminary Design for Free Product Capture in the Main Refinery Area, Witco Corporation, Lubricants Group, Bradford, Pennsylvania,* May 1996.

- R.E. Wright Associates, Inc. *Final Design for Free Product Capture in the Main Refinery Area, Witco Corporation Lubricants Group, Bradford, Pennsylvania,* June 1996.
- R.E. Wright Associates, Inc. *Draft Final Report, Act 2 Compliance Evaluation for the Former Witco Corporation Bradford Refinery, Bradford, Pennsylvania,* July 1997.
- R.E. Wright Associates, Inc. *Phase III Remedial Activities Continued at the Bradford Refinery, Bradford, Pennsylvania,* August 1997.
- R.E. Wright Associates, Inc. *Foster Brook Container Removal Activity and Refuse Site Characterization Report,* March 1998.
- PADEP, *Macroinvertebrate and Surface Water Sampling Results,* June 2000.
- Fluor Daniel GTI, *Investigation Report, Foster Brook Burn Pit/Lagoon Area(s),* January 1998.
- Enviro-Sciences, Inc. *PADEP Act 2 Facility Characterization Report, Former Witco Chemical Corporation, Bradford Refinery – Foster Brook Facility,* July 1999.
- PADEP; VOC, SVOC, and Actual Results, September 2000.
- Enviro-Sciences, Inc. *Crude Tank Farm Remedial Investigation Report – Bradford Refinery – Bradford, Pennsylvania,* March 2001.
- Enviro-Sciences, Inc. *Ecological Risk Assessment, Crude Tank Farm, Former Crompton Corporation, Bradford Refinery,* December 2001.
- Enviro-Sciences, Inc. *Baseline Human Health Risk Assessment, Crude Tank Farm, Former Crompton Corporation, Bradford Refinery,* December 2001.
- Environmental Remediation Recovery, Inc. *Site Characterization Report, Custer City Oil,* January 2002.
- ATC Associates, Site Characterization Report, National Transit Co., Foster Brook Station, June 2002.
- ATC Associates, Laboratory Analytical Results for PSH Characterization, October 16, 2002.
- Conestoga-Rovers & Associates, Summary of Work Completed, Site Characterization Activities, October 2002.
- Conestoga-Rovers & Associates, Horizontal Well Design/Installation and Performance Report, October 2002.
- MACTEC, *Site Characterization Reports*
  - *Tanks 22 and 173 (January 31, 2006)*
  - *Tank 248 (January 31, 2006)*
  - *Tanks 264 and 270 (September 30, 2005)*
  - *Tank 603 Release (January 30, 2006)*

- *Tank 618 (September 30, 2005)*
- *Tank 721 (September 30, 2005)*
- *Transfer Pump Area (June 29, 2005)*

These reports provide an extensive database of information for the Site and describe all of the investigative work that has been performed up through 2005. The information from all of these reports has been compiled, summarized, and incorporated for use in this SCR along with the additionally requested information that was specified in the SSD Work Plan prepared by CRA. The data and interpretations from all of the historic reports have been considered (and in some cases inserted in full) in this SCR. Relevant information from sites adjacent to this Site (such as Custer City Oil and National Transit) have also been incorporated into the database for this Site.

In addition, a few of the above reports discuss remedial activities that have been conducted on the Site in order to address specific environmental concerns that have been identified. These remedial efforts are further discussed in Section 9.0 of this SCR.

The historic investigation activities that have been performed at the Site and reported upon in the historical reports include the following:

i) collection of surface soil samples for analytical testing;

ii) advancement of soil borings, field characterization of subsurface conditions, and collection of subsurface soil samples for analytical testing;

iii) excavation of test pits to similarly characterize subsurface conditions;

iv) installation of groundwater monitoring wells to provide information for characterizing the groundwater conditions;

v) collection of groundwater samples for analytical testing;

vi) collection of SPL samples for physical and chemical analytical testing to provide product typing;

vii) measuring groundwater elevations in the groundwater monitoring wells to provide groundwater flow characteristics;

viii) performance of groundwater pumping tests to enhance the understanding of groundwater flow characteristics and SPL flow characteristics;

ix) measurement of SPL thicknesses on the groundwater table to enhance the understanding of SPL conditions;

x) delineation of the horizontal extent of SPL plume areas through various subsurface investigation methods (e.g., drilling, test pits);

xi) collection of surface water elevation data to enhance the understanding of groundwater and surface water interactions;

xii) collection of surface water and sediment samples from Tunungwant Creek to characterize the nature and extent of potential chemicals of concern and to facilitate risk assessment activities;

xiii) fate and transport modeling of potential chemicals of concern; and

xiv) collection of habitat data.

As noted in the foregoing, the historical investigations that have been conducted at the Site are extensive and provide a very thorough understanding of the Site conditions and the impact of oil product releases over the years on the local environment. Having supplemented the historic data with the additional data that has been collected during the recent study, it is now believed that the understanding of the Site conditions is suitable for moving into the remediation option assessment phase of the regulatory process.

The investigative activities that have been performed to date at the Site can be summarized as follows:

Main Refinery

	# Soil Samples	*# Boreholes/ Soil Sample Locations(1)*	*# Test Pits/ Holes*	*# Wells/ Piezometers*	*# Groundwater Samples*
Historical	266±	130±	0	210±	190±
Supplemental	3	0	0	30	89
Total	269±	130±	0	240±	279±

Crude Tank Farm

	# Soil Samples	*# Boreholes/ Soil Sample Locations(1)*	*# Test Pits/ Holes*	*# Wells/ Piezometers*	*# Groundwater Samples*
Historical	70±	60±	0	30±	50±
Supplemental	13	7	15	14	46
Total	83±	67±	15	44±	96±

Foster Brook Facility

	# Soil Samples	# Boreholes/ Soil Sample Locations(1)	# Test Pits/ Holes	# Wells/ Piezometers	# Groundwater Samples
Historical	260±	270±	4	120±	150±
Supplemental	84	93	2	12	44
Total	344±	363±	6	132±	194±

Packaging Plant

	# Soil Samples	# Boreholes/ Soil Sample Locations(1)	# Test Pits/ Holes	# Wells/ Piezometers	# Groundwater Samples
Historical	11±	3±	0	5	14±
Supplemental	0	0	0	5	10
Total	11±	3±	0	10	24±

Tunungwant Creek and Tributaries

	# Surface Water Samples	# Sediment Samples	# Macroinvertebrate Samples
Historical	46±	46±	9
Supplemental	29	0	27
Total	75±	46±	36

(1) Does not include locations where well/piezometer installed.

A listing of those historic soil sample locations for which a log is available is presented in Table 3.1. A listing of the historic wells for which a borehole/well installation log is available is provided in Table 3.2. The available historic logs are provided in Appendix M. A summary of the historic physical testing soil results is provided in Table 3.3.

The analytical results presented in this SCR are a collation of data available from historic and the 2003/2004/2005 investigations. Different lists of VOC parameters were analyzed for during the various investigations, resulting in differences in the VOC parameters reported. In some of the previous studies, the trimethylbenzene (TMB) data were reported and as a result, to the extent that these data were available, they were reported in this SCR. With regard to the samples analyzed in 2003 and 2004, the analytical list that was to be used for the investigations for this time frame was the one provided to PADEP in the SSD Work Plan. 1,2,4-Trimethylbenzene (1,2,4-TMB) and 1,3,5-Trimethylbenzene (1,3,5-TMB) were not included in that list. In response to a

PADEP request in September 2004, 1,2,4-TMB and 1,3,5-TMB were added to the list of parameters to be reported for future sampling events.

To reduce the uncertainty in the analytical data and to determine if TMB is of concern in the soil gas to indoor air and groundwater discharge to surface water pathways, the analytical laboratories were asked to review the chromatographs for a select set of the 2003/2004 samples. This sample set was based on the need to have TMB data for the soil gas samples and for the groundwater from those monitoring wells that were used to estimate the chemical loading to Tunungwant Creek. These results have been incorporated into this SCR.

In addition, samples collected for VOCs subsequent to September 2004 include 1,2,4-TMB and 1,3,5-TMB in the parameter list to be reported. The QAPP has been revised to incorporate these requirements.

A more detailed discussion on the significance of the 1,2,4 and 1,3,5-TMB data is provided in Appendix AU.

3.2 SUPPLEMENTAL SITE CHARACTERIZATION FIELD ACTIVITIES

The historical investigations that have been performed at the Site provide a very thorough understanding of the Site conditions. However, upon review of these various reports (in particular the most recent series of Enviro-Sciences, Inc. (ESI) reports), PADEP has provided comments on areas of deficiencies that need to be addressed in order to finalize the SCR and Risk Assessment Reports. The SSD Work Plan(approved on June 10, 2004), Step 3 ERA Work Plan (approved June 26, 2006), and Off-Site SPL Work Plan (approved November 1, 2005) specified the remaining work necessary to finalize each of the documents. The Ecological and Human Health Risk Assessments are submitted as separate documents to address the PADEP comments associated with those reports. This document addresses the comments associated with the SCR.

In accordance with the SSD Work Plan, Off-Site SPL Work Plan, and responses to PADEP comments on the draft June 2004 SCR and draft July 2005 SCR, the following field activities were performed to complete the site characterization:

i) borehole drilling and soil sample collection and analyses (physical and chemical);

ii) groundwater monitoring well installation, development, and four rounds of groundwater sampling and analyses;

iii) SPL sample collection and analyses (physical and chemical);

iv) groundwater level and apparent SPL thickness monitoring;

v) SPL bail-down tests;

vi) vadose zone well installation and soil gas collection and analyses;

vii) indoor air and ambient air sample collection and analyses;

viii) profiling of the horizontal wells;

ix) pumping tests in 3 newly installed vertical wells and 4 existing horizontal wells;

x) surface water sample collection and analyses;

xi) macroinvertebrate survey;

xii) wetland delineation and habitat characterization; and

xiii) abandoned underground pipeline investigation, including the 5-inch diameter crude pipeline running from the vicinity of the Custer City Oil facility to ARG's crude tank farm.

Additional details regarding each of the above are presented in the following sections.

It is noted that the initial surface water sampling and analyses described in Section 4.2 of the SSD Work Plan was not performed until May 2005 because the flow rate in Tunungwant Creek was too high prior to that date. By agreement reached with PADEP on the scope of the surface water sampling component of the investigative activities, surface water sampling was to be performed only when Tunungwant Creek was at low flow conditions. Low flow conditions were set at a maximum flow rate of 48.3 cfs (revised to 96.6 cfs on May 11, 2005). The decision to only sample surface water when low flow conditions exist is meant to represent worst case conditions when groundwater flow from the surrounding areas (such as from beneath the Site) make up the largest percentage of the flow in the Creek and is thus representative of highest chemical concentration release from the Site. The flow rates of 48.3 and 96.6 cfs were selected in consultation with PADEP and represents three and six times, respectively, the 7-day, 10-year low flow value of 16.1 cfs. Flow rates were determined from readings taken from a USGS staff gauge installed on the Route 219 bridge abutment north of Bolivar Drive.

3.2.1 SOIL CHARACTERIZATION

Surface and subsurface soil sampling was performed at the Refinery to aid in the site characterization activities. The methods and protocols for soil sampling, field documentation, and decontamination of sampling equipment are summarized in the following subsections.

A listing of the soil sampling and analyses performed during this supplemental effort is presented in Table 3.4.

3.2.1.1 BOREHOLE DRILLING AND SOIL SAMPLING

Prior to the start of borehole drilling, a decontamination pad was constructed at the location shown on Figure 3.1. This decontamination pad was used to clean all down hole equipment throughout the course of this investigation.

Borehole drilling and well installations commenced on July 1, 2003 and were completed on October 8, 2003, except for those boreholes/wells located on PennDOT and Buffalo & Pittsburgh Railroad, Inc. (B&R Railroad) properties. Access permission for these boreholes/wells was not received until February 2004 and the boreholes/wells were not completed until March 12, 2004. In accordance with PADEP comments received on the draft June 2004 SCR, three additional wells were installed in March 2005.

In total, 144 boreholes, including 9 for soil gas probes, were drilled and 52 groundwater monitoring wells installed. The locations of these boreholes and wells are shown on Figures 3.1, 3.2, and 3.3.

In some cases, modifications had to be made to the initially proposed locations of the monitoring wells. These modifications are described below.

Well	*Refinery Area*	*Description*
MW-101	MEK Unit	Due to access restrictions, the well was moved from inside to outside the dike wall.
NA	MEK Unit	Well between MW-64 and EMW-79 could not be installed due to utility interferences. No other location between MW-64 and EMW-79 was accessible.
MW-104	MEK Unit	Original location inaccessible. Location moved to the northwest by approx. 30 feet.

Well	*Refinery Area*	*Description*
MW-127 & MW-135	Platformer Unit	Additional wells installed to investigate seeps to Tunungwant Creek.
MW-123, MW-124, & MW-131	Dubbs Unit	Additional wells installed to investigate seep to Tunungwant Creek.
MW-125	Crude Unit, Upper Yard	Due to access restrictions and utility interferences, the well was moved from the east side to the west side of Tank 332.
NA	Erie Wye Unit, North of Kendall Avenue	The owner of the property for the planned location (Werzalit of America, Inc.) would not provide access. Underground locates of the property between Werzalit and Kendall Avenue identified only a very narrow corridor (approx. 18 inches) without underground utilities. Given the error often associated with the location of underground utilities, it was not deemed safe to install a well at this location.
MW-134	Adm/Research and Development Area	Due to the presence of an extensive growth of trees, the well was moved approximately 30 feet west.
MW-132 & MW-133	National Transit	Property owners adjacent to Bolivar Drive would not provide access permission. Wells were installed on National Transit property as close to the Bolivar Drive properties as practical.
MW-116 & MW-117	Packaging Plant	Due to access restrictions and underground utility interferences, well MW-116 was moved approximately 50 feet east and well MW-117 was moved approximately 70 feet north.
FBCD-2, -4, -6, and –13A	Construction Debris Area	The purpose of these borings was to delineate the extent of fill. This was visually obvious based on the steep grade (face) observed. Thus, the location of these borings were moved south, adjacent to the fill but still in non-filled areas.
MW-136 to 139	Main Refinery	The purpose of these wells was to assist in the evaluation of the effectiveness of the SPL IRM in SPL removal.
MWRW-11	Foster Brook	Due to strong odors in MWRW-09, MWRW-11 was installed closer to Tunungwant Creek to determine the extent off-Site impact.

Well	*Refinery Area*	*Description*
69SG	National Transit	Installed to assist in evaluation of soil vapor exposure route in human health risk assessment (HHRA).

A listing of the SSD boreholes drilled is presented in Table 3.5. A listing of the SSD wells installed is presented in Table 3.6. Stratigraphic and well installation logs are provided in Appendix N.

3.2.1.2 SURFACE SOIL SAMPLING

Surface soil samples were obtained to characterize areas of obvious impact from Refinery-related constituents of concern (COCs). Biased sampling locations were chosen based on visual observations of areas of staining, stressed vegetation, elevated areas (indicating a fill area), or other indicators of potential impact from COCs.

Surface soil samples from the Construction Debris area were collected using split spoon samplers. Surface soil samples from the Bauxite Fill and Fly-Ash areas were collected using a direct push Geoprobe™ type sampler. Details of each sampling method are provided in a following section. All sample containers were documented on chain of custody forms; labeled with the sample location, date, time, and analysis to be performed; packed in ice to maintain a temperature of 4°C ±2°C; and transported to the laboratory by courier in sealed coolers. Sample collection information, as described above, and soil descriptions were also recorded in a bound field notebook.

3.2.1.3 SUBSURFACE SOIL SAMPLING

Subsurface soil samples were collected from soil borings and test pits. Soil borings were advanced to collect soil samples from both the unsaturated and saturated soil columns for site characterization purposes. Biased subsurface soil sampling locations were chosen for the initial series of soil boring locations based on visual observations of areas of staining, stressed vegetation, or other obvious indicators of impact from COCs. Subsequent soil boring locations were chosen to adequately characterize potential COC-related impacts observed from the initial soil borings.

Continuous samples, used for soil classification, were collected during hand augering. Continuous soil samples were also obtained from ground surface to approximately four to six feet below the top of the observed saturated soil zone. Soil borings were advanced

and soil samples were collected using a combination of two methods: direct-push Geoprobe™-type methods and split-spoon soil samplers. The following subsections provide details of the two sampling methods.

Four unsaturated soil samples from each of the Main Refinery and Foster Brook Facility were to have been submitted for geotechnical analysis (i.e., porosity, dry bulk density, moisture content, and organic carbon content). Attempts to collect these samples using a Shelby Tube typically resulted in crushed tubes because of the dense or stoney nature of the soil. Thus, only 2 samples (MW-128A, Foster Brook, Former Burn Pit Area and MW-130A, Foster Brook, Bauxite Fill Area) were collected. The data (see Table 3.7) was used for the Site-specific soil gas evaluation in the HHRA.

A sampling program was also included to assess five specific areas in the Foster Brook Facility to determine whether these areas have been properly closed in compliance with the requirements of Chapter 288; in particular to evaluate the cover material that has been used to cover these areas. This sampling program was to have included the collection of two soil samples from four locations within each of the five areas (total of 40 samples). The samples were to have been collected from the 6- to 12-inch and 36- to 42-inch bgs intervals. The 6- to 12-inch samples were collected successfully with mini shelby tubes pushed by hand. Attempts to collect the 36- to 42-inch samples by hand were unsuccessful. The soils are dense and it was not possible to drive or pull a soil sample in a mini shelby tube. Soil sample collection was also attempted by pushing shelby tubes with the drill rig. Because of the dense soil condition, this resulted in collapsed shelby tubes. As a result, only the shallow samples were collected. The samples were tested for:

i) grain size (including hydrometer);

ii) hydraulic conductivity; and

iii) plasticity index.

In most cases, the need for the deeper samples was eliminated as the cover materials were never thicker than 24 inches at any location.

In addition, a soil sample was collected from each of the three areas in which soil gas probes were installed (i.e., Main Refinery office, Foster Brook loading office, and National Transit property). These samples were analyzed for physical parameters to assist in the evaluation of the soil gas exposure pathway in the HHRA. The samples were collected using a hand auger and mini-Shelby tube pushed by hand.

Test pits were excavated by hand or backhoe in December 2005/January 2006 in the Buffalo and Pittsburgh Railroad property north and south of Bolivar Drive to:

i) determine the source and/or pathway by which the SPL arrived at the SPL-32 location;

ii) determine the soil and groundwater conditions in the area of SPL-19 and SPL-32;

iii) confirm the integrity and proper closure of the abandoned pipelines in this area; and

iv) determine the soil and groundwater conditions in the area of the 1991 crude oil spill associated with the 5-inch pipeline and SPL-CC01.

The samples were collected from the area/depth exhibiting the greatest potential impact, or if such was not observable, from the bottom of the test pit.

A summary of the physical testing results is provided in Table 3.7. A description of the visual characteristics of the vegetative cover in these areas (e.g., well established, stressed, no vegetation, etc.), is provided in Section 5.12 along with a discussion of the findings of the cover/closure investigation.

All of the analytical results from the samples collected during the SSD were validated by CRA personnel for QA/QC. The QA/QC review of the results for the SSD soil samples collected from July to September 2003 are provided in Appendix O. The QA/QC review for the soil samples collected from October 2003 to January 2006 are provided in Appendix R. The reviews showed that the sample data were acceptable with the exceptions noted in Appendices O and R.

Geoprobe™ Soil Sampling

Some of the soil samples from the SSD were collected using a geoprobe drill rig. The geoprobe collected continuous soil samples using 2-inch diameter, four-foot long stainless steel soil samplers with disposable inner acetate liners. Once recovered, the acetate liners were cut once lengthwise to obtain a representative soil sample. This method minimizes sample loss and potential volatilization. A small representative soil sample was collected from each 2-foot interval and placed into separate ziplock bags for Volatile Organic Compound (VOC) headspace screening with a photoionization detector (PID), calibrated with a 100 parts per million (ppm) isobutylene standard. Each 2-foot soil interval was described by an on-Site geologist based on geologic properties, staining, odor, and visible free product in a bound field notebook, using the modified

Unified Soil Classification System. The stratigraphic information is presented on the Stratigraphic and Well Installation Logs provided in Appendix N.

One soil sample was collected from the upper 2 feet of the soil column for laboratory analyses. For identification purposes, these upper soil samples were labelled without a suffix after the numbers (e.g., CR-29).

One soil sample from the unsaturated soil column in each boring was also collected for laboratory analysis. The sample was collected from the 2-foot interval that exhibited either the highest PID reading or the greatest amount of staining, odor, or visible free product. If no significant indicators were encountered, the sample was taken from the 2-foot interval directly above the observed saturated soil zone. Soil samples collected from the unsaturated zone were labeled with the suffix A (e.g., CR-29A).

Samples from the saturated soil zone were also collected at a select number of boring locations. Saturated soil samples were collected from the interval 2 to 4 feet below the top of the saturated soil zone, and were labeled with the suffix "B" (e.g., CR-29B).

Soil samples were handled and all sample containers were documented, packed, and transported to the laboratory as described in Section 3.2.1.2.

Split-Spoon Soil Sampling

At some soil boring locations, decontaminated hollow stem augers and a wheeled or track drill rig were used to obtain split spoon samples, in a manner consistent with ASTM D-1586. The drill rigs used two-inch diameter, two-foot-long split-spoon samplers which were advanced ahead of the hollow stem augers at discrete two-foot intervals. Soil retrieved from the steel split-spoon samplers was accessed by removing one half of the split-spoon assembly. Disassembly of the split-spoons was performed with a minimal amount of movement so as to minimize the disturbance of the sample and to preserve the volatile compounds present to the extent possible. Soil logging, screening, sample collection, and sample identification were consistent with the methods described in the previous section for Geoprobe™ samples.

3.2.1.4 SOIL SAMPLING DECONTAMINATION PROTOCOLS

All non-dedicated or non-disposable sampling equipment, including, but not limited to, split-spoon samplers, scoops, and spatulas were decontaminated in the field in

accordance with ASTM D-5088-90 guidelines to prevent possible cross-contamination between sampling locations.

A "clean" area was established near the work zone and covered with clean plastic sheeting. A decontamination line was set up in the clean area, consisting of a bucket of Alconox® cleaning solution, tap water, distilled/deionized water, nitric acid solutions and acetone stored in plastic spray or squeeze bottles, and enough buckets to collect residual waste and decontamination fluids.

The following procedure was used to decontaminate sampling equipment:

i) Scraped, brushed or otherwise removed any gross residual material from the sampling equipment;

ii) Scrubbed sampling equipment using a standard brush in a tap water and Alconox® solution;

iii) Rinsed sampling equipment with regular tap water and allowed excess water to drain;

iv) Rinsed equipment with distilled and deionized water;

v) Rinsed sampling equipment with a 10% nitric acid solution and allowed excess acid to drain off of equipment;

vi) Rinsed with distilled and deionized water;

vii) Rinsed with pesticide-grade acetone; and

viii) Performed a final rinse with distilled and deionized water.

Decontaminated equipment was allowed to air dry and was wrapped in aluminum foil when not being used for sampling. All residual wastes and fluids were collected in Department of Transportation (DOT)-approved drums and treated/disposed as described in Section 3.2.19.

Heavy equipment, including but not limited to hollow-stem augers, drill rods, Geoprobe™ rods and backhoe buckets, were also decontaminated between sampling locations. Drill rigs, Geoprobe™ rigs, and backhoes were decontaminated on an as-needed basis, depending on the amount of residual soil collected on the wheels, tracks, and body.

To decontaminate heavy equipment, a temporary decontamination pad, consisting of heavy-gauge poly sheeting with elevated sides, was established in a central area of the work zone. The pad was constructed with a low area to act as a sump for the collection

of residual decontamination fluids. Equipment was staged on the decontamination pad for cleaning, and a generator-powered high-pressure steam cleaner was used to remove all visible soil, mud, grease, etc. from the equipment. All residual materials were pumped out of the sump and collected in DOT-approved 55-gallon drums and treated/disposed as described in Section 3.2.19.

3.2.2 MONITORING WELL INSTALLATION

3.2.2.1 LOCATION OF MONITORING WELLS

The initial monitoring well locations for the SSD were selected to address data gaps in the delineation of the extent of SPL or the extent of the dissolved phase petroleum based and chlorinated constituents. Subsequent monitoring well installations were located to enhance the existing characterization network and to address specific delineation requirements, as necessary. This included the installation of:

i) four additional monitoring wells (MW-136 through MW-139), which were installed to evaluate the effectiveness of the manual SPL removal;

ii) 17 soil gas probes in 9 boreholes to evaluate the soil gas exposure pathway in the HHRA;

iii) monitoring well MWRW-11 to determine the extent of potential impact from the Foster Brook Facility toward Tunungwant Creek;

iv) monitoring wells MW-143 and MW-144 to determine the extent of SPL downgradient of the MEK Unit; and

v) monitoring well MW-145 to determine the extent of SPL downgradient of the ROSE Unit.

3.2.2.2 MONITORING WELL CONSTRUCTION

All monitoring wells were constructed using four-inch diameter, 0.020-inch slotted schedule 40 polyvinyl chloride (PVC) screens and flush joint threaded risers. The wells were constructed in 10-inch outside diameter boreholes that varied in depth from 15 to 25 feet bgs (see Table 3.6). Monitoring well boreholes were advanced using hollow stem augers and split-spoon samplers per ASTM D-1586 standards, using either a wheel- or track-mounted drill rig. The well screens were placed in the boreholes so that they extend at least three feet above the static water level, which has been determined to be at 7 to 8 feet bgs in most cases. An R.W. Sidley #5 silica sand pack was placed in the

borehole annulus to approximately 2 feet above the top of the well screen. A 1 to 2-foot thick bentonite pellet seal was then placed above the sandpack. The remainder of the borehole was filled with a non-shrinking, 95:5 concrete mix with bentonite added to the ground surface. Construction was completed with either a 6-inch diameter steel protective stick-up casing with a locking cap or an 8-inch diameter flush-mounted road box and vented locking pressure cap, depending on well location. Groundwater monitoring well installation details are shown on the installation logs provided in Appendix N.

The well identifiers were etched into the concrete of the protective casing/road-box and/or indicated with permanent marker on the lid of the well. Field ties and identification of each well were also marked with permanent marker on nearby structures where possible.

3.2.2.3 MONITORING WELL DEVELOPMENT

Following installation, the monitoring wells were developed using a surge block and either a submersible or centrifugal pump. The screened interval was swabbed with a surge block for several minutes, after which the submersible or centrifugal pump intake was lowered to the approximate screen midpoint. Wells were developed to enhance the hydraulic connection with the surrounding aquifer materials and to remove as much fine sediment from the well screen and the surrounding sand pack as possible. Development continued until the purge water was visibly free of turbidity. The pH and specific conductance of the groundwater was also measured during well development.

Development water was collected in a portable plastic tank and discharged to one of the on-Site API separators.

A summary of the parameters measured during well development is provided in Appendix P.

3.2.3 GROUNDWATER SAMPLING

Four rounds of groundwater sampling were conducted in a manner consistent with recommendations presented in the PADEP Act 2 Technical Guidance Manual. Sampling for the first round was performed from September 16 to October 22, 2003 and for the second round from November 11 to December 11, 2003 for those wells which had been installed in 2003. The wells that were installed in 2004 and 2005 were sampled shortly

after their completion. The wells that were installed in February/March 2004 and April 2005 have only had one sample round collected due to the timing of the installation of these wells. The following presents the typical groundwater sampling procedures and protocols used during the SSD program for monitoring wells. The protocols take into consideration whether a measurable apparent thickness of SPL (e.g., greater than 0.01 foot of SPL) exists. Protocols used to sample wells with SPL is presented in the following section of this report.

Prior to sampling, wells were measured for groundwater depth and thickness of free product, if encountered. Depth to the bottom of the well was also recorded to determine total well volume. All wells were purged and subsequently sampled using a peristaltic pump. Disposable polyethylene tubing was attached to the pump and lowered into the well until the intake of the tubing was approximately 1 to 2 feet below the top of the static water column. New tubing was used at each monitoring well to avoid cross-contamination. The outlet of the tubing was attached to a flow-through cell that, in turn, emptied into a graduated bucket. The start time of purging was recorded to determine a purge rate that minimized the turbidity and the draw-down of the water level in the well. Purge rates were regulated to less than 4 gallons per minute maximum and were generally less than 2 gallons per minute.

As purging continued, the water quality was typically monitored for each monitoring well volume removed. The following parameters for each well volume were recorded in dedicated sampling logs: dissolved oxygen, pH, temperature, conductivity, oxidation reduction potential, turbidity, color, presence of film, and noticeable odors. Summaries of the parameters measured during purging are provided in Appendix Q. Purging was considered complete when:

i) the readings for the majority of the parameters stabilized for three consecutive readings (± 10%); or

ii) a maximum of 5 well volumes had been removed.

All wells provided adequate water during purging and no well went dry during purging or sampling. All instruments were calibrated to known industry standards and manufacturer requirements on a daily basis. Calibration data were recorded in a bound field notebook.

Samples were collected immediately after purging. To collect laboratory samples, the flow-through cell was detached from the pump, and the pump rate was reduced to

100 mL/min. Samples were collected in the appropriate laboratory-supplied bottles in the following order:

i) VOCs;

ii) SVOCs; and

iii) Metals (dissolved, samples field-filtered with a disposable 45-micron flow-through filter).

In addition, ferrous iron was measured in the field using a Hach kit.

A summary of the groundwater samples collected, including the field parameter values for the final purge volume, are provided in Tables 3.8, 3.9, 3.10, and 3.11 for Rounds 1, 2, 3, and 4, respectively. The QA/QC review of the SSD groundwater results are provided in Appendix R. The review showed that the sample data were acceptable with the noted exceptions.

A unique sample identification number, site location, date sampled, time sampled, sampler ID's, and analysis to be performed were labeled on all sample bottles, as well as on the chain of custody forms transported with the samples. Samples were transported for laboratory analysis in sealed coolers maintained at 4°C ±2°C . Purge water was collected in a mobile tank and discharged into one of the on-Site API separators.

3.2.4 GROUNDWATER/SEPARATE PHASE LIQUID INTERFACE SAMPLING

Groundwater/SPL interface sampling was conducted at the Site to provide groundwater quality from monitoring well locations that exhibited a measurable apparent thickness of SPL. Those wells listed in Tables 3.8, 3.9, and 3.10, in which SPL was present, were sampled in accordance with the interface sampling procedures and protocols described below. No SPL was present in the wells listed in Table 3.11.

A clean 1-inch diameter PVC pipe was covered with a double piece of Saran® Wrap held tightly in place with electrical tape, to ensure that no SPL would enter the inner annulus of the pipe. The PVC pipe was lowered into the well until the end of the pipe was approximately 1 foot below the SPL layer. Once the PVC pipe was in place and secured to the protective well casing, polyethylene tubing was inserted through the 1-inch pipe, allowed to perforate the sheeting on the end of the pipe, and extended approximately 0.5 foot further into the well. The tubing was attached to the peristaltic

pump and purging was conducted at an extremely low rate to inhibit entry of the SPL layer into the underlying groundwater column. The purge rate was generally less than 2 gallons per minute. The top of the SPL layer was constantly monitored in the annular space between the PVC pipe and the well casing to insure that no SPL reached the tubing intake. Purging and sampling was then conducted as described in Section 3.2.3. New polyethylene tubing was used at each well for each sampling event in wells containing SPL.

3.2.5 SEPARATE PHASE LIQUID SAMPLING

SPL samples were collected from 23 locations. A summary of the samples collected is presented in Table 3.12. SPL samples were collected from 22 of the 24 locations described in the SSD Work Plan. The two locations from which an SPL sample was not submitted (i.e., MW-62 and MW-94), had insufficient SPL to collect a sample. Also, a sample was collected from MW-10, located on the Custer City Oil property as the SPL at this location was visually very different from the SPL at the nearby GP-3 (Custer City) well.

The SPL samples were collected using a dedicated 2-inch disposable bailer with dedicated nylon twine at each well to prevent cross-contamination between wells. After measuring the depth to the SPL layer, the apparent thickness of the SPL layer, and the depth to groundwater, the bailer was lowered into the well annulus to collect a SPL sample. The bailer was then removed and any residual water in the bailer was drained into a separate graduated bucket. The remaining SPL was decanted into laboratory supplied containers and transported in tape sealed, temperature controlled coolers with a detailed chain of custody to Severn Trent Laboratories (STL). STL then subdivided the sample into the portions needed by each laboratory for those parameters to be analyzed by the various laboratories. The laboratories and parameters analyzed were:

Laboratory	*Parameters*
Texas Oil Technical Laboratories	TPH Oil & Grease Viscosity Density
Severn Trent Laboratories	VOCs SVOCs

For those wells from which sufficient SPL volume could not be obtained to perform all of the analyses, the available volume was subdivided and analyzed on a priority basis in the order presented above. The QA/QC review of the SSD SPL results are provided in Appendix S. The review showed that the sample data are acceptable with the noted exceptions.

All excess liquids retrieved from the wells were discharged into the on-Site groundwater treatment facility oil/water separator.

3.2.6 GROUNDWATER LEVEL/SEPARATE PHASE LIQUID APPARENT THICKNESS MONITORING

Following installation and regularly thereafter, groundwater elevation and apparent SPL thickness measurements were obtained for all of the monitoring wells found to contain SPL. All of these wells have been included in an interim SPL removal program which was approved by PADEP. Three groundwater and apparent SPL thickness measurement events were performed, on all of the available wells at the Site. These measurement events occurred in March/early April 2003, April 14 to 15, 2003 and December 17 to 19, 2003 for the entire refinery. All wells in a specific part of the Site were completed in a single day to provide a "snap-shot" of groundwater levels and apparent SPL thicknesses for that part of the Site. The measured water levels and apparent SPL thicknesses are provided in Tables 3.13, 3.14, and 3.15 for the March/April, April, and December events, respectively.

Measurement was performed using a properly decontaminated oil/water interface probe. The probe was slowly lowered into the monitoring well until a continuous tone was emitted, signifying the top of the product layer. The probe was then lowered further into the well until an intermittent tone was heard, which indicates that the groundwater layer had been reached. Next, the probe was slowly raised until the intermittent tone was replaced by a solid tone to mark the bottom of the product layer. This process was repeated to ensure the accuracy of the measurement data.

It is noted that when taking these measurements in areas where the SPL was very viscous (i.e., MW-71, MW-PP03), the SPL stuck to the probe and was carried down into the water column resulting in an inaccurate reading of the top of groundwater. This may have resulted in calculating an apparent SPL thickness greater than actually existed. Great care was exercised during the measurement of SPL thicknesses to minimize such inaccurate readings.

3.2.7 SPL BAIL-DOWN TESTS

The measured SPL thickness is referred to as "apparent" thickness because the SPL in a well is usually thicker than in the surrounding formation. Therefore, bail-down tests were performed at 10 locations by CRA to estimate the actual thickness and volume of SPL present. The 10 locations are listed in Table 3.16. Also listed in Table 3.16 are 6 locations tested by other parties.

The bail-down tests were performed as follows:

i) the static depth to the top of the SPL and groundwater were measured;

ii) SPL was removed from the well using a bottom-loading bailer or peristaltic pump. If a bailer was used, it was lowered as close as possible to the bottom elevation of the SPL detected. If a peristaltic pump was used, the intake of the tubing was lowered to the same point. Clear discharge tubing was used to observe the fluids being pumped. This allowed the intake of the tubing to be adjusted as needed to minimize the removal of groundwater;

iii) SPL and groundwater depths were monitored continually;

iv) the removal continued until there was less than 0.1 foot of SPL remaining. The tubing was then lowered into the groundwater until the water had been drawn down approximately 1 foot; and

v) removal stopped and the SPL and groundwater were monitored at 2-minute intervals for a minimum of 20 minutes.

The evaluation of the bail-down tests is provided in Appendix T. As described in Appendix T, the SPL thicknesses in the formation is much less than the apparent thicknesses measured in the wells. The SPL thickness and volume estimates are further described in Section 5.10.

3.2.8 HORIZONTAL WELL PROFILING

One of the tasks of the SSD was to determine the vertical profile of the horizontal wells that had been installed by ESI as a component of the interim groundwater remediation for the Site. Although installed by ESI, records of the installation details had been lost (due to a fire) for all but the first four of the 12 horizontal wells that had been installed.

The vertical profiles for horizontal wells HW-1 through HW-4 were provided to PADEP in the CRA report entitled "Horizontal Well Design/Installation and Performance Report" dated October 2002. The profiles are repeated in Appendix U. Horizontal wells HW-5 through HW-8 and HW-10 through HW-12 were profiled as part of the SSD. In addition, HW-1 was profiled for comparison to the previous profile to assess the accuracy of the profiling method used. Profiling was performed by pulling a pressure transducer through each well, stopping at 10-foot intervals, and recording the pressure readings. The pressure readings were converted to depths below the water table and then converted to elevations using available groundwater monitoring wells. It is recognized that the groundwater level over the entire length of a horizontal well (up to 400 feet long), would not be in perfect alignment with the elevations measured at the neighboring wells. However, the data collected from these monitoring well locations were sufficiently consistent to assume that the groundwater elevations between these accessible monitoring points was relatively flat. Therefore, the straight line interpolation used between the monitoring wells was sufficiently accurate for the purpose of measuring the depth below the water table along the length of the horizontal wells.

To insure that the groundwater table was as flat as possible throughout the area prior to the pressure readings being taken, all of the pumps in the horizontal wells were turned off 2 to 3 days before the profiling was conducted. When the water table measurements in the neighboring wells stabilized, the profiling was initiated. The pressure transducer was pulled through each well using a draw wire which was installed in the wells when the wells were cleaned in June 2003. Following the pressure transducer profiling, an oil-water interface probe was pulled into the horizontal well to measure the exact distance to the fluid (SPL and/or water) to determine the starting location of the pressure readings.

It was not possible to profile HW-9 because a draw wire could not be inserted through HW-9 during the well cleaning. The cause of this was found to be a section of missing pipe. The HW-9 pump chamber area was excavated on October 10, 2003 to determine why there were difficulties reinstalling the horizontal pump tubing. It was at this time that it was identified that a section of pipe was missing immediately adjacent to the HW-9 pump chamber. The section of pipe was repaired on October 10, 2003. It is planned to install a draw wire in HW-9 the next time the well is cleaned.

The HW profiles are provided in Appendix U and showed the following:

Well	*Screened Interval (feet from South End)*	*Low Point(s) (feet from South End)*	*Maximum Depth of Submergence (feet)*
HW-1	60 to 290	250	1.6
HW-2	120 to 420	150 and 290	1.5 to 2.0
HW-3	50 to 310	120	5.0
HW-4	60 to 325	100 and 160	1.5
HW-5	50 to 270 (1)	170	3.8
HW-6	25 to 490 (1)	100 and 410	4.0 to 6.0
HW-7	20 to 170 (1)	70	4.9
HW-8	65 to 300 (1)	140	5.5
HW-10	40 to 440 (1)	260	13
HW-11	30 to 290 (1)	90	6.5
HW-12	40 to 190 (1)	80	3.0

(1) Submerged Interval

The comparison of the ESI and CRA profiles for HW-1 showed that the screened interval for the CRA profile ranges from approximately 2 to 5 feet higher in elevation than the ESI profile. As described in Appendix U, it is possible that this difference is due to the inaccuracy of the electromagnetic profile method used by ESI which was likely affected by the large amount of metal in the areas the HWs were installed.

3.2.9 FORMATION PUMPING TESTS

Pumping tests have historically been completed at the Site to determine the groundwater formation characteristics. However, the previous long-term pumping test wells were screened/sandpacked over the majority of the saturated depth of the unconfined aquifer. In comparison, the historic groundwater analytical data identified that most of the chemicals attributable to petroleum product releases from the Refinery are present in the upper portion of the aquifer. In order to better define the hydraulic characteristics of the upper portion of the unconfined aquifer, additional pumping tests were performed. This included:

i) testing of 3 vertical wells installed in the upper portion of the unconfined aquifer; and

ii) testing of 4 of the horizontal SPL collection wells.

3.2.9.1 PUMPING TESTS (VERTICAL WELLS)

Pumping tests were performed the weeks of September 15 and 22, 2003 on three conventional (vertical) wells in areas near the horizontal wells. The locations for these three wells (MW-108, MW-120, and MW-126) are shown on Figure 3.4. These new pumping test wells were installed outside of the limits of the SPL plume. However, during pumping for the tests, SPL was drawn to all 3 of the pumping wells with larger quantities observed at MW-108 and MW-120. The stratigraphic and well installation logs for the wells are provided in Appendix N. A summary of the well installation details is provided in Table 3.6.

The primary objectives of the pumping tests were:

i) to determine the aquifer's hydraulic conductivity, transmissivity, and storativity particularly at the elevation of the nearby horizontal collector wells; and

ii) to provide baseline hydraulic parameters that can be used to compare to results of testing the horizontal collector wells, in order to assess the well efficiency of the horizontal collector wells.

The methodology used for performing the pumping tests and the results are described in Appendix V and Section 4.3.2.2.2 of this SCR.

3.2.9.2 PUMPING TESTS (HORIZONTAL WELLS)

Pumping tests were performed the weeks of September 8 and 15, 2003 on four of the horizontal wells (HW-1, HW-4, HW-8, and HW-10). The locations of these four horizontal wells are shown on Figure 3.4.

The primary objective of the horizontal collector wells aquifer testing was to assess the efficiency of the wells in collecting SPL and to determine long term pumping rates per unit length of the collectors that maximizes SPL collection while minimizing groundwater collection.

The methodology used for performing the horizontal well pumping tests are described in Appendix V and in Section 4.3.2.2.2 of this SCR.

3.2.10 SURFACE WATER

Initial surface water sampling was conducted by CRA and flow rate measurements were simultaneously conducted by MACTEC in May 2005 in Tunungwant Creek, Foster Brook, Kendall Creek, Bolivar Run, and the un-named tributary in the CTF to aid in the site characterization. As described in Section 3.2, surface water samples were not collected until May 2005 because the flows in Tunungwant Creek were greater than 48.3 cfs throughout the entire period. This criteria was relaxed to 96.6 cfs on May 11, 2005 shortly after which these low flow conditions occurred (on May 19/20, 2005) allowing the surface water sampling event to occur. In accordance with the COA, surface water sampling was again conducted on August 22 and 23, 2006 by CRA.

The surface water samples for both events were collected at the locations where the macroinvertebrate survey was performed.

The samples were collected proceeding from downstream locations to upstream locations to eliminate possible interference with subsequent sample locations. Because of the relatively shallow depth of flow in the Creek, the samples were collected by inserting the capped sample container to mid-depth. At this depth, the sample container was opened to allow it to be filled.

In addition to sampling the surface water, a sample from the sewer that traverses beneath the Dresser Industries facility stormwater drain was also collected at the same time for comparison purposes. The discharge from the storm sewer was collected by placing the sample container directly in the discharge stream from the sewer, allowing the sample container to overflow for approximately 30 seconds.

The QA/QC reviews of the surface water results is provided in Appendix R. The reviews showed that the sample data were acceptable with the noted exceptions.

An extensive surface water flow measurement event was performed on May 19 and 20, 2005. A copy of the report entitled "Surface Water Flow Evaluation" dated June 17, 2005 was prepared by MACTEC and is included in Appendix AQ. Flow measurements were obtained from the following locations:

i) at or in close proximity to the 14 stations where the surface water sampling was performed including eight locations in Tunungwant Creek, two locations in Foster Brook, two locations in Bolivar Run, one location in Kendall Creek, and

one location in the un-named tributary in the CTF prior to discharging into Tunungwant Creek; and

ii) four outfalls.

The field data sheets are included in the MACTEC report. A summary of the measurements are shown on Figure 3.5 and listed in Table 3.17. It is noted in the MACTEC report that the flow of 0.04 ft^3/sec from the most upstream outfall was inadvertently not included when calculating the groundwater contribution. The results shown on Figure 3.5 have been corrected to account for this error. Also, the value for Station T-6 in Table 3.17 has been corrected to 79.7 ft^3/sec. The upstream and downstream flows in the second paragraph of Section 4.2 of the MACTEC report were reversed. However, the conclusion that Bolivar Run between the two measurement stations is an influent (losing) stream is correctly stated in the report.

3.2.11 SOIL-GAS

Four soil-gas boreholes were installed in the vicinity of one of the office buildings in the Main Refinery and one in the Foster Brook Facility as shown on Figures 3.1 and 3.3, respectively. Two gas probes were installed in each borehole for a total of 16 probes. In addition, a single soil gas probe (69 SG) was installed in the National Transit Property adjacent to well MW-133 (see Figure 3.2). Subsequent to submission of the draft June 2004 SCR, Shell installed two soil vapor probes (VP-1 and VP-2) in close proximity to the easternmost property (i.e., Strouss) on the south side of Bolivar Drive. The locations of the probes are shown on Figure 3.2.

The gas probes installed by Chemtura were constructed of 1-inch diameter PVC pipe with the bottom one-foot of the pipe perforated and wrapped with filter fabric. Two probes were installed in each borehole at depths of approximately 3 to 4 and 8 to 10 feet bgs. The borehole interval between the two probes was sealed with bentonite. Typical soil gas probe details are shown on Figures 3.6 and 3.7. The probe installation details are provided in Table 3.6.

Soil vapor samples were collected on October 29 and 30, 2003 from 3 of the 8 Chemtura probes around the Refinery Office in the Main Refinery Area and from 6 of the 8 Crompton probes around the Foster Brook Gasoline Loading office (see Table 3.18). A second set of air samples was collected from 3 of the 8 probes at the Foster Brook Gasoline Loading Office on March 18, 2004 for confirmation purposes. In addition, two samples were collected from probe 69 SG in the National Transit property near the

residential properties on March 18 and March 23, 2004. The remainder of the probes were not sampled due to groundwater presence in the probe, even after removal of the groundwater the day before sample collection. The soil vapor samples were shipped to Air Toxics Ltd. Lab in California for analysis.

Prior to soil-gas sampling, a minimum of 2 probe volumes of air were withdrawn from the probe. Purging was performed using a personnel sampler pump set at a rate of approximately 2.0 L/min. for approximately 1 to 2 minutes. After purging, the gas probe valve was closed, the pump tubing removed from the gas probe, and the 6-liter Summa Canister attached to the probe. The valve on the probe and then the valve on the canister were opened and the soil gas sample collected.

The analytical results from the samples and the QA/QC review are provided in Appendix W. The QA/QC review indicated that the results are acceptable without qualification. A summary of compounds detected is provided in Tables 3.19, 3.20, and 3.21 for the Main Refinery office, Foster Brook Facility office, and National Transit Property, respectively. The results for the vapor points (VP-1 and VP-2) installed by Shell are also provided in Table 3.21.

3.2.12 INDOOR AND AMBIENT AIR

As a follow up to PADEP's comments on the draft June 2004 SCR, a sample of the indoor air within the Gasoline Loading Office at the Foster Brook loading facility was collected on November 30, 2004. The air data show that the sample meets all OSHA criteria, however it exceeds the Act 2 non-residential standards (see Table 3.22). A sample of the outdoor ambient air which was taken at the same time also exceeded the Act 2 standard, but was below the OSHA standard. In order to intercept any soil gas build up beneath this occasionally occupied space, Chemtura performed an interim remedial action to provide a preferred outlet for any air or soil gas trapped underneath the building. The interim action included the installation of 4-inch diameter perforations in the 2-foot high concrete foundation walls supporting this building. Six perforations were installed through the concrete foundation walls (see Figure 3.8) and vent plates were installed over these perforations. The vents allow a direct air exchange between the outdoor air and the air space directly beneath the floor slab of the building. It is noted that the 2-foot space between the ground surface and the building floor is an open air space (this space was not filled with soil). Thus the air space beneath the building will now be the same as the ambient outdoor air.

The QA/QC review of these results is presented in Appendix W. The results were acceptable without qualification.

Further indoor air evaluation has been performed. As noted in Appendix AR, air sampling is to be performed in the occupied building located within each SPL area that has the greatest potential exposure. In summary, the on-site SPL areas identified in Appendix AR with occupied buildings are:

SPL-11 There are two continually occupied buildings in this area, the Crude Unit Control Room and the Instrument Shops;

SPL-12 There are three continually occupied buildings in this area, the Barrel House, the Refinery Office, and the Quality Control Lab;

SPL-20 There are two continually occupied buildings in this area, the Packaging Plant and the Graham Packaging building; and

SPL-22 There are three frequently to continually occupied buildings in this area, two Offices and the Storage structure.

ARG performed indoor air sampling in four of these buildings in June 2005. These were:

i) the Crude Unit Control Room located within the footprint of SPL-11 (samples A-5 and A-6 in Table 3.23);

ii) the Quality Control Lab located within the footprint of SPL-12 (samples A-3 and A-7 in Table 3.23); and

iii) the two occupied offices in Foster Brook facility located within the footprint of SPL-22 (samples A-9 and A-11 in Table 3.23).

These buildings were selected in consultation with an OSHA representative as being the most probable for exposure. The sample collection itself was conducted by Mr. C Tom DeLong, a CIH with the PA/OSHA Consultation Program.

The samples were collected in the employee's breathing zone using sampling methods validated by an accredited industrial hygiene facility. Calibrated sampling pumps were used (copies of the pump calibrations are maintained by PA/OSHA).

The detected analytical results show that the sample results were all below the applicable OSHA and ACGIH levels. The lab report pages for Sample A-9 are provided in Appendix W to show the list of parameters analyzed. The list includes the BTEX compounds and three isomers of trimethylbenzene.

In summary:

i) ARG has monitored the indoor air quality at those locations identified as being the most probable for exposure;

ii) these locations were selected in consultation with an OSHA representative;

iii) the samples were collected by an OSHA representative; and

iv) the sample results were all less than the applicable OSHA and ACGIH levels.

In consideration of this, it is believed that no further characterization of the indoor air quality for the occupied on-site structures is needed for this SCR.

3.2.13 DECONTAMINATION PROTOCOLS

Minimal decontamination of sampling equipment was required for well sampling because dedicated tubing was used at every monitoring well. As a precautionary measure, the flow-through cell and Horiba Water Quality Checker were decontaminated after each well as described in Section 3.2.1.4. The nitric acid and acetone rinses were omitted for these instruments in order to protect the delicate sensors.

For groundwater/SPL sampling, the PVC pipe was also cleaned with Alconox, tap water wash, and deionized water rinse. No solvents were used on the PVC pipe. The polyethylene sheeting and rubber band used to cover the bottom end of the PVC pipe were disposed after each well. Disposable bailers were used to obtain SPL samples, and were left in each well after each sample was taken.

Decontamination water and spend decontamination fluids were discharged to the on-Site groundwater treatment facility.

3.2.14 SURVEYING

The facility, landforms, topography, monitor wells, soil boring locations, and sampling points at the facility were surveyed by E&M Engineers and Surveyors PC, a surveyor licensed in Pennsylvania. The horizontal and vertical datums used were NAD-83 for Pennsylvania north zone and NGVD-29, respectively. Elevations were measured in feet, above mean sea level (amsl). Monitor wells were surveyed for elevation using the north side of the top of each casing or the high point of the casing if cut-off on an angle.

Horizontal datum is accurate to ±0.1 feet and vertical datum is accurate to ±0.01 feet. The ground surface contours are shown on Figures 3.9, 3.10, and 3.11.

As part of the survey work, each groundwater monitoring well on the Site was resurveyed to insure that all water level data collected is on a common and correct datum. In conjunction with this survey, CRA has confirmed the well information for each well and, where necessary, has reassigned well names to be consistent across the entire Site. The renaming was necessary to clarify previous naming convention changes that had occurred over the years of investigations.

3.2.15 PIPELINE INVESTIGATIONS UNDERGROUND AND ABOVEGROUND

Initial excavations began on February 26, 2004 to expose and examine abandoned underground pipelines. Additional excavations were performed in December 2005 and January 2006. The investigation was performed to determine the integrity of the abandoned pipelines, identify pipeline contents (if any), inspect the adjacent and underlying soils for visual impact, and verify the adequacy of the pipeline abandonment methods historically used. The locations of the test pits are shown on Figure 2.6.

In TP-1 and TP-2, two and four pipes, respectively, were exposed at a depth of approximately 12 inches bgs. In TP-1, two pipes were uncovered with outside diameters of 3 and 4 inches and spaced approximately 9 inches apart. In TP-2, four pipes were uncovered. The distance between the two outermost pipes in TP-2 was approximately 3 feet. The outside diameters of the pipes were, from east to west, 4, 3, 4, and 2 inches. Based on the information provided by ARG, these pipelines were abandoned refined product (diesel/kerosene, etc.) lines used to transfer product between the Main Refinery and the Foster Brook Facility. Because of health and safety concerns due to the higher volatility and flammability of refined products, these pipes were not drilled and tapped. The integrity of the pipes was observed to be good to very good with only surface rust and no visual observations of leakage (see photos in Appendix X).

The Duke Center pipeline, historically used to transfer crude oil from Duke Center, PA to the Foster Brook Facility and to the CTF storage tanks, was excavated (i.e., TP-3) on February 27, 2004. The 5.5-inch outside diameter pipe was located approximately 20 inches bgs. The pipe was drilled. Upon puncturing the inside of the pipe, a hissing sound was heard indicating the contents of the pipe were under pressure. After the air had vented, 8 ounces of water was removed from the pipe using a peristaltic pump and pumped into a clear glass jar for visual examination. The hole was plugged using a

tapered steel pin. The water was clear with no indication of product (i.e., sheen). The integrity of the pipe was observed to be very good (at least 1/4-inch thick where drilled). No visual impacts of leakage were observed in the soils adjacent to or underlying the pipe (see photos in Appendix X).

A crude oil pipeline, historically used to transfer crude oil from the CTF to the Main Refinery (i.e., TP-4) was excavated on March 11, 2004. ARG's records show that this pipe was abandoned in 1987. The 6-inch outside diameter pipe was located approximately 28 inches bgs. The pipe was drilled. Upon puncturing the inside of the pipe, water flowed from the pipe in a fountain-like fashion rising to a height of approximately 12 inches above the pipe (see photos in Appendix X). Eight ounces of the fluids were collected in a clear glass jar for visual examination. The water was very clear with minimal suspended solids. The integrity of the pipe was very good, with minimal surface rust. Because of the water flowing from the pipe, it was not possible to measure the pipe wall thickness. No visual impacts of leakage were observed in the soil adjacent to and underlying the pipe (see photos in Appendix X). The hole was plugged using a tapered steel pin.

A fifth abandoned pipeline (Bradford Transit Bypass) was examined on March 11, 2004. No excavation was needed because the pipe lies on the ground surface. Based on information provided by ARG, this pipe was used to transfer refined product between the Main Refinery and the Foster Brook Facility. The line was taken out of service in February 1997. Valves #82 and #83 were opened (see sketch in Appendix X) and the pipe cap at the south end of the aboveground pipe was removed to visually inspect the pipe. Inspection of the aboveground portion of this pipe shows it to be in good condition. Tapping on the segment on ARG property caused a hollow-ringing tone indicating there is no liquid in this section. Removal of a cap on the segment leading off-Site showed an oil product to be present in this section of the line.

A test pit was excavated in December 2003 by Northern Pipeline Co. to evaluate the condition of an abandoned 6-inch line (owned by Shell) traversing the National Transit Property. The location of the test pit (TP-5) is shown on Figure 2.6. During excavation, the 5-inch Duke Center line was also exposed. Based on information provided by Shell, the 5-inch line was in good condition and no contamination of the soils was observed. Shell's 6-inch line, which was intentionally punctured, did contain some crude oil.

During construction in October 2004 of the groundwater treatment plant located in the northeast corner of the Administration and Research Area (see Figure 2.5), five abandoned pipelines were exposed. The pipelines were tapped and found to contain a

small amount of water with a minor petroleum odor. No product was observed in the pipelines.

To determine if underground conduits through which pipelines pass are acting as preferential migration pathways for the SPL observed upgradient of the NT property and south of Bolivar Drive, 6 test holes were excavated in June 2005 at the locations shown on Figure 2.6. The test holes ranged in depth from 1 to 2 ft bgs. No staining or petroleum odor was observed at any of the six locations. The field sheet is included in Appendix X.

Another investigative activity involved the excavation, inspection, and tapping of the various pipelines that traverse the area along and beneath the railway tracks and Bolivar Drive. The locations for these five excavations (i.e., TP01-06, TP02-06, TP05-06, TP08-05, and TP10-06) are shown on Figure 2.6. At each of the five identified pipe-crossing locations, the pipes were exposed, the sleeve or carrier pipe in which the pipelines traverse the road/rail bed were exposed (if any), the soils surrounding the pipes were examined for the presence of oil products, and any observations of unusual characteristics were noted. Because of the high water in the test pits, it was not possible to extend TP01-06, TP02-06, TP05-06, and TP10-06 to the depth of the pipelines, although the groundwater and soil conditions in the vicinity of these pipelines was confirmed.

TP01-06

TP01-06 was completed on January 18, 2006. The location of the test pit was in the same vicinity as test pit TP-5 excavated in December 2003, and was excavated adjacent to the pipeline marker for the Rixford line. The test pit was hand dug and extended seven feet from north to south (straddling the location of the Rixford line). No pipelines were uncovered during the excavation due to the high water. The total depth of the hole was 44 inches (16 inches below the encountered water level). The soil was a grayish-brown silty-clay containing rocks, wooden branches, and bottles. There was a slight hydrocarbon odor in the soil but no staining was observed. No SPL was present in the soil or in the water and there was no sheen present on the water surface. One water sample was collected from the test pit and one sample of the darker gray soil was collected from the bottom-center of the test pit. The soil sample location is shown on the test pit log provided in Appendix X.

TP02-06

TP02-06 was completed on January 25, 2006. The original location of TP02-06 was within the railroad's restricted work zone and was therefore moved west to the first

accessible location (at the base of the embankment coming down from the railroad). The test pit was hand dug and extended six feet from north to south (straddling the location of the below grade line which passes adjacent to MW-NT33). The total depth of the hole was 38 inches (26 inches below the water level). No pipelines were uncovered during this excavation. Because of the shallow depth of the encountered water, it was not possible to extend TP02-06 to the depth of the pipelines. The upper soil consisted of gravel and vegetative debris (grasses, sticks, weeds, etc.) followed by brown silty-sands to 12 inches below the ground surface. From 12 to 38 inches, the soil was gray sand with silt, cobbles, and gravel. No indicators of SPL were observed in the soil or in the water. There were no odors and there was no sheen on the water surface. One water sample was collected and one soil sample was collected from the bottom-center of the test-pit. The soil sample location is shown on the test pit log provided in Appendix X.

TP05-06

TP05-06 was completed on January 26, 2006. The location of TP05-06 is at the mouth of the surface water culvert running below Bolivar Drive as it discharges to the south. The test pit was hand dug and was approximately 1 foot by 1 foot within the ditch. No pipelines were uncovered during the excavation. The total depth of the test pit was 24 inches (16 inches below the encountered water level). The upper soil consisted of gravel with some vegetative debris to 8 inches below the ground surface. From 8 to 24 inches the soil was black silt with sand and gravel. No SPL was present in the soil or in the water and there were no odors. There was some sheen present on the water and soil surfaces. One water sample was collected from the test pit and one soil sample exhibiting a slight sheen when wet was collected from the bottom-center of the test pit. The high rate of water infiltration and a confined area for digging made it impractical to excavate to a sufficient depth to uncover the pipelines.

TP08-05

TP08-05 was completed on December 14, 2005. The location of TP08-05 is at the mouth of the surface water culvert running below Bolivar Drive at the point of entry on the north side of the road. The location of TP08-05 was selected with the concurrence of PADEP during the on-site meeting of November 1, 2005. The test pit was hand dug, approximately 4.5 feet across the ditch, extending from the property line (to the east), to the base of the embankment of the railroad tracks (to the west). The 5-inch crude oil pipeline was uncovered during the excavation (at a depth of approximately 28 inches). The pipe was observed to be in good condition. Because this pipeline had been tapped in February 2004 and found to contain only air and water (see Section 2.2.2), this pipeline was not tapped at this location. The total depth of the test pit was 46 inches

below the ground surface (36 inches below the encountered water level). The soil consisted of brown silty-clay, with rocks, bricks, etc. There was a six inch pocket of gray sand surrounding the 5-inch crude oil pipeline. The sand exhibited a slight hydrocarbon odor. No SPL was present in the soil or the water and there were no odors (other than from the soil adjacent to the pipeline). There was some sheen present on the water surface. One water sample was collected from the test pit, and one soil sample was collected from the soil surrounding the pipeline. The soil sample location is shown on the test pit log provided in Appendix X.

It is noted that if SPL had been observed in TP08-05, two additional test pits were to be excavated; TP06-06 located west of TP08-05 and TP09-06 located north of TP08-05. Because SPL was not present in TP08-05, these test pits were not excavated.

TP10-06

TP10-06 was completed on January 24, 2006. The location of TP10-06 is north of Bolivar Drive, down the embankment from the road, and directly across from where the abandoned refined product lines go underground. The test pit was hand dug and approximately 6.5 feet long running east to west, straddling the pipelines where they run below grade. No pipelines were uncovered during the excavation. The total depth of the hole was 66 inches below the ground surface (18 inches below water level). The upper soil consisted of dark brown sand, with gravel, brick and some vegetative debris to 3 inches below the ground surface. From 3 to 46 inches, the soil was dark brown silty sand. From 46 to 48 inches, the soil was light brown sand. From 48 to 66 inches, the soil was light to dark gray sand. No SPL was present in the soil or in the water. There were no odors and there was no sheen present on the water surface. One water sample was collected and one soil sample of the darker gray soil was collected from the bottom-center of the test pit. The soil sample location is shown on the test pit log provided in Appendix X. Soil stability issues prevented extending the test pit to the depth of the pipelines.

The analytical results confirm that there is no SPL present along the alignment of any of the pipelines. In fact, the saturated soil analytical results for TP01-06, TP02-06, TP05-06, and TP10-06 had no exceedances of the SHS MSCs except for arsenic (26 mg/kg in TP01-06) and lead (67 mg/kg in TP01-06 and 169 mg/kg in TP05-06) compared to their SHSs of 15 and 45 mg/kg, respectively. The results for the saturated soil samples collected from previous investigations show maximum arsenic and lead concentrations of 15.3 and 18 mg/kg, respectively. This comparison shows that these metals are present in the test pit soils at concentrations only slightly higher than the overall area.

With regard to water in the test pits, the following exceedances were detected:

Parameter	*SHS (mg/L)*	*Test Pits Max. Conc. (mg/L)*	*Location*	*B&P Railroad Max. Conc. (mg/L)*
Iron	0.3	27.8	TP01-06	47
Manganese	0.3	3.04	TP10-06	3.8
1,2,4-TMB	0.035	0.098	TP10-06	0.96
1,3,5-TMB	0.035	0.078	TP01-06	0.48
Benzene	0.005	0.017	TP01-06	0.23

The above results show that two metals and three VOCs had SHS exceedances in the test pit waters. The maximum concentrations for groundwater samples collected south of Bolivar Drive and in close proximity to the B&P Railroad property are also provided above. These results show that the test pit water maximum concentrations are less than the maximum concentrations previously detected in this portion of the B&P Railroad property. Thus, no relationship to the pipelines can be established for these concentrations.

As an additional check regarding the status of the abandoned refined product pipelines running beneath Bolivar Drive, the 3 and 4-inch diameter pipelines were opened on March 27, 2006. The pipelines were opened in the Foster Brook Facility just before they go underground in the vicinity of TP10-06. Photographs of the opened pipelines are provided in Appendix X. At the point of access, the pipes were empty. An interface probe was used to check for water and/or SPL presence further down along the pipes. The probe was lowered to depths of 3.5 and 4.5 feet below the top of the flange in the 3 and 4-inch pipelines, respectively at which point it was not possible to further lower the probe. At these depths, it is believed that a 90 degree bend is present which changes the pipe direction from vertical to horizontal.

Both the 3-inch and 4-inch diameter pipelines were dry at 3.5 and 4.5 feet below the flange, respectively and no liquid was observed on the probe when retrieved from either pipeline. ARG stated that they found a record of the 3-inch diameter pipeline being abandoned. However, the record does not specifically state whether the pipeline was drained and/or flushed.

On March 28, 2006, underground sections of these same two pipelines were uncovered and tapped on the south side of Bolivar Drive at the location shown on Figure 2.6. Field ties are provided in Appendix X. The pipelines were located at a depth of 1.5 feet below

the ground surface. The soil in the excavation was stained. The 3-inch diameter pipeline was full of clean water. The 4-inch diameter pipeline was initially one-quarter full of clear water, but when pumped, the water developed a yellow tint and had a strong hydrocarbon odor. No sheen was present. After sitting overnight in a clear glass jar, the water was clear and there was a yellow/orange sediment present in the bottom of the jar.

3.2.15.1 1991 CRUDE OIL PIPELINE SPILL

The final phase of the pipeline investigation program was to investigate the area around the reported 1991 Crude oil pipeline spill. The spill apparently accumulated in the low lying area immediately north of Bolivar Drive and east of the railroad tracks.

The Off-Site SPL Work Plan had specified that investigation be undertaken at two separate locations in this area; one for the spill area and one for the pipeline. Upon examination of the field conditions by PADEP and CRA personnel on November 1, 2005, it was readily apparent that any accumulation of oil from the pipeline spill would accumulate in the depression formed by the elevated ground surfaces of the surrounding features (Bolivar Drive and the railroad). Thus, any SPL release would accumulate in the depression which lies immediately above the location of the 5-inch Duke Center pipeline. As a result, only one excavation was necessary to address both of these locations.

The location of the test pit (TP8-05) was set in the only available location between the steep road bank to the south, the MCI telephone line to the north, and the railroad embankment to the west. No SPL was observed and no odor was present except in the soil immediately adjacent to the exposed pipeline.

Based on 2005 testing, the SPL in SPL-CC01 can be described as:

i) petroleum products consisting of carbon chains in the C6 to C42 range, mainly in the C9 to C13 and C24 to C28 ranges;

ii) specific gravity of 0.857; and

iii) a viscosity ranging from 7.53 to 8.12 centipoise (cp).

The chemical data for the supplemental samples collected in 2005/2006 show that the saturated soil analytical results for TP08-05 had no exceedances of SHS MSCs except for lead at 49 mg/kg (SHS = 45 mg/kg). Furthermore, the analytical results for the soil

samples analyzed from SB-12 (approximately 25 feet north of TB08-05), SB-13, or SB-14 (ref. Table 5, and Figure 2, Custer City Oil SCR, January 2002), which are all located within or in close proximity to SPL-CC01, had no exceedance of an SHS. SB-12 is located between the area of the 1991 crude oil spill and SPL-CC01. No SPL was observed in either TP08-05 or SB-12. Thus, this supports that the 1991 crude oil pipeline spill has not contributed SPL in SPL-CC01.

With regard to test pit water, the following exceedances were detected in the test pit water collected from TP08-05:

		Max. Concentration	
Parameter	***SHS (mg/L)***	***TP08-05 (mg/L)***	***GP-CC-1 (mg/L)***
Manganese	0.3	0.35	NR
Benzo(a)anthracene	0.0036	0.099	ND0.002
Benzo(a)pyrene	0.0002	0.088	ND0.0006
Benzo(b)fluoranthene	0.0012	0.11	NR
Benzo(g,h,i)perylene	0.00026	0.049	ND0.00057
Benzo(k)fluoranthene	0.00055	0.042	ND0.00065
Chrysene	0.0019	0.10	ND0.0018
Dibenz(a,h)anthracene	0.00036	0.015 J	NR
Indeno(1,2,3-cd)pyrene	0.0036	0.052	ND0.002

Note:

NR - Not Reported in Custer City Oil SCR, January 2002

The test pit water results show exceedances for one metal and eight PAHs. No VOCs exceeded their groundwater SHSs. For comparison, the results for well GP-CC-1 which is located approximately 25 feet north of TP08-05 and in close proximity to the area of the 1991 Crude Oil Spill, are also provided. The results show higher concentrations in the area of TP08-05, thus indicating some potential residual impact to soil from the 1991 Crude Oil Spill in the area of TP08-05. The pattern of lower groundwater concentrations in GP-CC-1 combined with the groundwater flow direction of east to west further supports that the 1991 crude oil pipeline spill has not contributed to SPL-CC01.

Taking into consideration the following factors, it is concluded that the area of the 1991 crude oil spill has been adequately characterized:

i) the large number of monitoring wells in close proximity to the area of the 1991 pipeline release;

ii) the 1991 release has not contributed SPL in SPL-CC01;

iii) the 1991 release has not contributed to the SPL in MW-NT33;

iv) the remedial actions implemented shortly after the spill occurred adequately addressed the release;

v) the results of the February 2004 pipeline investigation confirmed that the pipeline no longer contains crude oil; and

vi) the results of the 2005/2006 test pits in which no SPL was observed.

3.2.16 MACROINVERTEBRATE SAMPLING

Twenty-seven benthic macroinvertebrate samples were collected the week of September 8, 2003 from locations selected on September 8, 2003 in consultation with on-Site PADEP representatives. Due to Site specific conditions encountered at the time of the sampling, some of the sample locations were slightly adjusted from those presented in the SSD Work Plan. The samples were collected using methods consistent with PADEP-RBP Benthic Macroinvertebrate Sample Collection and Processing Methodology for Cause/Effect Surveys. That is, macroinvertebrates were collected from riffle areas with a standard D-net (mesh size 500 microns). Basically these methods include two kick samples during a standardized period at each stream station in a riffle/run habitat to collect a minimum of 200 organisms per station.

All organisms were preserved in the field with 70 percent ethanol and placed in an appropriate container. These samples were then delivered to Normandeau Associates (a qualified taxonomic laboratory in Spring City, PA) for identification and counting. Each sample bottle was labeled internally and externally. Samples and check samples were preserved following taxonomic identification. Following taxonomic identification and counting, a biometrics assessment in accordance with RBP Protocol was conducted. The results of the macaroinvertebrate sampling is presented in the Screening Level Ecological Risk Assessment (SERA) report that has been prepared for this Site. The SERA is being submitted under separate cover to PADEP.

3.2.17 WETLAND DELINEATION AND HABITAT CHARACTERIZATION

The field surveys to delineate the wetlands and characterize the ground surface habitat were performed by CRA's ecological group. The results and assessment thereof are presented in the SERA Report. The SERA is being submitted under separate cover to PADEP. E&M Engineers and Surveyors PC performed an accurate areal survey of the delineated wetland areas.

3.2.18 INTEGRITY OF WELL MW-CR19

A concern existed with respect to the integrity and/or monitoring point elevation for well MW-CR19 because the historic fluid levels measured in this well were typically lower than the surrounding wells. A field check of the well identified:

i) well is closed with an expandable J-plug cap;

ii) the surface casing and casing seal were observed to be secure;

iii) the well riser pipe has no kinks, bends, or obstructions and appears to be structurally sound; and

iv) based on probing to depth, no significant infilling of the well has occurred.

Furthermore, no ground settlement around the well was observed which supports that the integrity of the well is sound.

The measuring point elevation previously used was 1422.48 ft amsl. The elevation resurveyed in 2004 was 1422.94 ft amsl, a difference of 0.46 feet. Following the application of this correction factor, the April and December 2003 rounds of groundwater levels show that a "sink" is not present in the area of MW-CR19 (see Figures 4.8b and 4.9b). Thus, the previous surveyed measuring point elevations likely caused the appearance of a groundwater "sink" in this area.

3.2.19 GROUND SURFACE CHARACTERISTICS

The entire Site was visually surveyed to determine the ground surface characteristics. For this survey, the ground surface was subdivided into one of the following categories:

i) low permeable cover (e.g., asphalt and concrete in good condition);

ii) permeable cover (e.g., asphalt and concrete in poor condition, gravel, sand, etc.);

iii) vegetated (e.g., grass, shrubs, trees, etc.);

iv) buildings and tanks; and

v) lagoons.

The areas identified are shown on Figures 3.12, 3.13, and 3.14 for the Main Refinery, Crude Tank Farm/Packaging Plant, and the Foster Brook Facility, respectively.

In summary, the area for each of the above ground surface characteristics for each Exposure Unit are:

Exposure Unit	*Ground Surface (acres)*				
	Low Permeable	*Permeable*	*Vegetated*	*Buildings/ Tanks*	*Lagoon*
EU-1 (Main Refinery)	9.2	11.7	0	6.6	0
EU-2 (Administration/Research)	2.9	0	2.2	0.75	0
EU-3 (Crude Tank Farm)	0.03	11.7	5.2	0.89	0
EU-4 (Foster Brook Facility South)	3.3	11.2	11.5	2.3	0.19
EU-5 (Foster Brook Facility North)	21.2	0	0	0	0
EU-6 (Packaging Plant)	1.4	4.5	0	2.9	0
EU-8 (National Transit Property)	0.05	1.0	5.7	0.33	0

Exposure Unit-7 is Tunungwant Creek and its tributaries which traverse the Site. An area for EU-7 was not calculated.

3.2.20 HANDLING OF INVESTIGATION DERIVED WASTES

All decontamination waters were discharged to ARG's API separator for treatment by ARG prior to discharge to Tunungwant Creek. All well development, purging, horizontal well cleaning, and pumping test fluids were discharged to either the MEK Area or Dubbs Area API separators for treatment prior to discharge to Tunungwant Creek. The flow rates were monitored to insure that the combined volume along with the groundwater being pumped by the horizontal and vertical wells did not exceed the permitted 66 gpm discharge rate to ARG's treatment facility.

SPL collected during the investigation was discharged to either Crompton's oil/water separator or ARG's Tank 109 for re-use in the refinery.

Solids generated by decontamination activities, including the polyethylene lining from the decontamination pad, were placed into DOT-approved drums. All of these wastes were sent off Site for disposal at a regulated facility.

Sample tubing, gloves, and other miscellaneous wastes were placed into plastic garbage bags and placed into an ARG rolloff designated for sanitary landfill waste.

Soils generated from boreholes and monitoring well installations were placed into 55-gallon DOT-approved drums. These soils were disposed at an appropriate off-Site facility.

4.0 ENVIRONMENTAL SETTING

4.1 CURRENT LAND USES, PHYSIOGRAPHY, CLIMATE, TOPOGRAPHY, HYDROLOGY, AND WATER USE

4.1.1 CURRENT LAND USE

The majority of the Site consists of industrial land. Industrial lands extend from the southern boundary of the Site north to Foster Brook, except for two residential buildings located on the south side of Bolivar Drive. It is noted that both these buildings are currently being used for commercial purposes. North of Foster Brook, the Site consists of vegetated undeveloped land. Other developed land uses adjacent to the Site consist of residential, commercial, and industrial land use. Residential, commercial, and industrial areas are predominantly located east of the Buffalo & Pittsburgh Railway system and south and west of the Site south of Mill Street. Residential and commercial areas are also present west of the Packaging Plant.

4.1.2 PHYSIOGRAPHY

The City of Bradford is located in the Deep Valleys Section of the Appalachian Plateaus Physiographic Province. The Deep Valleys Section is characterized by deep, steep-sloped valleys separated by uplands. Bedrock is commonly exposed or buried under a thin mantle of soil in the valley walls. The valley bottoms are commonly filled with glacially-derived sediments.

4.1.3 CLIMATE

The City of Bradford experiences a humid continental type climate, characterized by large annual and daily temperature changes.

Precipitation data for the period from 1971 to 2000 from the Bradford Airport were reviewed. The annual average precipitation is approximately 47 inches. The mean monthly precipitation data are presented on Figure 4.1.

Regional precipitation runoff data for McKean County suggests that average annual runoff is approximately 20 to 25 inches (USGS, 1997). Evapotranspiration for McKean County in the north-central portion of Pennsylvania, where elevations are higher and temperatures are lower, is estimated to be approximately 15 inches annually (Fleeger, 1999). Therefore, annual regional groundwater recharge is estimated to be

approximately 7 to 12 inches. A greater amount of groundwater recharge is expected where the bedrock valley walls intersect the overburden in-filling the bedrock valley due to increased run-off from upland areas where only a thin veneer of soil covers the bedrock, if any, and infiltration/evapotranspiration would be reduced.

Within the City of Bradford, urban development including stormwater control, greatly reduces infiltration by increasing runoff. Similar storm water controls are present at the Site, including ditching and catchbasins that collect and direct storm water off Site, reducing local infiltration to the water table.

4.1.4 TOPOGRAPHY

Topographic relief in the vicinity of the Site is significant, with the valley floor at elevations of approximately 1,410 to 1,450 feet above mean sea level (AMSL). The valley walls rise 600 to 800 feet above the valley floor to the uplands, found at elevations of approximately 2,000 to 2,300 feet AMSL. The valley floor is flat bottomed, approximately 2,500 to 4,000 feet wide.

4.1.5 HYDROLOGY

The City of Bradford is located in the Tunungwant Creek Valley. Tunungwant Creek flows northward through the City of Bradford, and bisects the Site. Approximately 1,500 feet upstream of the Site (south), Tunungwant Creek is split into two branches, the East Branch and the West Branch. There are three man-made reservoirs along the West Branch and tributaries to the West Branch of Tunungwant Creek.

The Tunungwant Creek drainage basin upstream of the City of Bradford encompasses approximately 138 square miles. In the vicinity of the Site, four small tributary streams (Kendall Creek, Bolivar Run, Foster Brook, and the un-named tributary in the CTF) flow into Tunungwant Creek. These tributary streams are also deeply incised, and flow from the nearby uplands to Tunungwant Creek except for the unnamed tributary which begins in the CTF. As described in Section 2.5, the banks of Tunungwant Creek have undergone stabilization and significant modification, with sheet pile and concrete flood control walls along sections of the creek, including within the Main Refinery portion of the Site.

A USGS surface water gauging station 030109560 is located adjacent to the southern end of the Foster Brook Facility (see Figure 3.3). The gauge is located on the off-ramp from

State Route 219 to Bolivar Drive and is identified as "SG-USGS" on the Site figures. Surface water flow rates measured at this gauging location during the period October 2000 to September 2001 range from a low of 14.7 cubic feet per second (ft^3/sec) (August 2001) to a high of 535 ft^3/sec (April 2001). The seven-day low flow with a recurrence interval of 2 years is 24 ft^3/sec and with a recurrence interval of 10 years(i.e., 7Q10) is 16.1 ft^3/sec (Page and Shaw, 1977).

Surface water flow rate measurements were obtained in September 2003 for Tunungwant Creek at Station 1 (upstream of the Site) and SG-USGS (immediately south of the Foster Brook Plant), and for Kendall Creek and Bolivar Run prior to discharging to Tunungwant Creek. A surface water stage measurement was also obtained in December 2003 from SG-USGS and this measurement was converted to flow using stage/flow chart provided by PADEP. The measured surface water flow rates are presented below.

Station	*Flow Rate* (1) *(ft^3/sec)*	*Date*
Tunungwant Creek at SG-USGS	98.7	Sept. 8, 2003
Tunungwant Creek at Station 1	68.0	Sept. 10, 2003
Kendall Creek	6.1	Sept. 10, 2003
Bolivar Run	1.0	Sept. 10, 2003
Tunungwant Creek at SG-USGS	350	Dec. 18,2003

Note:
(1) Flow rate measured using a flow meter.

The surface water flow rate for Tunungwant Creek at Station 1 represents the sum of groundwater discharge (i.e., baseflow), surface water runoff, and inflows from tributaries occurring upgradient of the Site. The flow rate for Tunungwant Creek at SG-USGS represents the flow measured at Station 1 combined with the groundwater discharge occurring between Station 1 and SG-USGS, the surface water flow from Kendall Creek, Bolivar Run, the un-named tributary, and surface water runoff and storm sewer/outfall discharge between Station 1 and SG-USGS. There are six outfalls associated with the Site and several storm sewers associated with the municipal storm sewer system.

The most recent rainfall event prior to measuring the surface water flow rates occurred on September 3 and 4, 2003, when approximately 0.6 inches of precipitation fell in the Bradford area. The surface water depth, or stage, at SG-USGS was measured to decline from 1.96 to 1.84 feet from September 8 to 11, 2003. The declining stage indicates a reduction in surface water flow demonstrating that surface water flow in the Creek was

being influenced by runoff from the September 3 and 4, 2003 rainfall event when the surface water flow rate measurements were obtained. As a result, the flow rate measurements are not directly comparable. The flow rate measured at SG-USGS on September 8, 2003 (4 days following the rainfall event) reflects a greater amount of surface water runoff than the flow rates measured at the other three locations on September 10, 2003 (6 days following the rainfall event). However, the flow rate measurements can provide an approximate indication of the amount of groundwater discharge occurring to Tunungwant Creek in the Site area, as described below.

The difference in the flow rate measurements between Station 1 and SG-USGS less the surface water flow contributed by Kendall Creek and Bolivar Run is 23.6 ft^3/sec. This difference (23.6 ft^3/sec) represents the groundwater discharge to Tunungwant Creek occurring between Station 1 and SG-USGS, and contributions from surface water runoff and discharge from storm sewers/outfalls. As described above, the surface water flow rate measured at SG-USGS on September 8, 2003 reflects surface water runoff from the September 3 and 4, 2003 rainfall event. Considering the significant degree of ground covered by impermeable surfaces in the Site area (i.e., buildings and roadways), it would be reasonable to attribute approximately 50 percent of the 23.6 ft^3/sec to surface water runoff. This provides an approximate estimate of the groundwater discharge to Tunungwant Creek occurring between Station 1 and SG-USGS of roughly 10 ft^3/sec.

When compared to the 7Q10 of 16.1 ft^3/sec for Tunungwant Creek at Bradford, the estimated groundwater discharge of 10 ft^3/sec is considered to overestimate the groundwater discharge that actually occurs. The 7Q10 can be considered to represent strictly baseflow derived from groundwater discharge. The 7Q10 of 16.1 ft^3/sec at Bradford represents the cumulative groundwater discharge occurring over the approximate 9-mile length of Tunungwant Creek upstream of Bradford. The distance between Station 1 and SG-USGS is approximately 1.5 miles, approximately 17 percent of the Creek length upstream of Bradford. Reducing the 7Q10 to a groundwater discharge rate per mile of Creek provides an estimate of the groundwater discharge occurring over the 1.5 miles between Station 1 and SG-USGS of 2.7 ft^3/sec. This is considerably less than the groundwater discharge rate of 10 ft^3/sec estimated from the surface water flow rate measurements.

The estimated groundwater discharge rates described above are considered in the development of the groundwater flow model for the Site presented in Appendix AK.

A more accurate assessment of surface water and groundwater interaction was performed on May 19 and 20, 2005. At that time, the flow in Tunungwant Creek was less than 6 times the 7Q10 flow. In conjunction with this low flow condition, surface

water samples were collected and a surface water measurement campaign was conducted.

A detailed evaluation of the May 19 and 20, 2005 surface water flow condition is presented in the June 2005 MACTEC report entitled "Surface Water Flow Evaluation". In summary, the evaluation showed:

i) that the flows measured on May 19 and 20, 2005 were base flows (i.e., groundwater) because no significant precipitation had occurred for at least one week prior to the measurements;

ii) the flow rate measured in the vicinity of the SG-USGS gage (i.e., 96.4 ft^3/sec) was consistent with the interpolated flow rate based on the gage reading (i.e., 95.3 ft^3/sec);

iii) the groundwater contribution as measured between the upstream measurement station (T-8 - just downstream of the confluence of the east and west branches of Tunungwant Creek) and the downstream measurement station (T-2 - 150 feet upstream of the confluence of Foster Brook with Tunungwant Creek) was 5.93 ft^3/sec;

iv) the surface water contributions into Tunungwant Creek at the Site were as follows:

Kendall Creek - 8.97 ft^3/sec,

Unnamed tributary in Crude Tank Farm - 0.03 ft^3/sec,

Bolivar Run - 2.83 ft^3/sec, and

Foster Brook - 7.67 ft^3/sec.

Given the flow conditions measured on May 19 and 20, 2005, it is possible to further refine the base flow conditions that would most likely be expected during a 7Q10 event. Again, it would be expected that groundwater flow conditions at the Site under 7Q10 conditions would be directly proportional to the conditions measured under the May 19 and 20, 2005 conditions (both conditions are under base flow conditions with no impact from precipitation). Using straight proportioning, and the conditions experienced on May 19 and 20, 2005, the 5.93 ft^3/sec of groundwater flow constitutes 6.1% of the 96.84 ft^3/sec Creek flow. Proportionally, for a 7Q10 base flow of 16.1 ft^3/sec (as measured at the SG-USGS near Station T-3), the expected groundwater flow from the Site would be on the order of 0.99 ft^3/sec.

Thus, a discharge of 1.0 ft^3/sec is the best estimate of groundwater flow from the Site into Tunungwant Creek and the portions of its tributaries that traverse the Site under

7Q10 flow conditions. This value will be carried forward for use in estimating chemical loadings from the Site for 7Q10 flow conditions.

4.1.6 WATER USE

Potable water is supplied by the Bradford City Water Authority to the developed areas of the City of Bradford and Foster Township. The source of the potable water is three man-made reservoirs along the West Branch or tributaries to the West Branch of Tunungwant Creek.

The City of Bradford Ordinance No. 2956.1 (copy included in Appendix AA) requires that the "owner of any improved property abutting upon the water system shall connect such improved property with and shall use such water system for both potable and non-potable water use...". It is noted that a few years ago, the City of Bradford purchased the rights to supply Foster Township with water. To confirm that the Township has no separate ordinance, they were contacted by phone on September 17, 2004 and a CRA representative was verbally informed by the Township that they do not have a separate ordinance.

It is noted that pursuant to the City ordinance, unless the City notifies (i.e., directs) the property owner to connect to the City supply, such a connection may not occur. However, the probability of groundwater use beneath and downgradient of the ARG refinery is low because:

i) the Plant does not use groundwater for any purpose and has no plans to do so;

ii) Tunungwant Creek and its tributaries through the refinery are the receptors of all groundwater flowing beneath the refinery;

iii) a large portion of the refinery abuts Tunungwant Creek and its tributaries. Thus these areas are not subject to groundwater use;

iv) for the portions of the refinery that do not abut Tunungwant Creek, the properties located between the Refinery and Tunungwant Creek are commercial/industrial. There are no residential properties;

v) the groundwater is high in naturally occurring iron and manganese which makes the groundwater undesirable for human consumption; and

vi) a piped water supply is available. Combined with item v above, this makes use of the groundwater even more undesirable.

To confirm item i), inquiries were made of ARG personnel in May 2005. They confirmed that there is currently no groundwater use, except for monitoring and remediation purposes, on the refinery property.

Based on the above, it is believed highly unlikely that the groundwater beneath the refinery or in any impacted area downgradient of the refinery will be used.

Information regarding the permitted groundwater withdrawals in the vicinity of the Site were obtained from PADEP. A map showing the locations of the withdrawals is included in Appendix AA. There are six groundwater withdrawal permits within the area, and only one within 1,000 feet of a Point of Compliance for the Site (i.e., for Werzalit of America Inc.). The Werzalit site (40 Holley Drive) is located north of the Erie Wye portion of the Main Refinery, north of Kendall Avenue and west of Tunungwant Creek. The water from this well is not used for drinking water or agricultural purposes. No record of groundwater withdrawal rates was available.

Also included in Appendix AA is a figure showing the location of the reservoirs which supply potable water to the City of Bradford. No groundwater wells are used as a community water supply source and no Zone-2 wellhead protection areas are present within the limit defined as:

i) 1,000 feet from the POCs for the Site do not intersect a radius of 0.5 miles from a community water supply well; and

ii) 1,000 feet from the POCs for the Site do not intersect any area designated by PADEP as a Zone-2 wellhead protection area under Chapter 109.

As is described further in Sections 9.2 and 9.5, groundwater pumping through both vertical and horizontal extraction wells, respectively, occurs in the Main Refinery area in conjunction with the remedial activities implemented at the Site. The locations of the vertical and horizontal extraction wells are presented on Figure 9.1. The vertical extraction wells are screened to approximately 10 feet below the water table, and the horizontal extraction wells are located slightly below the water table. A detailed profiling of the horizontal extraction wells is presented in Appendix U. Estimates of the average vertical and horizontal extraction well pumping rates occurring in December 2003 are presented in Appendix AK (Groundwater Flow Model Development).

4.2 GEOLOGIC CONDITIONS

4.2.1 REGIONAL GEOLOGY

4.2.1.1 BEDROCK GEOLOGY

The bedrock formations in the vicinity of the Site, in descending order, include (Socolow, 1980):

i) Pottsville Group (Pennsylvanian age) - predominantly gray sandstone and conglomerate, thin shale, claystone, limestone, and coal beds;

ii) Shenango Formation through Oswayo Formation (undivided) (Mississippian and Devonian age) - green-gray, olive, and buff sandstone and siltstone, and gray shale;

iii) Catskill Formation (Devonian age) - grayish - red sandstone, siltstone, and shale, some gray sandstone and conglomerate;

iv) Venango Formation (Devonian age) - light gray siltstone and blue-gray shale, some gray sandstone; and

v) Chadakoin Formation (Devonian age) - light gray and brown siltstone and sandstone, and medium gray shale, oil bearing in part.

Based on Socolow's geologic map (1980), the bedrock exposed near the Site and the bedrock underlying the Site are composed of the Chadakoin Formation. The remaining overlying formations are exposed or subcrop in the valley wall and upland areas.

Beneath the Chadakoin Formation are older geologic units, the Giraud Shale and Northeast Shale. These units have also been referred to by other names, including the Conneaut Group, "Chemung", and Canadaway Formation. The oil-bearing zones in the Bradford Field occur primarily in the "Bradford Third", found in the Canadaway Formation (Northeast Shale).

4.2.1.2 STRUCTURAL GEOLOGY

The regional structural geology consists of a series of widely spaced shallow plunging anticlines and synclines that trend northeast-southwest. A syncline is located beneath the City of Bradford trending approximately parallel to and beneath the West Branch of Tunungwant Creek.

The bedrock units are fractured as a result of the folding of the formation that has occurred. Major fractures in the bedrock tend to be approximately parallel to and perpendicular to the northeast-southwest structural trend.

4.2.1.3 OVERBURDEN GEOLOGY

The overburden deposits filling the Tunungwant Creek valley consist of various glacially-derived materials. These deposits vary from coarse sand and gravel outwash deposits to glacial lake silts and clays and are termed stratified drift. In the vicinity of the Site, the overburden generally consists of (in descending order):

i) alluvium and fill;

ii) sand and silty sand, and silty sand and gravel;

iii) clay;

iv) sand and gravel;

v) clay;

vi) sand and gravel; and

vii) bedrock.

The depths and thicknesses of these units can vary considerably along the infilled valley, and vary laterally due to bedrock subcrops and historical positions of glaciofluvial channels.

The base of the Tunungwant Creek buried channel is approximately 180 feet below ground surface at Custer City, located 6 miles south of Bradford, and is approximately 250 feet deep at the Foster Brook Facility. The base of the buried channel slopes approximately 24 feet per mile northward while the surficial deposits slope approximately 12 feet per mile northward, giving an overall thickening of the overburden deposits of approximately 12 feet per mile northward.

4.2.2 SITE GEOLOGY

4.2.2.1 BEDROCK GEOLOGY

Bedrock was encountered at a limited number of locations including five on-Site borings (two deep and three shallow) and two borings at the Custer City Oil site. Bedrock

fragments were observed at three borings on the National Transit Property, which are not indicative of bedrock presence at these locations. The exposure of bedrock at ground surface is common along the west and east flanks of the valley, such as along S.R. 219 at the Kendall Avenue exit, close to the Main Refinery, and in the road-cuts east of the Foster Brook Facility.

Bedrock was encountered at two deep on-Site borings, as described below:

i) BW-301 (nka EMW-40, Main Refinery - Crude Unit) - bedrock at 177 feet bgs, elevation 1,250 feet AMSL, consisting of gray green to dark gray shale and mudstone, hard, fossiliferous, and weathered; and

ii) BW-418 (nka BW-418, Foster Brook Facility) - bedrock at 232 feet bgs, elevation 1,187 feet AMSL, consisting of gray shale with clay interbeds, soft and very weathered.

Bedrock was also encountered at three shallow borings in the Platformer Unit of the Main Refinery, where a subsurface bedrock ridge is present, as described below:

i) MW-407 (nka EMW-15, Main Refinery - Platformer Unit) - bedrock at 29 feet bgs, elevation 1,402 feet AMSL, consisting of gray brown to reddish brown shale, moderately hard and slightly weathered;

ii) HG-408 (nka RW-8, Main Refinery - Platformer Unit) - bedrock at 65 feet bgs, elevation 1,367 feet AMSL, consisting of gray brown to reddish brown shale, hard and slightly weathered; and

iii) MW-410 (nka EMW-14, Main Refinery - Platformer Unit) - bedrock at 35 feet bgs, elevation 1,396 feet AMSL, consisting of gray brown to reddish shale, moderately hard and slightly weathered.

Bedrock was encountered at the Custer City Oil site, located near the Foster Brook Facility, at two boring locations (MW-CC-8 and GP-CC-2). The observed depth to bedrock ranged from 8 to 12 feet bgs, with elevations of 1,407 to 1,408 feet AMSL at MW-CC-8 and GP-CC-2, respectively. Where described, the bedrock consisted of sandstone.

The stratigraphic logs for monitoring wells MW-NT-11, MW-NT-12, and MW-NT-13 located on the National Transit Property south of Bolivar Drive mention sandstone, sandstone with pebbles, and sandstone fragments with some pebbles. This is interpreted as the presence of sandstone cobbles and boulders rather than actual

bedrock, as the description is inconsistent with bedrock in the area, the standard penetration test blow counts were low, and there were no other drilling locations with bedrock nearby or exposures of bedrock in Tunungwant Creek.

The contoured top of bedrock surface map, based on these few points and nearby bedrock outcrops, is presented on Figure 4.2. The observed top of bedrock elevations described above are also presented on Figure 4.2.

4.2.2.2 OVERBURDEN GEOLOGY

The overburden geologic units are fully identified in the two deep on-Site boreholes that extend to bedrock [i.e., BW-301 (nka EMW-40) and BW-418 (nka BW-418)]. In addition, monitoring well BW-302 (nka EMW-67) was 208 feet deep without encountering bedrock. Most of the remaining monitoring wells and boreholes at the Site are shallow, being generally less than 30 feet deep. Only 19 monitoring wells extend to the first, or upper, clay unit observed beneath the Site at approximately 70 to 85 feet bgs.

The overburden at the Site generally consists of the following units, in descending order:

i) Fill material: sand and gravel fill, demolition debris, waste materials and similar material deposited to fill low-lying areas and/or provide base for construction of roads or other features, typically only a few feet thick;

ii) Upper silty sand alluvial unit: typically a fining upward sequence grading from gravelly sand to sandy silt with occasional areas of clayey silt, laterally and vertically variable, typically the upper 30 feet;

iii) Upper alluvial unit: typically sand with varying amounts of silt and gravel, laterally and vertically variable, often cobbly to bouldery, typically found from 30 feet bgs to the upper clay unit, at approximately 75 feet bgs;

iv) Upper clay unit: composed of dark gray silty clay, usually laminated and/or varved, found at depths of approximately 73 to 80 feet bgs, 3 to 7 feet thick, followed by a sand unit up to 15 feet thick, then another clay unit approximately 4 feet thick;

v) Intermediate alluvial unit: typically sand with varying amounts of silt and gravel, laterally and vertically variable, often cobbly to bouldery, extending to the lower clay unit;

vi) Lower clay unit: composed of dark gray clayey silt to silty clay, usually laminated and/or varved, found at depths of approximately 128 to 132 feet bgs, and 10 to 20 feet thick;

vii) Lower alluvial unit: typically sand with varying amounts of silt and gravel, laterally and vertically variable, with clayey silt to silty clay units of variable thickness, overlying bedrock.

The coarse-grained deposits vary laterally and vertically due to the nature of deposition. The depositional environment, a glaciofluvial meltwater stream, is characterized by a high sediment load and shifting channels in an overall accretionary depositional environment. The fine-grained deposits tend to persist laterally due to deposition in a glaciolacustrine setting (Glacial Lake Bradford). The thicknesses of the fine-grained deposits vary laterally due to depositional variations (pre-existing topography and depositional rates) and subsequent erosion by flowing meltwater.

The geologic units are depicted on a series of three cross-sections (Cross-Sections A-A', B-B', and C-C') that trend parallel to Tunungwant Creek. The cross-section locations are provided on Figures 4.3a, 4.3b, and 4.3c, with Cross-section A-A' presented on Figure 4.4, Cross-section B-B' presented on Figure 4.5, and Cross-section C-C' presented on Figure 4.6. These cross-sections utilize the deep borings to illustrate the vertical extent of the geologic units within the buried channel, and also depict the subsurface bedrock ridge found in the area of the Platformer Unit of the Main Refinery (see Cross-section A-A').

The upper alluvial units extend from the ground surface to the upper clay unit. The upper clay unit behaves as an aquitard and forms a natural hydrogeologic boundary beneath the Site, as is discussed further in Section 4.3.2.2). A total of 19 boreholes at the Site encountered the upper clay unit. Table 4.1 provides a list of these boreholes along with the observed depth to the upper clay unit, elevation of the top of the upper clay unit, and the thickness of the upper clay unit (where the upper clay unit is fully penetrated). The top of the upper clay unit elevation varies from 1,344 to 1,358 feet AMSL. The top of the upper clay unit elevation contours are presented on Figure 4.7.

The upper alluvial units overlying the upper clay unit vary significantly in composition as depicted on the cross-sections (Figures 4.4, 4.5, and 4.6). Due to erosion and re-deposition, and lateral facies changes, these units generally can not be correlated over significant distances. Where present, fine-grained units in the upper alluvial units have been correlated on the cross-sections as these are considered to be more extensive, similar to the two major clay units.

4.2.2.3 OVERBURDEN PHYSICAL PROPERTIES

The available historical overburden physical properties data consist primarily of grain-size results from historical investigations. These data are presented in Table 3.3. CRA collected samples from the unsaturated zone (typically 05 to 1.0 feet bgs) and from a deeper interval (typically 4 to 6 feet bgs), all in the Foster Brook Facility. These samples were analyzed for grain-size, moisture content, dry and wet unit weight, porosity, specific gravity, Atterberg Limits, and permeability. These data are presented in Table 3.7.

The grain-size data for the sample BP-4A (0.5 to 1.0 feet bgs) were inconsistent with the permeability testing. Discussions with the geotechnical laboratory indicate that this is a result of a layered sample of limited volume, and a preponderance of material greater than approximately 1/2-inch diameter in a small volume sample. Therefore, the grain-size data were modified by removing the weights of material retained on the 1/2-inch and larger sieves, and the grain-size curve was replotted. The revised grain-size distribution indicates that the sample consists of 19.1 percent gravel, 46.8 percent sand, and 34.1 percent silt and clay. This revised data has been added to the physical properties table, adjacent to the original data and an explanatory note added.

Table 3.3 provides the historical physical properties data. As no historical permeability testing was conducted, an estimate of the bulk hydraulic conductivity was calculated based on the Hazen (1911) method and provided in Table 3.3. The Hazen method is an empirical method applicable to sands with an effective grain size (10 percent of the soil passes this diameter) of between approximately 0.1 and 30 millimeters (Fetter, 1988). The Hazen formula is:

$$K = C\,(D_{10})^2$$

Where:

K is hydraulic conductivity (cm/sec);
D_{10} is effective grain size (cm); and
C is a dimensionless coefficient.

The coefficient C varies from approximately 40 for poorly sorted very fine sand to 150 for well sorted coarse sand (Fetter, 1988). A coefficient of 100 has been used for the Hazen method calculations listed in Table 3.3.

4.3 HYDROGEOLOGIC CONDITIONS

4.3.1 REGIONAL HYDROGEOLOGY

4.3.1.1 REGIONAL BEDROCK HYDROGEOLOGY

Groundwater in the bedrock is found primarily in fractures and joints, along with groundwater in the pore spaces. The groundwater is typically found at shallow depths in the bedrock, in the uppermost weathered zone. Bedrock groundwater in the shallow bedrock system discharges as seeps or springs to the surface water system, and in the buried valley, discharges to the overburden aquifer units. There is limited discharge of this water upward to shallower units.

Circulation of groundwater to deeper bedrock systems is very restricted and the groundwater found in deep bedrock systems is primarily saline, connate water associated with the original deposition of the unit.

4.3.1.2 REGIONAL OVERBURDEN HYDROGEOLOGY

Groundwater is typically found at shallow depths in the overburden deposits. The groundwater in the coarse-grained alluvial deposits form aquifer units, while the fine-grained units form aquitards that restrict groundwater flow between aquifer units.

4.3.2 SITE HYDROGEOLOGY

4.3.2.1 BEDROCK HYDROGEOLOGY

There are no monitoring wells completed in the bedrock at the Site. Monitoring well BW-301 (nka EMW-40) has the lowest of three screens separated by sections of riser pipe forming a single well extending 7 feet into bedrock. No references to hydrogeologic testing of or hydrogeologic parameters for the bedrock unit have been encountered in documents reviewed by CRA.

The bedrock is described as weathered shale in all five boreholes that encountered bedrock at the Site. It is anticipated that the shale bedrock would be several orders of magnitude less permeable than the coarse-grained overburden units, and likely similar to or slightly more permeable than the upper clay unit. As such, the bedrock is considered to be an aquitard.

4.3.2.2 OVERBURDEN HYDROGEOLOGY

The coarse-grained alluvial units comprise three separate aquifer units separated by clay aquitard units. These hydrogeologic units are, in descending order:

i) Upper aquifer: a water table (unconfined) aquifer comprised of the fill material (where saturated), upper silty sand alluvial unit, and the upper alluvial unit, extending to the top of the upper clay unit;

ii) Upper clay aquitard: comprised of the upper clay unit and forming a lower boundary to the upper aquifer;

iii) Intermediate (second) aquifer: a confined aquifer comprised of the intermediate alluvial unit, and is not monitored at the Site;

iv) Lower clay aquitard: comprised of the lower clay unit;

v) Lower (third) aquifer: a confined aquifer comprised of the lower alluvial unit and is not monitored at the Site; and

vi) Bedrock: comprised of the shale and sandstone bedrock and acting as a lower aquitard to the lower aquifer, and as lateral aquitards to the intermediate and upper aquifers. Small amounts of groundwater may discharge from the bedrock into the overburden aquifer units.

Historical groundwater investigations conducted by R.E. Wright Environmental, Inc. (R.E. Wright) have documented the hydraulic relationship between the upper and intermediate aquifers present beneath the Site. The relationship documented was based on data collected from three wells [BW-301 (nka EMW-40), BW-302 (nka EMW-67), and BW-418]. Through the installation of a WESTBAY® multilevel monitoring system at BW-301, R.E. Wright reported that:

i) piezometric heads increased with depth under static conditions, thus the potential for groundwater flow between the upper and lower saturated zone is upward; and

ii) during the long-term pumping test completed at HG-303 (nka EMW-36), no change in piezometric head was observed in the monitoring points below the confining strata, while piezometric head changes within the upper monitoring ports above the impervious zone closely mirrored pumping test patterns.

The groundwater elevations (interpreted through recorded pressure readings) for BW-301 in the upper, intermediate, and lower aquifers were monitored and reported for

the HG-303 pumping test (April, 1996). Based on the results of this test REWEI reports no significant pressure change was observed in the aquifer below the clay when the aquifer above the clay was pumped. This indicates only a very limited communication between the upper and intermediate aquifers, and demonstrates the confining nature of the upper clay unit.

This interpretation was extended to the Foster Brook area of the Site upon installation of BW-418 (R.E. Wright, March, 1998). During the pumping test of nearby HG-417 (nka HG-417A), R.E. Wright reported that no influence was measured on the intermediate aquifer below the upper clay unit as a result of stressing the shallow aquifer beneath Foster Brook.

CRA was unable to confirm the above findings by R.E. Wright due to the following:

- CRA field staff report that the Westbay system previously installed in BW-301 has been removed and BW-301 is no longer available for data collection; and
- BW-418 was not available for the three groundwater measuring events conducted by CRA as its location was unknown at the time of the groundwater sampling conducted by CRA, although its location was later identified upon completion of the land cover survey.

However, groundwater elevation data collected by CRA at the adjacent shallow and intermediate aquifer monitoring wells MW-11 and BW-302 (nka EMW-67) is in good agreement with the historical information presented by R.E. Wright. BW-302 is screened solely in the intermediate aquifer (screened between 102 and 112 ft bgs). MW-11 is located approximately 7 feet from BW-302 and is screened in the shallow portion of the upper aquifer (screened between 3.3 and 23.3 ft bgs). Thus, the relationship between groundwater elevations measured at these two monitoring wells locations can substantiate the upward hydraulic gradients documented by R.E. Wright. The groundwater elevations measured by CRA at these locations are summarized below.

	Groundwater Elevation (ft AMSL)		
Location	*March 2003*	*April 2003*	*December 2003*
MW-11 (upper aquifer)	1418.37	1418.06	1418.01
BW-302 (nka EMW-67) (intermediate aquifer)	1424.78	1425.00	1424.72
Hydraulic Head Difference	6.63	6.72	6.71

The difference in groundwater elevation measurements between these two locations consistently demonstrates and verifies the upward hydraulic gradient from the intermediate to upper aquifers and confining nature of the upper clay unit.

The focus of most of the hydrogeological investigations has been the upper aquifer, and almost all monitoring wells at the Site are completed in the upper aquifer.

4.3.2.2.1 SPL AND GROUNDWATER ELEVATIONS

During the SSD, the depths to SPL and groundwater were measured on three occasions; late March/early April 2003 during the initial well inventory; April 14 to 15, 2003; and December 17 to 19, 2003. The depth to SPL and groundwater have been converted to elevations based upon the well survey conducted in December 2003 and January 2004. Due to the presence of SPL in some wells, the water table can be depressed and it is necessary to adjust (or correct) the measured water table elevations to account for the SPL that flows atop the groundwater. The "corrected groundwater elevations" have been determined using the specific gravity for the SPL in the individual well from historic or current investigations, wherever available. For monitoring wells without specific gravity data, the specific gravity was assumed based on data for nearby monitoring wells. If there were no nearby wells with SPL, the average specific gravity value of 0.85 was used. Notations to this effect are included in the SPL and groundwater elevation tables.

The depth to SPL and groundwater, the elevations of the SPL and groundwater and the corrected groundwater elevation data are presented in Table 3.13 (March/April 2003), Table 3.14 (April 14 to 15, 2003), and Table 3.15 (December 17 to 19, 2003).

The SPL apparent thickness and corrected groundwater elevations are presented on a series of figures for the April and December 2003 monitoring events. These figures are:

i) Figure 4.8a/b/c - Corrected Groundwater Elevations - April 14 to 15, 2003;

ii) Figure 4.9a/b/c - Corrected Groundwater Elevation - December 17 to 19, 2003; and

iii) Figure 4.10a/b/c - Apparent SPL Thickness - December 17 to 19, 2003.

The "a" designation in the figures refers to the Main Refinery area, "b" is the Crude Tank Farm and Packaging Plant areas, and "c" is the Foster Brook Facility.

These Corrected Groundwater Elevation and SPL Thickness contours were hand drawn rather than computer interpolated. This allowed for a degree of hydrogeological judgment in the depiction of the contours. The groundwater flow directions are generally toward Tunungwant Creek, where groundwater discharges to surface water.

The apparent thickness of SPL in a monitoring well is not the same as the thickness in the subsurface adjacent to the monitoring well, as further described in Appendix T. The SPL thickness and volume estimates are further discussed in Section 5.10.

4.3.2.2.2 UPPER AQUIFER HYDROGEOLOGIC PARAMETERS

Estimates of the hydrogeologic parameters transmissivity, storativity, hydraulic conductivity, and porosity have been determined through a variety of methods including grain size analysis, single-well response tests, and pumping tests.

The porosity values presented in Table 3.7 were estimated based on moisture content and unit weight, and the permeability values were obtained by testing (ASTM D508-90). Since all of these samples were collected above the water table, the estimated porosity and permeability testing results may not be directly applicable to the upper aquifer, but are expected to be very good estimates. The permeability results range from 6.24×10^{-4} to 3.4 feet/day. Hydraulic conductivity estimates were calculated using the Hazen method for the historic grain size data, for which permeability testing was not conducted. The Hazen hydraulic conductivity values are presented in Table 3.3, and range from approximately 14 to 1,814 feet/day.

Single-well response tests were completed at the Site and on the National Transit Property and Custer City Oil site. These data were reviewed, noted to be incorrectly analyzed, and subsequently were reanalyzed. The discussion of these single-well response tests and the data reanalysis is provided in Appendix Y. The revised hydrogeologic parameter results of these single-well response tests are provided in Table 4.2.

As shown in Table 4.2, the corrected hydraulic conductivity values for the Site locations range from 0.22 to 128.5 ft/day with a geometric mean of 2.3 ft/day. All wells are screened within the shallow portion of the Upper Aquifer. For the wells located on the National Transit Property, the values range from 7.3 to 15.7 ft/day with a geometric mean of 9.4 ft/day. The hydraulic conductivity values for the Custer City Oil site range from 2.78 to 38.8 ft/day with a geometric mean of 7.3 ft/day.

CRA used the corrected information for the evaluation/modeling presented in this SCR.

Historic pumping tests were conducted on seven vertical wells. These data were reviewed and determined to be generally acceptable. The discussion of these pumping tests and the data analysis are provided in Appendix Y. The corrected hydrogeologic parameter results of these pumping tests are provided in Table 4.3.

Overall, it appears that the pumping tests were performed correctly. Data analysis was also generally performed correctly with the following exceptions:

i) The Pumping Test at HG-303 - The Forchheimer (1930) equation correction factor calculations may be incorrect which may result in some uncertainty in the aquifer hydrogeologic property values. The uncertainty is considered to be within a factor of two for the reasons stated in Section 3.2. In addition, the first pumping phase aquifer property values may be more reliable estimates depending on how the data were analyzed for the two pumping phases;

ii) The Pumping Test at HG-408 - The aquifer thicknesses were not corrected for the presence of shale bedrock at depths shallower than the clay aquitard. An estimated aquifer thickness was used by CRA to determine an estimated hydraulic conductivity (see Section 3.4); and

iii) The Pumping Test at HG-413 - The Hantush (1960) analytical method for partially or fully penetrating wells in a leaky confined aquifer were used, even though the aquifer appears to be leaky unconfined. It is unlikely that using this analytical solution has caused significant error in the calculated aquifer hydraulic properties, as shown by the results for pumping test HG-417, for which both analytical methods were used.

Therefore all of the aquifer hydrogeologic property values presented on Table 4.3 are believed to be reasonably accurate values, with the exceptions noted for the four monitoring wells (RW-3, RW-4, MW-411, and MW-412) from the HG-408 pumping test where the transmissivity and hydraulic conductivity values are suspected by R.E. Wright to be incorrect as the values were inconsistent with other aquifer tests performed by R.E. Wright.

CRA used the confirmed data for in the development of the groundwater flow model for the Site presented in Appendix AK.

CRA conducted three vertical well pumping tests and four horizontal well pumping tests in September 2003 to assess the effectiveness of vertical and horizontal wells on the

containment and removal of SPL. The discussion of the performance of these tests and data analysis is provided in Appendix V. The hydrogeologic parameter results for the vertical well pumping tests are provided in Table 4.4. The hydrogeologic properties for the vertical pumping test wells are summarized in the following:

Pumping Well	*Hydraulic Conductivity (ft/day)*		*Storativity*		*Vertical/Horizontal Hydraulic Conductivity Anisotropy Ratio*	
	Range	*Geometric Mean*	*Range*	*Geometric Mean*	*Range*	*Arithmetic Mean*
MW-108	19.4 to 76.7	45.3	3.49E-07 to 2.43E-03	1.09E-05	0.1	0.1
MW-120	1.6 to 69.5	12.6	6.91E-06 to 1.71E-03	4.85E-04	0.03 to 0.8	0.22
MW-126	28.8 to 47.7	37.0	7.41E-07 to 2.79E-06	1.73E-06	0.06 to 0.1	0.08
Overall Range/Mean	1.6 to 76.7	27.6	3.49E-07 to 2.43E-03	2.09E-05	0.03 to 0.8	0.13

The variability in the above values indicate that the upper aquifer is laterally anisotropic in the vicinity of each pumping well and between testing locations. This is consistent with the observations noted from the available stratigraphic logs, and is discussed with respect to cross-sections presented on Figures 4.4, 4.5, and 4.6.

The pumping tests also caused significant amounts of SPL to be pulled into the pumping well due to the drawdown of the water table. The elapsed time from the start of each pumping test and SPL thickness from each of the three pumping wells is presented on Figure V.35. Recovery data are also presented using elapsed time since pumping began.

It was observed during the MW-108 pumping test that significant volumes of SPL were brought into the pumping well. Approximately 6.5 gallons of SPL was removed twice during the pumping test to prevent the SPL/water interface from reaching the pump intake causing the sudden drops in SPL thickness. The SPL removed during this test appeared to be light brown in color, fresh, and unweathered, in contrast to the SPL at MW-15 which was dark brown and weathered, with particulates in the SPL. The SPL thickness was 2.1 feet at the end of the drawdown phase of the test and remained at approximately 2.1 feet throughout the recovery phase of the test, which lasted approximately 8 hours. Subsequent manual SPL removal was performed at this well to remove the accumulated SPL from MW-108.

It was observed that an SPL thickness of 1.31 feet was present in pumping well MW-120 upon completion of the drawdown phase of this test. The SPL thickness declined to 1.06 feet upon completion of the approximate 16 hours of recovery monitoring.

Subsequent manual SPL removal was performed at this well to remove the accumulated SPL from MW-120.

It was observed that an SPL thickness of 0.53 feet was present in pumping well MW-126 upon completion of the drawdown phase of this test. The SPL thickness declined to 0.38 feet upon completion of the approximate 19 hours of recovery monitoring. Subsequent manual SPL removal was performed at this well to remove the accumulated SPL from MW-126.

The results of these pumping tests indicate that the SPL in the Main Refinery portion of the Site can be mobilized and pulled into a well by depressing the water table. The magnitude of the volume of SPL that can be mobilized will depend on SPL formation thickness, SPL characteristics (viscosity, specific gravity), and formation characteristics and variability (grain size, sorting, pore throat dimensions). However, in the case of mobile SPL, temporary groundwater pumping with separate SPL removal (dual phase remedial system) may be a remedial option for some areas of the Site to reduce total SPL in the subsurface.

Hydrogeologic parameters could not be accurately determined for the horizontal wells due to the lack of appropriate analytical solutions.

The testing of the horizontal wells provided sufficient information in the form of SPL/water level changes to conclude that the horizontal wells are an effective means to significantly reduce or prevent seepage of SPL to Tunungwant Creek. The water level recovery when the horizontal wells were initially shut down (September 8 to 10, 2003) indicates that the operation of the horizontal wells provides approximately one-half to greater than one foot of drawdown in the aquifer on a long-term basis.

The water levels in Tunungwant Creek were similar to or higher than the groundwater levels in monitoring wells within the Upper Yard during the HW-1 and HW-4 pumping tests, indicating a slight inward gradient from the Creek to the horizontal wells. However, in the Main Refinery area where the HW-8 and HW-10 pumping tests were conducted, the groundwater elevations were approximately 3 feet higher and one to two feet higher, respectively, than the Creek elevations at the Kendall Avenue bridge. This shows that a horizontal gradient from the Site groundwater to the Creek still exists at these locations.

The drawdown generated by pumping of the individual horizontal wells (HW-1, HW-4, and HW-8) provided much less drawdown than when all the horizontal wells were pumping. This indicates that the overlapping influences of the horizontal wells

provides significantly more drawdown in the aquifer than the pumping of the individual wells. The drawdown from HW-10 occurred primarily in a localized area, due to the shape of the well (i.e., much greater depth beneath Kendall Avenue), the relatively steep horizontal hydraulic gradient, and the low pumping rate.

The lack of SPL along much of the length of HW-1 suggests that this horizontal well may not be required for SPL removal. The SPL at monitoring well EMW-18, the most southerly well along HW-1 with SPL (the other monitoring locations for the HW-1 pumping test did not have SPL), should also be captured by HW-2. However, should HW-1 be shut down, the SPL thickness at EMW-18 should be monitored regularly to ensure that HW-2 is providing effective SPL capture.

An expanded description of the SPL and the volume of SPL currently underlying the Site is provided in Section 5.10.

4.4 SPL SEEPS AND IRON STAINING OBSERVATIONS IN TUNUNGWANT CREEK

One of the primary concerns that PADEP has expressed about the Site is the potential impact that groundwater seeps may have on the quality and aesthetics of Tunungwant Creek.

The locations of SPL seeps into Tunungwant Creek for the years 2003/2004 are shown on Figure 4.11. These seeps are primarily located in the concrete flood control wall area and discharge from the weepholes at the base of the wall. In addition to the seeps from the weepholes, SPL discharges were observed in 2003 and 2004 from 11 other discrete locations. These locations are presented on Figure 4.12 and are described in Table 4.5. These locations will be used as the baseline from which to measure the effectiveness of the ongoing remedial actions. Figure 4.11 shows that the majority of the SPL seeps were from the weepholes along the east side of Tunungwant Creek. The SPL seeps along the west side of the Creek accounted for only a fraction of the SPL discharge.

There are currently a number of remedial actions being performed to prevent SPL seeps into Tunungwant Creek. These are:

i) SPL impacted groundwater is being removed by the horizontal collector wells and vertical recovery wells located behind the flood control walls;

ii) manual SPL removal from monitoring wells in which SPL has been identified to be present;

iii) active SPL removal is occurring from select wells, typically resulting in larger SPL removals;

iv) monitoring for and addressing SPL seeps, if any (using absorbent pads, booms, etc.) along the shoreline to prevent entry into Tunungwant Creek; and

v) monitoring, reporting, and addressing sheens on Tunungwant Creek in accordance with the Consent Order and Agreement (COA).

The COA requires that visual inspections of the area of Tunungwant Creek shown on Figure 4.22 be conduced on a daily basis (or such other frequency determined by agreement between Chemtura, ARG, and PADEP) and that a log is to be maintained describing all observations, any petroleum, iron precipitate, and/or petroleum sheens, abatement actions taken, and the results thereof. The inspection log documents whether observed conditions are newly discovered or continuing from a previous observation, and documents possible or apparent causes and sources such as remedial system shut downs, precipitation events, creek stage, and non-Site related events.

A discharge of petroleum, iron precipitate, and/or petroleum sheens more than 25 feet in length or, in the judgment of Chemtura and/or ARG, likely to become more than 25 feet in length is immediately reported to PADEP. SPL observed accumulating or seeping from weep holes or stream banks which is greater than three feet in length is reported immediately to PADEP.

Within ten days after orally reporting a release of petroleum, iron precipitate, and/or petroleum sheens in Tunungwant Creek, Chemtura and/or ARG document such observations in a written report to PADEP ("Release Report"). Each Release Report includes a description of the release, the location of the occurrence, the measures that Chemtura and/or ARG undertook, and/or are continuing to take, and the results thereof. If Chemtura and/or ARG do not take measures to address the occurrence, the Releases Report includes the reasons for such inaction.

The sheens observed since monitoring and reporting of sheens has been required by the COA are presented in Table 4.6. Only 28 sheens have been observed. Of these, 11 were non-reportable and of the 17 reportable sheens, 8 were determined to have been sourced from properties other than the ARG Refinery.

The figures listed below show the areas that exhibited iron precipitate staining in November 2004, November 2005, and November 2006.

Figures 4.13, 4.14 and 4.15	November 2004
Figures 4.16, 4.17 and 4.10	November 2005

Sufficient information is not available to prepare a figure showing the locations of historic iron staining. It is to be noted that the observed stained areas are believed to coincide with the more recent historic stained areas. The reason for this is that the orange staining that results from the iron releases would be expected to last for many years and would continue to be present for many years after a high iron concentration release.

Comparison of the November 2004 and November 2005 iron stained areas shows no or minimal observable changes in the areal extent or degree of iron staining. The November 2006 observations show that decreases in the areal extent and degree of staining occurred between November 2005 and November 2006. Specifically, these are:

i) the areal extent of iron staining upstream of Mill Street has decreased;

ii) the sheen observed in 2004 and 2005 at the City storm water outfall east of the Werzalit property and north of the Kendall Avenue bridge was no longer observed; and

iii) the staining along the CTF east shoreline upstream of the Conrail bridge has decreased from light staining throughout most of the area to isolated patches throughout most of the area.

It should be noted that iron is ubiquitous in the ground and groundwater throughout the area. It is acknowledged that the SPL presence beneath the Refinery is enhancing the anaerobic condition of the groundwater . This results in the more soluble form of iron and higher iron concentrations than would normally be exhibited in the groundwater. The dissolved iron travels with the groundwater flow and is discharged to the surface water bodies. When exposed to the oxygenated surface water, the iron converts to a less soluble form and precipitates out of solution, leaving the orange staining. The implemented remedial actions for the groundwater will result in improvements in the groundwater quality which should in turn result in improvements in surface water quality. This, in turn, should result in less orange staining of the creek bed. This will be confirmed by inspecting the Creek annually and comparing the size of the iron stained areas.

5.0 CHEMICAL SITE CHARACTERIZATION

Over the years, a considerable amount of data has been collected at the Site regarding all aspects of the environmental conditions. All of these data have been compiled, tabulated, and summarized for inclusion in this Site Characterization Report.

This section of the report presents the results of the chemical Site Characterization activities completed to date. The collected data have been grouped into discussion units to match the environmental Exposure Units (EUs) developed for the Site. Each of the environmental Exposure Units has its own unique characteristics and usage patterns which must be taken into consideration in assessing the data.

As appropriate, all of the analytical data has been screened by comparison to the applicable and appropriate guidance values established by PADEP (and USEPA where necessary). The analytical results for the groundwater and soil media were compared to the most stringent PADEP Chapter 25, Act 2 Statewide Health Standard (SHS) Medium Specific Concentrations (MSCs) for each chemical analyzed. This procedure provided a conservative approach to identifying those compounds to be carried forward in the HHRA to develop a Site-Specific Standard (SSS).

The appropriate SHS MSC for groundwater was selected from PADEP Title 25, Chapter 250, Appendix A, Tables 1 and 2, based on the following:

i) the aquifer underlying the Site was considered as used for MSC selection purposes;

ii) the total dissolved solids (TDS) concentration of the groundwater is <2,500 mg/L; and

iii) the land use is Non-Residential (NR).

The appropriate SHS MSC for soil was selected from PADEP Title 25, Chapter 250, Appendix A, Tables 3 and 4, based on the following:

i) most stringent MSC for Direct Contact Numeric Values and Soil to Groundwater Numeric Values;

ii) the land use is Non-Residential (NR);

iii) the groundwater underlying the aquifer is used; and

iv) the groundwater TDS concentration is <2,500 mg/L.

For soils, the results were segregated into 3 intervals:

i) surface soil (0 to 2 ft bgs);

ii) unsaturated soil (2 ft bgs to the seasonally high groundwater table or a maximum of 15 ft bgs, whichever occurred first); and

iii) saturated soil (from the seasonally high groundwater table to 15 ft bgs).

For the saturated soils, the standard used was 1/10th of the generic value for the appropriate parameters.

The appropriate SHS MSC for surface water was selected based on the most stringent of the following:

i) residential groundwater SHS MSC; and

ii) Chapter 16, Table 1, Water Quality Criteria.

For the sediment media, residential direct contact Act 2 criteria were used.

The data are presented for each of the eight Exposure Units in the following sections. A summary table of the compounds exceeding their respective SHS MSCs is provided for each media in each Exposure Unit. The summary in the tables is based on the number of locations sampled, not the number of samples collected and analyzed. Soil samples collected at different depths in the same borehole were counted as individual locations. Presenting the summary in this manner will prevent the summary from being skewed by a few locations which were sampled/analyzed more frequently than other locations. A complete summary including the compounds detected at concentrations less than or equal to their respective SHS MSCs is also presented in each subsection.

It is noted that naphthalene was analyzed historically as a SVOC in some samples and as a VOC in other samples. During the SSD activities, it was analyzed as a VOC. In all of the table summaries provided in this report, naphthalene has been included in the parameter group under which it was analyzed whereas it has been presented as a VOC on the figures and drawings.

The sample locations designated as background for each Exposure Unit are provided in Table 5.1.

One activity that PADEP requested be performed was a QA/QC review of the historic data. This was done to determine whether the historic data could be relied upon for evaluating site conditions. To the extent that QA/QC information was available, it was possible to validate the majority of the historic data. In most cases, the historical data were deemed acceptable. For some of the older reports, the QA/QC information was not available and therefore, a meaningful validation of the data from these reports could not be made. In general, this report relies primarily upon the most recent data, all of which has been evaluated for QA/QC. Older data were only used in a few instances to fill in data gaps or to provide an indication of expected trends. While some of the older data may not be fully validated, the data are generally consistent with that in the same vicinity/time frame and thus are useful. Consequently, the conclusions drawn from the data are valid. The results of the QA/QC reviews of the historic data are provided in Appendix AB.

5.1 MAIN REFINERY (EXPOSURE UNIT 1)

This section presents the analytical results for the Main Refinery. The results for each media applicable to the Main Refinery and exceedances of the most stringent criteria are described in the following subsections.

5.1.1 GROUNDWATER

The available data for the EU1 groundwater are provided in Table AC.1 of Appendix AC. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.2 and a summary of those compounds which were detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.3. There are analytical results for up to 87 wells on the Main Refinery. The data from these on-Site wells were also compared to the data from 6 background wells and 3 downgradient wells.

As shown in Table 5.2, four metals exceeded their Act 2 criteria in the background sample locations. The metals were aluminum (1 of 6), arsenic (1 of 6), iron (6 of 6), and manganese (6 of 6). By comparison, in the on-Site locations, 12 dissolved metals exceeded their Act 2 criteria. Eight of these 12 metals exceeded the criteria only 4 times or less out of the 80 locations monitored. For these eight metals, the exceedances were generally less than 5 times their Act 2 criteria except for antimony for which the single exceedance was approximately 50 times its criteria. The four metals with the greatest number of exceedances were manganese (78 of 79), iron (72 of 79), arsenic (38 of 80), and

aluminum (6 of 79). These are the same four metals which exceeded their Act 2 criteria in the background locations. For these four metals, the maximum exceedance concentration in the on-Site locations ranges from 1.5 to 40 times higher than the background maximum concentration. The large number of exceedances for dissolved iron and manganese are consistent with the results for total iron (18 of 18) and total manganese (4 of 4).

For the three downgradient wells, iron was in exceedance at one well (100 times its SHS MSC) and manganese was in exceedance at two wells with the maximum concentration 6 times greater than its SHS MSC. No SVOCs or VOCs were in exceedance in the three downgradient wells.

The iron and manganese exceedances are shown on Figure 5.1. The exceedances for the remaining metals are shown on Figure 5.2. In summary, the number of locations with exceedances for the metals, other than iron and manganese, were:

	Groundwater - Metals										
	Al	*Sb*	*As*	*Be*	*Cd*	*Pb*	*Ni*	*Ag*	*Th*	*Zn*	*Total*
MEK Unit	4		8		3		2			1	18
ROSE® Unit			8			1			2		11
Platformer Unit			1								1
Dubbs Unit			3								3
Crude Unit Upper Yard	1		3	1							5
Crude Unit Rail Loading											0
Barrel House			3								3
Crude Unit	1	1	9		1	1	1	1			15
Erie Wye			3								3
	6	1	38	1	4	2	3	1	2	1	59

As shown above and on Figure 5.2, arsenic is present in the groundwater beneath the entire Main Refinery. The areas with the greatest number of metals exceedances were the MEK Unit (18 of 59), the Crude Unit (15 of 59), and the ROSE® Unit (11 of 59). The remaining areas of the Main Refinery had 5 or fewer exceedances in each area.

For the SVOCs, 10 compounds exceeded their Act 2 criteria. Nine of the 10 parameters are Polycyclic Aromatic Hydrocarbons (PAHs). The other compound is pentachlorophenol. Seven of the 10 parameters exceeded the criteria only 4 times or less out of 33 locations for pentachlorophenol and out of 85 locations for the other six parameters. The maximum concentrations for these seven parameters ranged from slightly above its criteria (phenanthrene) to 40 times its criteria (benzo(a)anthracene).

The three SVOCs with the greatest number of locations with exceedances were benzo(a)pyrene (13 of 85), benzo(k)fluoranthene (7 of 85), and chrysene (6 of 85). The maximum concentrations for these three parameters ranged from 50 to 140 times their criteria.

As shown on Figure 5.3, one exceedance of the two pentachlorophenol exceedances occurred in each of the MEK Unit and the Crude Unit Upper Yard. Furthermore, 15 of the 41 PAH exceedances occurred in the southern half of the MEK Unit. The unit with the next greatest number of PAH exceedances (9 of 41) is the Dubbs Unit. A summary of the SVOC exceedances by unit in the Main Refinery is:

	Benzo(a)Anthracene	*Benzo(a) Pyrene*	*Benzo(b) Fluoranthene*	*Benzo(g,h,i) Perylene*	*Benzo(k) Fluoranthene*	*Chrysene*	*Dibenzo(a,h) Anthracene*	*Fluoranthene*	*Pentachlorophenol*	*Phenanthrene*	*Total*
MEK Unit	1	4	2	1	3	3	1		1		16
ROSE® Unit	1					1					2
Platformer Unit		1		1							2
Dubbs Unit		2	1	1	2	1		1		1	9
Crude Unit Upper Yard		1		1					1		3
Crude Unit Rail Loading											0
Crude Unit	1	1			1	1		1			5
Barrel House	1	3			1						5
Erie Wye											0
	4	12	3	4	7	6	1	2	2	1	42

It is noted that Table 5.2 shows 13 exceedances for benzo(a)pyrene, whereas Figure 5.3 shows 12. The difference is the exceedance in well EMW-54, which well could not be located. Further, the coordinates provided by ESI place EMW-54 in Tunungwant Creek, which is an unlikely location. Thus, the results for EMW-54 could not be plotted on Figure 5.3.

For the VOCs, four petroleum related parameters exceeded their Act 2 criteria, benzene (21 of 87), naphthalene (3 of 78), 1,2,4-TMB (2 of 21), and 1,3,5-TMB (1 of 21). The only

other VOCs to have an exceedance were the chlorinated organics methyl ethyl ketone (MEK) (1 of 36), methylene chloride (1 of 84), and trichloroethene (TCE) (2 of 83). In addition, the MEK, methylene chloride, and TCE concentrations only slightly exceeded their criteria. The maximum concentrations for 1,2,4-TMB, 1,3,5-TMB, naphthalene and benzene were approximately 20, 11, 3, and 300 times their criteria, respectively.

As shown on Figure 5.4, the greatest number of locations with benzene exceedances occurred in the MEK Unit (6 of 21) and the Dubbs Unit (7 of 21). Erie Wye had 3 locations with benzene exceedances, Crude Unit had 2 locations, with one each in the Crude Unit Upper Yard, Platformer Unit, and the Barrel House. The methylene chloride exceedance and one of the two trichloroethene and 1,2,4-TMB exceedances occurred in Erie Wye. The other trichloroethene exceedance occurred in the Crude Unit Upper Yard and the 1,3,5-TMB and second 1,2,4-TMB exceedances occurred in the Dubbs Unit.

Table 5.3 shows the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. In summary, for the on-Site wells, 7 metals, 12 SVOCs (not including naphthalene which exceeded its SHS MSC when analyzed as a VOC), and 18 VOCs are listed in Table 5.3.

For the 3 downgradient wells, 5 metals are listed in Table 5.3. No VOCs or SVOCs are listed in Table 5.3.

5.1.2 SURFACE SOIL

The available data for the EU1 surface soil are provided in Table AC.2 of Appendix AC. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.4 and a summary of those compounds which were detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.5. Analytical results for up to 12 locations on the Main Refinery are available. The data from these on-Site soil sampling locations were also compared to the data collected from up to 7 background surface soil locations.

As shown in Table 5.4, the only metal to exceed the Act 2 criteria in the background surface soil was lead and that only occurred at one of the seven locations. The concentration was approximately 9 times the criteria. For the on-Site locations, only 2 metals exceeded their Act 2 criteria. These were cadmium (1 of 12) and lead (1 of 12) and the maximum concentration only slightly exceeded their Act 2 criteria. It is noted that the on-Site lead concentration was about 8 times lower than the background

concentration. The cadmium exceedance occurred in the Erie Wye Unit and the lead exceedance occurred in the ROSE® Unit (see Figure 5.5).

Consequently, there are no metals of environmental concern in the surface soils of the Main Refinery.

For the SVOCs, the only parameter to exceed the Act 2 criteria in the background samples was benzo(a)pyrene and this only occurred at one of the background locations. No SVOCs were detected at concentrations in exceedance of the Act 2 criteria in any of the on-Site locations. Consequently, there are no SVOCs of environmental concern in the surface soils of the Main Refinery.

For the VOCs, only benzene exceeded its criteria and did so only at one location (CUSB-08 in the Crude Unit) of the 10 on-Site locations sampled. The concentration of the exceedance was approximately 2 times greater than the criteria.

Table 5.5 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.5 are those petroleum related compounds which were not analyzed for in the EU-1 surface soil but may be present based on their detection in another exposure unit. In summary, 14 metals, 3 SVOCs, and 11 VOCs are listed in Table 5.5.

5.1.3 UNSATURATED SOIL

The available data for the EU1 unsaturated soil are provided in Table AC.3 of Appendix AC. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.6 and a summary of those compounds which were detected at concentrations less than or equal to their respective SHS MSCs is provided in Table 5.7. Analytical results for up to 98 locations on the Main Refinery are available. The data from these on-Site locations were also compared to the data collected from the 2 background unsaturated soil locations.

As shown in Table 5.6, only 2 metals exceeded their Act 2 criteria in the on-site samples and only in one or two locations out of 90. These were lead (2 of 90) and mercury (1 of 89). It is observed that the one surface soil location and the 2 subsurface soil locations with lead exceedances occurred in the ROSE® Unit. The mercury exceedance occurred in the Platformer Unit (see Figure 5.5). The maximum concentration of the lead and mercury exceedances were 1.5 to 2.5 times their criteria, respectively. The maximum on-Site lead concentration of 720 mg/kg was less than the concentration of 3,920 mg/kg

in the background surface soil sample. Given these minimal exceedances and their infrequent nature, there are no metals of environmental concern in the unsaturated soil in the Main Refinery.

For the SVOCs, only benzo(a)pyrene exceeded its criteria at five of the 98 on-Site locations. One exceedance occurred in each of the ROSE® Unit, Barrel House, and Dubbs Unit. Two exceedances occurred in the Platformer Unit. Both of the Platformer Unit exceedances were in close proximity to each other. Given these minimal and infrequent exceedances of only one parameter, the SVOCs are not of environmental concern in the unsaturated soil in the Main Refinery.

For the VOCs, only two compounds exceeded their criteria in the on-Site locations; benzene (9 of 97) and naphthalene (1 of 84). The maximum exceedance concentration for benzene and naphthalene were 22 and 3 times their respective criteria. The majority of the benzene exceedances occurred in the ROSE® Unit and Dubbs Unit with 3 each out of the total of 9 exceedances. The remaining 3 benzene exceedances were 1 for each of the Crude Unit, Erie Wye, and the Crude Unit Upper Yard. The single naphthalene exceedance occurred in the Crude Unit Upper Yard. Given there was only one minimal exceedance of naphthalene, there is no environmental concern for naphthalene. Benzene will be further evaluated in the HHRA. All other VOCs are not of environmental concern in the unsaturated soils in the Main Refinery.

Table 5.7 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.7 are those petroleum related compounds which were not analyzed for in the EU-1 unsaturated soil but may be present based on their detection in another exposure unit. In summary, 15 metals, 14 SVOCs (not including naphthalene which exceeded its SHS MSC when analyzed as a VOC), and 13 VOCs are listed in Table 5.7.

5.1.4 SATURATED SOIL

The available data for the EU1 saturated soil are provided in Table AC.4 of Appendix AC. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.8 and a summary of those compounds which were detected at concentrations less than or equal to their respective SHS MSCs is provided in Table 5.9. Analytical results for up to 112 locations on the Main Refinery are available. The data from these on-Site locations were also compared to the data collected from the 3 background saturated soil locations.

As shown in Table 5.8, five metals exceeded their Act 2 criteria in the on-Site locations. These were lead (22 of 93), arsenic (13 of 93), antimony (7 of 93), cadmium (3 of 93), and mercury (3 of 93). The maximum exceedance concentrations for antimony, arsenic, and cadmium were approximately 2 to 4 times their criteria. For lead and mercury, the maximum concentrations were approximately 8 and 25 times their criteria, respectively.

The number of exceedances for each Unit within the Main Refinery were:

	Sb	*As*	*Cd*	*Pb*	*Hg*	*Total*
MEK Unit	1	3		2		6
ROSE® Unit	3	5	1	3		12
Platformer Unit				2	1	3
Dubbs Unit	1			1		2
Crude Unit Upper Yard	2	2	1	2	1	8
Crude Unit Rail Loading		1		6	1	8
Crude Unit		1		5		6
Barrel House		1		1		2
Erie Wye			1			1
	7	13	3	22	3	48

The above shows that the saturated soil locations with metals concentrations in exceedance of their Act 2 SHS MSC are spread throughout the Main Refinery (EU1).

For the SVOCs, seven compounds exceeded their Act 2 criteria in the on-Site locations. All were PAHs. Benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and fluoranthene, each had only one location with an exceedance out of 112 locations. The exceedance concentrations ranged from only slightly exceeding (fluoranthene) to 10 times (benzo(b)fluoranthene). Chrysene had two locations out of 112 with an exceedance. The maximum exceedance was 4 times its criteria. The remaining two compounds, anthracene and benzo(a)pyrene each had four exceedances out of 112 and the maximum exceedance concentrations were 4 to 20 times their criteria, respectively. As shown on Figure 5.6, the majority of the unsaturated soil SVOC exceedances occurred in two, relatively small areas, one in the vicinity of Tank 250 in the ROSE® Unit (7 of 14) and the second in the vicinity of Unifier Reactor in the Platformer Unit (4 of 14). The remaining SVOC exceedances are scattered throughout the Main Refinery. Given the infrequent and minimal exceedances, these 6 parameters are not of environmental concern.

For the VOCs, two compounds exceeded their Act 2 criteria in the on-Site locations. These were benzene (11 of 101) and naphthalene (3 of 93). Similar to the unsaturated soil, the majority of the saturated soil exceedances for benzene occurred in the Dubbs

Unit (5 of 11) and the ROSE® Unit (2 of 11). In addition, 2 of the 11 exceedances occurred in the Crude Unit. One of the remaining 2 exceedances occurred in each of the Platformer Unit and Erie Wye. It was observed that 7 of the locations had exceedances in both the unsaturated and saturated soil. Out of the 14 total exceedances, six occurred in the Dubbs Unit and two occurred in each of the ROSE® Unit, Crude Unit, and Crude Unit Upper Yard. The remaining two exceedances were located throughout the Main Refinery. In summary, the exceedance locations were:

	Surface Soil/Unsaturated Soil/Saturated Soil		*Total*
	Benzene	*Naphthalene*	
MEK Unit			0/0/0
ROSE® Unit	0/3/12		0/3/2
Platformer Unit	0/0/1		0/0/1
Dubbs Unit	0/3/5	0/0/1	0/3/6
Crude Unit Upper Yard	0/1/0	0/1/2	0/2/2
Crude Unit Loading Rail			0/0/0
Barrel House			0/0/0
Crude Unit	1/1/2		1/1/2
Erie Wye	0/1/1		0/1/1
	1/9/11	0/1/3	1/10/14

0/4/6 – Number of locations with exceedances in surface soil/unsaturated soil/saturated soil.

The maximum exceedance concentration for the VOCs ranged from 7 (benzene) to 9 (naphthalene) times their criteria.

Table 5.9 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.9 are those petroleum related compounds which were not analyzed for in the EU-1 saturated soil but may be present based on their detection in another exposure unit. In summary, 10 metals, 9 SVOCs (not including naphthalene which exceeded its SHS MSC when analyzed as a VOC), and 16 VOCs are listed in Table 5.9.

5.1.5 SOIL GAS

Soil gas samples were collected in October 2003 from probes installed around the Main Refinery Office. This location for testing was selected due to the presence of the SPL floating on the groundwater table in this area and the fact that this building is routinely

occupied by Site workers for a regular 8-hour day. Thus, the exposure potential for the workers in this building exemplifies a worst case scenario. Of the 8 gas probes installed around the office building, only 3 probes were sampled as the remaining 5 probes encountered the groundwater table.

The available data for the soil gas samples are provided in Appendix W. A summary of the compounds detected is provided in Table 3.19. As shown in Table 3.19, the compounds detected in the Main Refinery Office soil gas samples were acetone, benzene, cyclohexane, methyl cyclohexane, xylenes, and toluene. All concentrations were relatively low level (e.g., <360 ppbv for benzene). It is believed the relatively low concentrations are due to the nature of the crude oil products handled in this area of the Main Refinery. Further discussion of the soil gas results is provided in Section 8.0 of this SCR.

5.1.6 SUMMARY

Comparison of the compounds which exceeded their criteria in the groundwater and soil media of EU1 show the following:

i) there are a number of areas and media in EU1 that have been impacted;

ii) iron and manganese are present above their criteria in both the background and on-Site groundwater. Background concentrations were less than on-Site concentrations;

iii) lead is the only metal which exceeded its criteria in all four media although at only 2 locations in each media except for saturated soil (in which exceedances occurred at 22 of 93 locations). Background lead exceedance was detected at a greater concentration in one background surface soil sample than the concentrations for all the on-Site soil samples;

ii) arsenic often exceeded its criteria in both the background (1 of 6) and on-Site groundwater (38 of 80 locations) and in the on-Site saturated soil (13 of 93);

iii) the primary SVOCs with exceedances were PAHs. An exceedance for Benzo(a)pyrene was detected in a background surface soil sample. The background exceedance was less than the on-Site exceedance concentrations; and

iv) the primary VOCs with exceedances were benzene and naphthalene, with benzene being the principal compound.

A summary of the exceedances by parameter group (i.e., metals (other than iron and manganese), VOCs, and SVOCs), and media (i.e., groundwater, surface soil, unsaturated soil, and saturated soil) for each area of the Main Refinery is shown in Table 5.10. As shown in Table 5.10, the areas of the Main Refinery in which the groundwater has the greatest number of exceedances are the MEK Unit (40 of 126) the Crude Unit (22 of 126), and the Dubbs Unit (21 of 126). For these three areas, the metals have the greatest number of exceedances, followed by the SVOCs and then the VOCs. For the soils, the areas with the greatest number of exceedances are the ROSE® Unit (28 of 97), the Dubbs Unit and the Crude Unit Upper Yard (both with 13 of 97), and the Platformer Unit (11 of 97). In the soil, the metals have the greatest number of exceedances followed by the VOCs and then the SVOCs. The unit with only a few exceedances (0 of 126 for groundwater and 8 of 97 for soil) was the Crude Unit Rail Loading.

5.2 ADMINISTRATION, RESEARCH AND DEVELOPMENT AREA (EXPOSURE UNIT 2)

This section presents the analytical results for the Administration, Research and Development Area.

5.2.1 GROUNDWATER

The available data for the EU2 groundwater are provided in Table AD.1 of Appendix AD. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.11 and a summary of those compounds which were detected at concentrations less than or equal to their respective SHS MSCs is provided in Table 5.12. There are analytical results for up to nine wells installed in the Administration, Research and Development Area. The data from these on-Site wells were also compared to the data from 4 background wells.

As shown in Table 5.11, three dissolved metals exceeded their criteria at the background locations. These were aluminum (3 of 4), iron (4 of 4), and manganese (4 of 4). The maximum exceedance concentrations were approximately 14, 139, and 80 times their criteria, respectively. For the on-Site locations, four dissolved metals (aluminum, arsenic, iron, and manganese) and one total metal (iron) exceeded their Act 2 criteria. The number of locations with exceedances were 1 of 8 for aluminum, 4 of 8 for arsenic, and 8 of 8 for iron and manganese. For the three metals with exceedances in both the background and on-Site locations, the maximum exceedance concentrations for the on-Site locations were lower for aluminum, twice as great for iron, and eight times as

great for manganese as the background maximum concentrations. The locations with iron and manganese exceedances are shown on Figures 5.1 and 5.8. The locations for the remaining metals with exceedances are shown on Figures 5.2 and 5.9. As shown on Figures 5.2 and 5.9, the locations with the aluminum and arsenic exceedances occurred along the downgradient boundary of EU2.

No SVOCs were detected at concentrations that exceeded the Act 2 criteria.

For the VOCs, three VOCs were detected in the background samples above their criteria. These were the chlorinated VOCs cis-1,2-dichloroethene (3 of 4), trichloroethene (3 of 4), and vinyl chloride (3 of 4). For the on-Site locations, four VOCs were detected above their criteria. These were benzene (1 of 9) and three chlorinated organics, cis-1,2-dichloroethene (2 of 9), trichloroethene (2 of 9), and vinyl chloride (2 of 9). The lone benzene exceedance concentration was 1.5 times its criteria. For cis-1,2-dichloroethene and vinyl chloride, the maximum on-Site concentration was less than the maximum background concentration whereas for trichloroethene, the reverse was observed. The wells with the maximum chlorinated VOC concentrations were MW-2 and MW-84. These wells are located downgradient of the Pure Seal property which is believed to be the source for the chlorinated organics detected on the Site.

The locations with VOC exceedances are shown on Figures 5.4, 5.11, and 5.12. As shown on these drawings, all of the VOC exceedances occurred in the northern portion of EU2 and are not believed to be Site related.

Table 5.12 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.12 are those petroleum related compounds which were not analyzed for in the EU-2 groundwater but may be present based on their detection in another exposure unit. In summary, 7 metals and 14 VOCs are listed in Table 5.12. No SVOCs are listed in Table 5.12.

5.2.2 SURFACE SOIL

The available data for the EU2 surface soil are provided in Table AD.2 of Appendix AD. Analytical results for 3 locations for metals only are available. No metals were detected at concentrations that exceeded their Act 2 criteria.

Table 5.13 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. In summary, 14 metals are listed in Table 5.13.

5.2.3 UNSATURATED SOILS

The available data for the EU2 unsaturated soil are provided in Table AD.3 of Appendix AD. Analytical results for up to 6 on-Site locations are available. Also, data are available for one background location. No metals, SVOCs, or VOCs were detected at concentrations that exceeded their Act 2 criteria.

Table 5.14 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.14 are those petroleum related compounds which were not analyzed for in the EU-2 unsaturated soil but may be present based on their detection in another exposure unit. In summary, 12 metals, 13 SVOCs, and 9 VOCs are listed in Table 5.14.

5.2.4 SATURATED SOILS

The available data for the EU2 saturated soil are provided in Table AD.4 of Appendix AD. Analytical results for up to 6 on-Site locations are available. Also, results are available for one background location. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.15. The only metal with an exceedance was lead (1 of 4) with the exceedance concentration being approximately 2 times the criteria. No SVOCs or VOCs were detected at concentrations that exceeded their Act 2 criteria.

Table 5.16 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.16 are those petroleum related compounds which were not analyzed for in the EU-2 saturated soil but may be present based on their detection in another exposure unit. In summary, 11 metals, 16 SVOCs (including naphthalene which is also included in Table 5.16 under VOCs), and 9 VOCs are listed in Table 5.16.

5.2.5 SUMMARY

Comparison of the compounds which exceeded their criteria in the groundwater and soil media of EU2 described above show the following:

i) the area has been minimally impacted by Site related activities;

ii) iron and manganese are present above their criteria in both the background and on-Site groundwater. Background concentrations were less than on-Site concentrations;

iii) lead was detected at an exceedance concentration in only the saturated soil and this occurred only at one location and only barely above the criteria;

iv) no SVOCs had exceedances in any of the groundwater or soil media;

v) the only petroleum product based VOC detected in the groundwater was benzene and that was only at one location; and

vi) exceedances of chlorinated organics were detected in the background and on-Site groundwater. The chlorinated organics detected in the groundwater are not attributable to the refinery and are believed to be sourced from the Pure Seal property located upgradient of the Site. The lack of detectable chlorinated organics concentrations in the surface soil, unsaturated soil, and saturated soil support this.

5.3 CRUDE TANK FARM (EXPOSURE UNIT 3)

This section presents the analytical results for the Crude Tank Farm.

5.3.1 GROUNDWATER

The available data for the EU3 groundwater are provided in Table AE.1 of Appendix AE. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.17 and a summary of those compounds detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.18. There are analytical results available for up to 35 wells in the Crude Tank Farm. The data from these on-Site wells were also compared to the data from 3 background wells.

As shown in Table 5.17, two dissolved metals exceeded their criteria in the background locations. These were iron (2 of 3) and manganese (2 of 3). For the on-Site locations,

four dissolved metals exceeded their Act 2 criteria. Manganese (13 of 13) and iron (9 of 14) were the metals with the greatest number of exceedances. The iron and manganese exceedances are shown on Figure 5.8. Arsenic had exceedances at 4 of 29 locations whereas thallium had only 1 exceedance. Three of the four arsenic exceedances were within two times the criteria with one arsenic exceedance 22 times the criteria. The locations of exceedances for these two metals are shown on Figure 5.9. The arsenic exceedances occurred in the vicinity of Tanks 711, 718, and 721 and the thallium exceedance occurred in the Former Rendering area. For the two metals with exceedances in both the background and on-Site locations (iron and manganese), the maximum exceedance concentrations for the on-Site locations were 1.5 and 8 times greater than the background maximum concentration, respectively. It is noted that the primary constituents of the fire extinguishing agents (i.e., magnesium, aluminum, and sodium) described in Section 2.2.2.1 were not detected above their criteria.

No SVOCs were detected at concentrations that exceeded their respective Act 2 criteria.

For the VOCs, four chlorinated VOCs exceeded their criteria in the background locations. These were tetrachloroethene (3 of 3), trichloroethene (3 of 3), cis-1,2-dichloroethene (1 of 3), and vinyl chloride (1 of 3). For the on-Site locations, benzene (9 of 35), ethylbenzene (1 of 36), 1,2,4-TMB (1 of 9), and six chlorinated organics had exceedances. The chlorinated organics were tetrachloroethene (7 of 31), trichloroethene (7 of 31), 1,1-dichloroethene (1 of 31), cis-1,2-dichloroethene (6 of 30), vinyl chloride (6 of 31), and methylene chloride (1 of 31). For the chlorinated VOCs with exceedances in both the background and on-Site locations, the background concentrations are greater than the on-Site concentrations. This supports the expectation that it is an off-Site source that is responsible for these VOCs. The locations with the petroleum related VOC exceedances are shown on Figure 5.11. As shown on Figure 5.11, six of the nine benzene exceedances occurred in the southern portion of the CTF. Two of the remaining benzene exceedances and the single ethylbenzene exceedance occurred in the Fire Training Area. The remaining benzene exceedance occurred in the area of Tank 721. The chlorinated VOCs with exceedances are shown on Figure 5.12. As shown on Figure 5.12, all of the chlorinated VOC exceedance occurred principally in the northern portion of the CTF and in the Fire Training and Former Rendering Plant areas.

Table 5.18 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.18 are those petroleum related compounds which were not analyzed for in the EU-3 groundwater but may be present based on their detection in another exposure unit.

In summary, 10 metals, 17 SVOCs (including naphthalene which is also included in Table 5.18 under VOCs), and 12 VOCs are listed in Table 5.18.

5.3.2 SURFACE SOIL

The available data for the EU3 surface soil are provided in Table AE.2 of Appendix AE. Analytical results for up to 29 on-Site locations are available. The data from these on-Site locations were also compared to the data collected from the 7 background locations. A summary of the compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.19 and a summary of those compounds which were detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.20.

As shown in Table 5.19, only two metals exceeded their Act 2 criteria; arsenic in 3 of 20 locations and lead in 2 of 20 locations. Two of the 3 arsenic locations are in the vicinity of Tank 721 and the third is in the Fire Training Area. The 2 lead locations are in the southern half of the CTF (see Figure 5.13). The maximum exceedance concentrations were 1.7 times the criteria for both metals. Given these minimal and infrequent exceedances of only two metals, metals are not an environmental concern in the surface soils of the CTF. It is noted that the primary constituents of the fire extinguishing agents were not detected above their criteria.

No SVOCs were detected at concentrations which exceeded their respective Act 2 criteria.

Only one VOC (benzene) exceeded its Act 2 criteria in 1 of 29 locations (i.e., CRSS-04, see Figure 5.14). The concentration at this one exceedance location was approximately 11 times the criteria.

Table 5.20 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.20 are those petroleum related compounds which were not analyzed for in the EU-3 surface soil but may be present based on their detection in another exposure unit. In summary, 14 metals, 15 SVOCs, and 10 VOCs are listed in Table 5.20.

5.3.3 UNSATURATED SOIL

The available data for the EU3 unsaturated soil are provided in Table AE.3 of Appendix AE. A summary of the compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.21 and a summary of those compounds which were detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.22. Analytical results for up to 34 on-Site locations are available.

As shown in Table 5.21, only two metals exceeded their Act 2 criteria; arsenic and lead both in 1 of 33 locations with concentrations less than 2 times their criteria. Both exceedances occurred at sample location CR-33, which is adjacent to Tank 721 (see Figure 5.13). The concentrations of the three primary constituents of the fire extinguishing agents were not above their criteria.

No SVOCs were detected at concentrations which exceeded their respective Act 2 criteria.

Only one VOC (benzene) exceeded its Act 2 criteria in 2 of 34 locations. The maximum concentration was approximately 5 times the criteria. Both benzene exceedances occurred in the southern half of the CTF, in the same general area as the surface soil exceedance (see Figure 5.14).

Table 5.22 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.22 are those petroleum related compounds which were not analyzed for in the EU-3 unsaturated soil but may be present based on their detection in another exposure unit. In summary, 13 metals, 11 SVOCs, and 13 VOCs are listed in Table 5.22.

5.3.4 SATURATED SOILS

The available data for the EU3 saturated soil are provided in Table AE.4 of Appendix AE. A summary of the compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.23 and a summary of the compounds detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.24. Analytical results for 11 locations are available.

As shown in Table 5.23, only two metals exceeded their Act 2 criteria; arsenic and lead both in 2 of 11 locations. The maximum concentrations for arsenic and lead were approximately 2.5 and 1.6 times their respective criteria. One of the locations for arsenic

(CR-36B) and both locations for lead (CR-25B and CR-33B) are located adjacent to Tank 721. The other location for arsenic is in the southern part of the CTF (see Figure 5.13). The concentrations of the three primary constituents of the fire extinguishing agents were not above their criteria. No SVOCs were detected at concentrations which exceeded their respective Act 2 criteria. Only one VOC (benzene) exceeded its Act 2 criteria in 1 of 11 locations. The maximum concentration was approximately 1.5 times the criteria. This exceedance occurred in the same location as one of the unsaturated soil exceedances (see Figure 5.14).

Table 5.24 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.24 are those petroleum related compounds which were not analyzed for in the EU-3 saturated soil but may be present based on their detection in another exposure unit. In summary, 13 metals, 2 SVOCs, and 7 VOCs are listed in Table 5.24.

5.3.5 SUMMARY

Comparison of the compounds which exceeded their criteria in the groundwater and soil media of EU3 described above show the following:

i) this area has been minimally impacted;

ii) iron and manganese are present above their criteria in both the background and on-Site groundwater and are the only metals in groundwater which had exceedances at more than 4 locations. Background concentrations were less than on-Site concentrations;

iii) arsenic and lead were detected above their Act 2 criteria in the on-Site groundwater (arsenic only), surface soil, unsaturated soil, and saturated soil, although in a minimal number of locations. No exceedances above criteria were detected for these compounds in the background samples;

iv) no SVOCs had exceedances in any of the groundwater and soil media;

v) the primary petroleum product based VOC detected above criteria was benzene and only at very few locations;

vi) the majority of the metals and petroleum related organic compound exceedances occur in the vicinity of Tank 721 and the area of the January and March 2004 Transfer Pump Area Crude Oil spills; and

vii) the chlorinated organics detected are not attributable to the refinery.

5.4 FOSTER BROOK FACILITY SOUTH (EXPOSURE UNIT 4)

This section presents the analytical results for the southern portion of the Foster Brook Facility.

5.4.1 GROUNDWATER

The available data for the EU4 groundwater are provided in Table AF.1 of Appendix AF. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.25 and a summary of those compounds detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.26. There are analytical results for up to 78 wells installed in the southern section of the Foster Brook Facility, as well as 11 wells installed off-site and downgradient of this exposure unit and two test pits installed upgradient of this exposure unit. The data from these on-Site wells were also compared to the data from up to four background wells.

As shown in Table 5.25, two dissolved metals exceeded their criteria in the background locations. These were iron (1 of 1) and manganese (1 of 1). For the on-Site locations, four total metals (arsenic, iron, lead, and thallium) and seven dissolved metals (aluminum, arsenic, iron, lead, manganese, thallium, and zinc) exceeded their respective Act 2 criteria. For the off-site downgradient locations, four dissolved metals had exceedances; aluminum (2 of 11), arsenic (2 of 11), iron (9 of 11), and manganese (10 of 11).

For the on-site wells, the total metals lead and thallium had only one location with an exceedance, whereas arsenic was 4 of 9 and iron was 3 of 4. The maximum concentrations ranged from 1.4 (arsenic) to 40 (iron) times their criteria. The dissolved metals thallium and zinc had only one location out of 66 with an exceedance. Lead and aluminum had only 2 of 66 and 5 of 64 locations, respectively, with an exceedance. The maximum concentrations for lead and thallium were approximately 1.2 times their criteria whereas for aluminum and zinc, it was 4 times. Arsenic (32 of 66), iron (63 of 64), and manganese (63 of 64) were the principal metals with exceedances. The maximum concentrations were 5, 680, and 560 times their respective criteria.

The iron and manganese exceedances are shown on Figure 5.15. The remaining metals with exceedances are shown on Figure 5.16. The majority of the arsenic exceedances (15 of 32) occurred in the Light End Tank Farm. The areas with the greatest total number of

metal exceedances were the Light End Tank Farm (19 of 41) and the Former Burn Pit Area (5 of 41). The remaining areas of EU4 had 1 to 4 exceedances each. The two off-site locations with arsenic exceedances are downgradient of the Light End Tank Farm/Former Impoundment Area. The number of locations with exceedances for each EU4 area are presented below.

	Groundwater – Metals – EU4					
	Al	*As*	*Pb*	*Th*	*Zn*	*Total*
Bulk Haul Loading Area		2				2
Light End Tank Farm	1	15	1	1	1	19
Downgradient of Light End Tank Farm/Former Impoundment Area		2				2
Barrel House		1				1
Former Impoundment Area	2	2				4
Independent Production Area North		1				1
Garage/Shed Area		2				2
Bauxite Fill		2	1			3
Fly Ash Area						
Former Burn Pit Area	2	3				5
Crude Rail Unloading		2				2
	5	32	2	1	1	41

For the two metals with exceedances in both the background and on-Site locations (iron and manganese), the maximum concentrations for the on-Site locations were 60 (iron) and 20 (manganese) times greater than the background locations.

For the SVOCs, no exceedances were detected in either the background or off-site downgradient locations except for naphthalene at one downgradient location. Ten compounds exceeded their respective Act 2 criteria in the on-site locations. All ten compounds are PAHs and had five or fewer locations with exceedances except for naphthalene which had 11 of 66. The maximum concentration ranged from 1.3 (pyrene) to 20 times (dibenzo(a,h)anthracene) their criteria. As shown on Figure 5.17, 13 of the 26 exceedances (not including naphthalene) occurred in the Former Burn Pit Area five occurred in one location in the Garage/Shed Area and the remaining eight occurred in the area of the 1991 crude oil pipeline spill.

For the VOCs, eight and six compounds exceeded their respective Act 2 criteria for the on-Site and downgradient wells, respectively. For the on-Site wells, seven of the eight

are related to petroleum products. These were identified as 1,2,4-TMB (1 of 3), benzene (43 of 80), ethylbenzene (13 of 80), naphthalene (10 of 72), methyl tert butyl ether (7 of 64), toluene (5 of 80), and total xylenes (4 of 78). The other compound detected on-site was the chlorinated organic 1,2-dichloroethane (7 of 73). The maximum concentrations for the petroleum related compounds ranged from 1.1 times (total xylenes) to 4500 times (benzene) and 5300 times (MTBE) their respective criteria. For the chlorinated organic 1,2-dichloroethane, the maximum concentration was 30 times greater.

For the off-Site downgradient wells, all six compounds with exceedances are related to petroleum products. These were: 1,2,4-TMB (1 of 4), 1,3,5-TMB (1 of 4), benzene (5 of 11), ethylbenzene (1 of 11), naphthalene (1 of 11), and total xylenes (1 of 11). The maximum concentrations for 1,2,4-TMB, 1,3,5-TMB, ethylbenzene, naphthalene, and total xylenes were greater in the downgradient locations than for the on-Site locations. The maximum off-Site benzene concentration was less than the on-Site locations.

The locations with VOC exceedances are shown on Figure 5.18. The majority of the on-site exceedances (45 of 91) occurred in the Light End Tank Farm. The areas with the next greatest number of VOC exceedances were the Former Burn Pit area (16 of 91) and the Garage/Shed area (14 of 91). The remaining areas of EU4 had 0 to 9 exceedances each. The number of locations with exceedances are presented below.

On-Site Groundwater – VOCs

	Benzene	*Ethylbenzene*	*MTBE*	*1,2,4-TMB*	*Naphthalene*	*Toluene*	*Xylene*	*1,2-DCA*	*Total*
Bulk Haul Loading Area	2								2
Light End Tank Farm	15	6	7		5	5	2	5	45
Barrel House	1			1					2
Former Impoundment Area	7	1			1				9
Independent Production Area North									0
Garage/Shed Area	5	2			4		1	2	14
Bauxite Fill	3								3
Fly Ash Area									NS
Former Burn Pit Area	8	4			3		1		16
Crude Rail Unloading									0
	41	13	7	1	13 (1)	5	4	7	91

NS – Not Sampled.

(1) The sum of naphthalene exceedances does not equal the sum of 21 of 136 in Table 5.25 because some of the same locations were analyzed by both SVOC and VOC methods.

Table 5.26 shows the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.26 are those petroleum related compounds which were not analyzed for in the EU4 groundwater but may be present based on their detection in another exposure unit. In summary, 12 metals, 16 SVOCs, and 15 VOCs are listed in Table 5.26.

5.4.2 SURFACE SOIL

The available data for the EU4 surface soils are provided in Table AF.2 of Appendix AF. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.27 and a summary of those compounds detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.28. Analytical results for up to 40 on-Site locations are available.

As shown in Table 5.27, three metals exceeded their respective Act 2 criteria in the on-Site locations. These were antimony (5 of 34), lead (3 of 34), and selenium (3 of 34). The maximum concentrations were 20, 3, and 1.5 times the criteria for antimony, lead, and selenium, respectively. All five of the antimony and three of the five lead exceedances occurred in the Light End Tank Farm (see Figure 5.19). The remaining lead exceedance occurred in the Former Burn Pit Area. All three of the selenium exceedances occurred in the Former Burn Pit Area.

No SVOC exceeded its Act 2 criteria.

For the VOCs, one compound (benzene) exceeded its Act 2 criteria in one on-Site location at approximately 3 times its criteria.

For the off-Site downgradient locations, two metals exceeded their respective SHS MSC; lead (2 of 7) and selenium (2 of 7). All exceedances were downgradient of the Former Burn Pit Area.

With regard to SVOCs, only benzo(a)pyrene exceeded its criteria at one location by approximately twice its criteria.

For the VOCs, seven compounds exceeded their respective SHS MSC. Four of the seven are related to petroleum products and were 1,2,4-TMB (2 of 4), 1,3,5-TMB (2 of 4), benzene (1 of 7), and naphthalene (1 of 4). The maximum concentrations of these four compounds were 10, 15, 11, and 4 times greater than their respective criteria. The other three compounds were the chlorinated organics 1,1-dichloroethane (1 of 7), 1,2-dichloroethane (1 of 7), and 1,1,1-trichloroethane (1 of 7). The maximum concentrations of these three compounds were 3, 10, and 1.7 times greater than their respective criteria.

As shown on Figure 5.21, all of the surface soil SVOC and VOC exceedances occurred in or downgradient of the Former Burn Pit Area, except for 1 benzene exceedance which occurred in the Light End Tank Farm.

Table 5.26 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.26 are those petroleum related compounds which were not analyzed for in the EU4 surface soil but may be present based on their detection in another exposure unit. In summary, 18 metals, 16 SVOCs (including naphthalene which also exceeded its SHS MSC when analyzed as a VOC), and11 VOCs are listed in Table 5.28.

5.4.3 UNSATURATED SOILS

The available data for the EU4 unsaturated soil are provided in Table AF.3 of Appendix AF. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.29 and a summary of those compounds detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.30. Analytical results for up to 115 on-Site locations are available. In addition, analytical results are available for select VOCs at one background location.

As shown in Table 5.29 for the on-Site locations, four metals exceeded their respective Act 2 criteria. These were arsenic (1 of 89), lead (3 of 89), selenium (1 of 89), and mercury (1 of 89). The maximum concentrations of these four metals were 4, 1.2, 1.4, and 3 times greater than their respective criteria. The one arsenic exceedance, one mercury exceedance, and three lead exceedances occurred in the Garage/Shed Area (see Figure 5.19). The selenium exceedance occurred in the Former Burn Pit Area.

For the SVOCs, only naphthalene (4 of 67) and benzo(a)pyrene (3 of 92) exceeded their respective Act 2 criteria. The maximum concentrations of these two compounds were 10

and 5 times greater than their respective criteria. All exceedances occurred in the Garage/Shed area.

For the VOCs, seven compounds exceeded their respective Act 2 criteria. Six of the seven are related to petroleum products and were identified as 1,2,4-TMB (1 of 4), 1,3,5-TMB (1 of 4), benzene (38 of 115), ethylbenzene (6 of 115), naphthalene (6 of 110), and toluene (3 of 115). The maximum concentrations of these five compounds were 8, 20, 290, 2, 190, and 3.5 times greater than their respective criteria. The other compound was the chlorinated organic methyl chloride (2 of 24) with a maximum concentration of 5 times greater than its criteria.

For the off-Site downgradient locations, two metals exceeded their respective SHS MSC; lead (1 of 14) and selenium (2 of 14). All exceedances were downgradient of the Former Burn Pit Area.

No SVOCs were detected in exceedance of their respective SHS MSC. For the VOCs, four compounds exceeded their respective SHS MSC; 1,2,4-TMB (3 of 4), 1,3,5-TMB (3 of 4), benzene (5 of 9), and ethylbenzene (2 of 14). The maximum off-Site concentrations for all four compounds were less than the maximum on-Site concentrations. All exceedances were downgradient of the Former Burn Pit Area.

As shown on Figure 5.21, the greatest number of exceedances (34 of 58) occurred in the Light End Tank Farm. The Garage/Shed Area had the next greatest number of exceedances with 13.

Table 5.30 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.30 are those petroleum related compounds which were not analyzed for in the EU4 unsaturated soil but may be present based on their detection in another exposure unit. In summary, 18 metals, 18 SVOCs, and 18 VOCs are listed in Table 5.30.

5.4.4 SATURATED SOIL

The available data for the EU4 saturated soil are provided in Table AF.4 of Appendix AF. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.31 and a summary of those compounds detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.32. Analytical results are available for up to 52 on-Site locations.

As shown in Table 5.31, two metals exceeded their Act 2 criteria in on-Site locations. These were arsenic (3 of 24) and lead (1 of 24). The maximum concentration of arsenic and lead were 2.5 and 1.1 times greater than their criteria. One arsenic exceedance occurred in each of the Light End Tank Farm, the Former Impoundment Area, and the Bauxite Fill Area and the lead exceedance occurred in the Band House Area (see Figure 5.19).

For the SVOCs, six compounds exceeded their respective Act 2 criteria. All six compounds were PAHs and had two or fewer locations out of 54 with exceedances except for naphthalene (11 of 42). The maximum concentrations of these six compounds were 1.2, 5, 2.1, 1.6, 3, and 19 times greater than their respective criteria. All exceedances occurred in the Garage/Shed Area (see Figure 5.20).

For the VOCs, four compounds exceeded their respective Act 2 criteria. These were benzene (10 of 40), ethylbenzene (1 of 40), naphthalene (2 of 25), and toluene (1 of 40). The maximum concentrations of these four compounds were 240, 2.2, 1.6, and 4 times greater than their respective criteria.

For the off-Site downgradient locations, one metal (lead) exceeded its SHS MSC at one of nine locations. The exceedance was 8 times its criteria.

With regard to SVOCs, only naphthalene exceeded its SHS MSC at one of nine locations. The exceedance was 3 times its criteria.

For the VOCs, benzene (1 of 9) and naphthalene (1 of 9) had exceedances 32 and 5 times their respective criteria.

As shown on Figure 5.21, the greatest number of exceedances again occurred in the Light End Tank Farm (9 of 24), Garage/Shed Area (8 of 24), and the Former Burn Pit Area (4 of 24). A summary of the exceedance locations is presented on the following page.

Table 5.32 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.32 are those petroleum related compounds which were not analyzed for in the EU4 saturated soil but may be present based on their detection in another exposure unit. In summary, 18 metals, 12 SVOCs, and 6 VOCs are listed in Table 5.32.

5.4.5 SOIL GAS

Soil gas samples were collected in October 2003 from probes installed around the Foster Brook Gas Blending Office. This location for testing was selected due to the presence of the SPL floating on the groundwater table in this area and the fact that this building is routinely occupied (although not for an entire 8 hours/day) by Site workers. Thus, the exposure potential for the workers in this building exemplifies a worst case scenario for this area of the Site. Of the 8 gas probes installed around this office building, only 6 probes were sampled as the remaining 2 probes encountered the groundwater table. Additional soil gas samples were collected in March 2004 from 3 of the 8 probes to confirm the October 2003 results. The available data for the soil gas samples are provided in Appendix W. A summary of the compounds detected is provided in Table 3.20. As shown in Table 3.20, the compounds detected in the Foster Brook Facility office soil gas samples were benzene, cyclohexane, ethylbenzene, xylenes, methyl cyclohexane, and toluene at relatively elevated concentrations. It is believed these elevated concentrations are due to the refined light end products handled in this area of the Foster Brook Facility, some of which are present as SPL on the groundwater table. Further discussion of the soil gas results is presented in Section 6.0 of this SCR.

Volatile Organic Compounds
On-Site Surface/Unsaturated/Saturated Soil (EU-4) (1)

	Benzene	*Ethylbenzene*	*Naphthalene* (2)	*Toluene*	*1,2,4-TMB*	*1,3,5-TMB*	*Chloromethene*	*Total*
Bulk Haul Loading Area								0/0/0
Light End Tank Farm	1/25/4	0/3/0	0/2/5	0/3/0				1/33/9
Barrel House								
Former Impoundment Area	0/4/0	0/1/0	0/0/1					0/5/1
Independent Production Area								0/0/0
North Garage/Shed Area	0/6/2	0/1/1	0/4/5	0/0/1	0/1/0	0/1/0		0/13/9
Bauxite Fill	0/0/1	0/1/0						0/1/1
Fly Ash Area								0/0/0
Former Burn Pit Area	0/0/3		0/0/1				0/2/0	0/2/4
Crude Rail Unloading	0/3/0		0/0/1					0/3/1
	1/38/10	0/6/1	0/6/13	0/3/1	0/1/0	0/1/0	0/2/0	1/57/25

Notes:

(1) 0/1/4 - number of exceedances in surface soil/unsaturated soil/saturated soil.
(2) This sum of locations with naphthalene exceedances is less than the sample of locations from Table 5.16 because some samples were analyzed by both VOC and SVOC methods.

5.4.6 SUMMARY

Comparison of the compounds which exceeded their criteria in the groundwater and soil media of EU4 show the following:

i) there are three primary areas of EU4 that have been impacted; the Light End Tank Farm, the Former Burn Pit Area, and the Garage/Shed Area;

ii) iron and manganese are present above their criteria in both the background and on-Site groundwater. Background concentrations were less than on-Site concentrations;

iii) arsenic is the only other metal which had exceedances in the groundwater at the majority of the locations. No exceedances of the arsenic criteria were detected in the background sample;

iv) the primary SVOCs detected were the PAHs benzo(a)pyrene and naphthalene; and

v) the primary petroleum based VOCs detected were benzene and naphthalene.

A summary of the exceedances by parameter group and media for each area within the Foster Brook South is shown in Table 5.33. As shown in Table 5.33, the areas of Foster Brook South in which the groundwater has the greatest number of exceedances are the Light End Tank Farm (64 of 157), the Former Burn Pit Area (33 of 157), and the Garage/Shed Area (21 of 157). The primary parameter group with exceedances are the VOC which is consistent with the light end petroleum products handled in the Foster Brook Facility South.

For the soils, the same three areas have the greatest number of exceedances, with the Former Burn Pit (11 of 122), the Light End Tank Farm (52 of 122), and the Garage/Shed Area (36 of 122). Again, the VOCs have the greatest number of exceedances.

5.5 FOSTER BROOK FACILITY NORTH (EU EXPOSURE UNIT 5)

This section provides the analytical results for the northern portion of the Foster Brook Facility.

5.5.1 GROUNDWATER

The available data for the EU5 groundwater are provided in Table AG.1 of Appendix AG. A summary of those compounds which exceeded their respective non-residential SHS MCS is provided in Table 5.34 and a summary of those compounds detected at concentrations less than or equal to their respective SHS MSC is provided in Table 5.35. There are analytical results for up to 9 wells installed in the northern section of the Foster Brook Facility. The data from these on-Site wells were also compared to the data from two background wells.

As shown in Table 5.34, three dissolved metals exceeded their criteria at the background locations. These were iron (2 of 2), manganese (2 of 2), and aluminum (1 of 2). For the on-Site locations, four total metals (beryllium, cadmium, lead, and nickel) and five dissolved metals (aluminum, beryllium, iron, manganese, and nickel) exceeded their respective Act 2 criteria. For the total metals, only nickel (3 of 6) had an exceedance at more than one location. The maximum concentration for the total metals was approximately 2 times greater than their respective criteria. The dissolved metals with an exceedance of more than one location were iron (3 of 3) and manganese (3 of 3). For the three metals with exceedances in both the background and on-Site locations, the maximum on-Site concentrations were 19, 1, and 7 times those of the background locations for aluminum, iron, and manganese, respectively.

The iron and manganese exceedances are shown on Figure 5.15. The remaining metals with exceedances are shown on Figure 5.16. As shown on Figure 5.16, all the metal exceedances occurred within the central portion of EU5.

No SVOCs were detected at concentrations which exceeded their Act 2 criteria.

For the VOCs, two compounds exceeded their respective Act 2 criteria in on-Site locations. They were both chlorinated organics; methylene chloride (1 of 11) and trichloroethane (2 of 11). The maximum concentrations were 1.2 and 9 times greater than their respective criteria. Similar to the metal exceedances, these occurred in the central portion of EU5.

Table 5.35 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. In summary, 6 metals and 3 VOCs are listed in Table 5.35.

5.5.2 SURFACE SOIL

The available data for the EU5 surface soil are provided in Table AG.2 of Appendix AG. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.36. Analytical results for up to 28 on-Site locations are available.

As shown in Table 5.36, three metals exceeded their respective Act 2 criteria at on-site locations. These were arsenic (2 of 28), lead (1 of 28), and thallium (1 of 28). The maximum concentrations were 1.6, 1.1, and 1.5 times greater than their respective criteria. All of these exceedances occurred in the Container Removal area, with 3 of the 4 exceedances occurring at RAS-19 (see Figure 5.19).

No SVOCs or VOCs were detected at concentrations which exceeded their Act 2 criteria.

Table 5.37 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. In summary, 18 metals, 12 SVOCs, and 8 VOCs are listed in Table 5.37.

5.5.3 UNSATURATED SOIL

The available data for the EU5 unsaturated soil are provided in Table AG.3 of Appendix AG. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.38. Analytical results are available for up to 25 on-Site locations.

As shown in Table 5.38, two metals exceeded their respective Act 2 criteria. These were arsenic (1 of 25) and lead (1 of 25). For arsenic, the maximum concentration was 1.3 times its criteria and for lead it was 2.5 times its criteria. Both exceedances occurred at the same location (FBCD-11A) located on the border between the Construction Debris Area and Refuse Area (see Figure 5.19).

No SVOCs or VOCs were detected at concentrations which exceeded their Act 2 criteria.

Table 5.39 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. In summary, 18 metals, 11 SVOCs, and 8 VOCs are listed in Table 5.39.

5.5.4 SATURATED SOIL

The available data for the EU5 saturated soil are provided in Table AG.4 of Appendix AG. A summary of those compounds which exceeded their respective non-residential SHS MSC is provided in Table 5.40. Analytical results are available for up to 11 on-Site locations.

As shown in Table 5.40, five metals exceeded their respective Act 2 criteria. These were arsenic (6 of 11), lead (2 of 11), cadmium (1 of 11), mercury (1 of 11), and nickel (1 of 11). The maximum concentrations were 2.9, 10, 4, 3, and 1.6 times greater than their respective criteria. The locations with arsenic (6 of 6) exceedances occurred in an area which included the northern portion of the Refuse area and the adjoining southern portion of the Construction Debris area. The single exceedances of cadmium, mercury, and nickel and the 2 lead exceedances also occurred in this area, with 4 of these 5 exceedances occurring at one location (FBCD-11B).

No SVOCs or VOCs were detected at concentrations which exceeded their Act 2 criteria.

Table 5.41 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. In summary, 15 metals, 7 SVOCs, and 8 VOCs are listed in Table 5.41.

5.5.5 SUMMARY

Comparison of the compounds which exceeded their criteria in the groundwater and soil media of EU5 show the following:

i) this area has been minimally impacted;

ii) iron and manganese are present above their criteria in both the background and on-Site groundwater. The iron background concentration was greater than the on-Site concentrations whereas the manganese background concentration was less than on-Site concentrations;

iii) the exceedances for the other metals occurred at only a few locations, primarily in the container removal area, and the exceedances were generally less than two times their Act 2 criteria; and

iv) no SVOCs or VOCs were detected at concentrations greater than their Act 2 criteria.

5.6 PACKAGING PLANT (EXPOSURE UNIT 6)

This section provides the analytical results for the Packaging Plant.

5.6.1 GROUNDWATER

The available data for the EU6 groundwater are provided in Table AH.1 of Appendix AH. A summary of those compounds which exceeded their respective residential SHS MSC is provided in Table 5.42. There are analytical results for 9 wells installed at the Packaging Plant. The data from these on-Site wells were also compared to the data from the one background well.

As shown in Table 5.42, two dissolved metals exceeded their respective Act 2 criteria in both background and on-site locations. These were iron (1 of 1 for background, 7 of 9 for on-site) and manganese (1 of 1 for background, 8 of 9 for on-site). The maximum on-site concentrations were 80 and 610 times their respective criteria. The maximum on-site concentrations for iron and manganese were 2 and 20 times greater, respectively, than the maximum background concentrations. The locations with iron and manganese exceedances are shown on Figure 5.8.

No SVOCs were detected at concentrations which exceeded their Act 2 criteria.

Three VOCs exceeded their respective Act 2 criteria. These were the chlorinated organics trichloroethene (7 of 9), cis-1,2-dichloroethene (4 of 9), and vinyl chloride (5 of 9). The maximum concentrations were 30, 6, and 30 times their respective criteria. The VOCs with exceedances are shown on Figure 5.12. The VOC concentrations are greater in the area of SPL presence, in the area of the northeast corner of the Packaging Plant.

To determine the potential source of the chlorinated solvents, ARG conducted a review of their purchasing records. A copy of the letter from ARG describing the review is included in Appendix K. The review identified that two 55-gallon drums of TCE were purchased for the Platformer Unit (EU1) in 2001 and again in 2003. No record regarding the use or storage of chlorinated solvents in the Packaging Plant was found. Thus, it is unlikely that refinery operations are the source of the chlorinated solvents detected beneath the Packaging Plant.

ARG/Chemtura are of the opinion that the electronics facility located upgradient and west of the Packaging Plant is a likely source of the chlorinated VOCs based on the

recognized use of large quantities of chlorinated VOCs by the electronics industry. Rather than pursue the installation of additional off-site wells, SSSs have been developed for the chlorinated solvents to demonstrate that further characterization in the Packaging Plant area is not needed. The SSSs and their development are presented in Appendix M of the HHRA. As shown in Tables M58 and M61 of the HHRA, the SSSs are significantly greater than the measured concentrations. Thus, no additional characterization of the chlorinated VOCs is needed.

Table 5.43 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.43 are those petroleum related compounds which were not analyzed for in the EU6 groundwater but may be present based on their detection in another exposure unit. In summary, 8 metals, 4 SVOCs, and 9 VOCs are listed in Table 5.43.

5.6.2 SURFACE SOIL

No historic surface soil samples were collected. During the SSD, no impacts were observed at ground surface. Thus, no surface soil samples were collected during the SSD.

5.6.3 UNSATURATED SOIL

The available data for the EU6 unsaturated soil are provided in Table AH.2 of Appendix AH. Analytical results are available for 5 locations.

No metals, SVOCS, or VOCs were detected at concentrations which exceeded their Act 2 criteria.

Table 5.44 presents the compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.44 are those petroleum related compounds which were not analyzed for in the EU6 unsaturated soil but may be present based on their detection in another exposure unit. In summary, 14 metals, 2 SVOCs and 1 VOC are listed in Table 5.44.

The lack of chlorinated VOC results in the unsaturated soil samples supports the position that these compounds were not sourced from the Packaging Plant.

5.6.4 SATURATED SOIL

No historic saturated soil samples were collected. During the SSD, no potentially impacted soil was observed in the saturated zone soils. Thus, no saturated samples were collected during the SSD.

5.6.5 SUMMARY

Comparison of the compounds which exceeded their criteria in the groundwater and soil media of EU6 show the following:

i) this area has been minimally impacted;

ii) the only media with Act 2 exceedances was the groundwater;

iii) the only metals with exceedances were iron and manganese and in both the background and on-Site groundwater. The background concentrations were less than the on-Site concentrations;

iv) no SVOCs were detected at concentrations greater than their Act 2 criteria; and

v) only three VOCs were detected at concentrations greater than their Act 2 criteria and these were chlorinated organics not attributable to the refinery.

5.7 TUNUNGWANT CREEK (EXPOSURE UNIT 7)

This section provides the analytical results for Tunungwant Creek and its tributaries.

5.7.1 SURFACE WATER

The available data for the EU7 surface water are provided in Table AI.1 of Appendix AI. A summary of those compounds which exceeded the more stringent of the Chapter 16 or Chapter 93 Water Quality Criteria or Act 2 residential groundwater SHS MSC is provided in Table 5.45. The surface water concentrations presented in Tables 5.45 and 5.47 are the actual sample concentrations. The conversion of the May 2005 concentrations to concentrations under 7Q10 flow conditions is presented in Section 6.0. Because the flow conditions in the Creek were above that allowed by PADEP to produce an accurate assessment of the impact of Site conditions on the surface water data, surface water samples were not collected until May 2005. At the time, the flow in the Creek was 96.4 cfs, which was below the agreed upon flow of 96.6 cfs. For the August 2006

sampling event, the flow in the Creek over the two days of sample collection ranged from 39.8 to 44.7 cfs. The surface water data include the results of samples collected in 1997, 1999, and 2000 which is prior to the initiation of pumping of the horizontal groundwater recovery wells. Surface water conditions in the post horizontal well operation era (after January 2003) are expected to have improved.

The surface water samples were collected from up to 54 locations along the length of the Site. These data were also compared to data available from 18 upstream (background) locations.

As shown in Table 5.45, for the samples up to and including May 2005 three total metals exceeded their criteria at the background locations. These were aluminum (4 of 16), beryllium (1 of 18), and thallium (1 of 18). In the August 2006 samples, two metals exceeded their criteria at the background location. These were aluminum (1 of 9) and manganese (9 of 9). For the on-Site locations, for the samples up to and including May 2005 the total metals aluminum (7 of 46) and iron (1 of 46) exceeded their respective criteria. The location with the single iron exceedance of 2.2 mg/L is immediately downstream of the outfall from the ARG wastewater treatment plant. At the time of sample collection (i.e., August 2000) the treatment plant had a permitted discharge limit of 7.0 mg/L. For the August 2006 samples, total iron (1 of 20) and total manganese (20 of 20) exceeded their respective criteria. The lone iron exceedance was adjacent to the Creek's east bank just downstream of the Bolivar Drive bridge.

The maximum concentrations in May 2005 for aluminum and iron were 5 and 1.4 times greater than their respective criteria. For these two metals, the Site reach maximum concentrations were 1.8, and 2.2 times greater than the background maximums, respectively. It is noted that for the May 2005 surface water samples, the only total metal with an exceedance was aluminum and only at one upstream location.

For the May 2005 dissolved metals at the background locations, manganese (7 of 9) and mercury (3 of 9) were in exceedance of their criteria. For the August 2006 samples of dissolved metals at the background locations, only manganese (6 of 9) was in exceedance of its criteria. For the on-Site locations in May 2005, dissolved iron (3 of 20) and manganese (17 of 20) were in exceedance with the maximum concentrations (0.354 and 0.177 mg/L, respectively) only slightly greater than their criteria (0.3 and 0.05 mg/L, respectively).

The metals exceedances are shown on Figures 5.22, 5.23, and 5.24 for the Main Refinery, Crude Tank Farm/Packaging Plant, and Foster Brook Facility, respectively. The

comparison for the metals with exceedances in both the background and Site locations (i.e., aluminum and manganese) for the May 2005 samples is presented in Table 5.46.

With regard to the SVOCs in May 2005, five and eight compounds were in exceedance of their respective SHS MSC for the background and on-Site locations, as listed below. For the August 2006 SVOCs, 13 and eight compounds exceeded their criteria for the background and on-Site locations.

	Background		*On-Site*	
Compound	*May 2005 and earlier*	*August 2006*	*May 2005 and earlier*	*August 2006*
2,6-Dinitrotoluene		2 of 9		
3,3'-Dichlorobenzidene		1 of 9		
Benzo(a)anthracene	5 of 18	3 of 9	5 of 54	2 of 20
Benzo(a)pyrene	1 of 18	2 of 9	1 of 54	1 of 20
Benzo(b)fluoranthene	1 of 18	3 of 9	2 of 54	3 of 20
Benzo (g,h,i) perylene		2 of 9		
Benzo(k)fluoranthene		2 of 9	1 of 54	1 of 20
Bis(2-ethylhexyl) phthalate		1 of 9		5 of 20
Chrysene	1 of 19	3 of 9	3 of 54	3 of 20
Dibenz(a,h)anthracene		2 of 9	1 of 54	
Hexachlorobenzene		3 of 9	2 of 20	2 of 20
Indeno(1,2,3-cd)pyrene	1 of 18	2 of 9	1 of 54	
Pentachlorophenol		2 of 9		1 of 20

A summary of the SVOC concentrations by creek/tributary for those compounds with exceedances in both the May 2005 and August 2006 results are provided in Table 5.46. As shown in Table 5.46 and Figure 5.25, all eight of the SVOCs with exceedances in May 2005 were being discharged from the Dresser Outfall at concentrations approximately 2 to 3 times those detected in Tunungwant Creek. In August 2006 only pentachlorophenol was in exceedance in the Dresser Outfall discharge. The only SVOC with exceedances in the upstream Tunungwant Creek reaches in May 2005 was benzo(a)anthracene. For the August 2006 upstream samples, the number of SVOCs with exceedance increased to 12 with significant increases in concentration. The SVOCs detected in the Tunungwant Creek reaches adjacent to the Site in May 2005 were benzo(a)anthracene, benzo(b)fluoranthene, and chrysene. All the exceedances occurred at sample transect SW-007, located just upstream of the confluence of Bolivar Run with Tunungwant Creek. The Site reach sample concentrations were greater than the upstream sample concentrations. In the August 2006 samples, five PAHs had

concentrations in exceedance at sample location SW-004A located downstream of the Kendall Avenue bridge. The concentrations at this location were less than the upstream background concentrations. For Kendall Creek and Bolivar Run, the only SVOC in exceedance in May 2005 was benzo(a)anthracene with the upstream concentrations being greater than the downstream concentrations for both tributaries. In August 2006, no SVOCs were in exceedance at any of these four locations. This demonstrates that the Site is not impacting these tributaries for these compounds. No SVOCs were in exceedance in the CTF tributary in May 2005. In the August 2006 samples, four SVOCs were in exceedance. These SVOCs may be attributable to the diesel release reported in May 2004 by ARG. While these SVOCs were present in the CTF tributary, they were not detected in the flow of Tunungwant Creek downstream of the tributary. This demonstrates that their presence in the tributary is of minimal consequence.

With regard to Foster Brook, no SVOCs were in exceedance in either the upstream or mouth of Foster Brook sampling locations in May 2005. For the August 2006 samples, four SVOCs were in exceedance in both the upstream and mouth of Foster Brook sampling locations. The concentrations in the upstream and mouth samples were essentially the same indicating no or very minimal contributions from the Site.

With regard to VOCs, only 2 chlorinated organics, methylene chloride and PCE, had exceedances in May 2005. All of the PCE exceedances, except for one, occurred along the east bank samples adjacent to and downstream of the north end of the Crude Tank Farm. For the August 2006 samples, PCE was again in exceedance in the same area at increased concentrations. This pattern is consistent with the large plume of chlorinated organics in the groundwater as shown on Figure 5.35. The remaining PCE exceedance in May 2005 was in the mouth of Foster Brook and in August 2006 was in the middle sample of the most downstream location (i.e., SW-13B). The two methylene chloride exceedances occurred in the west bank and middle samples at the most downstream location (i.e., SW-013A and SW-013B). No methylene chloride exceedances were detected in August 2006. Considering no other surface water samples including the sample closest to the Site at the most downstream location (i.e., SW-13A) had no exceedance for methylene chloride in 2005, supports that this parameter is not attributable to the Site.

The total petroleum hydrocarbon results are also summarized in Table 5.46. As shown in Table 5.46, TPH concentrations in the upstream Creek locations and all tributaries were non-detect in May 2005. In August 2006, TPH was detected in upstream samples and in the mouth of Kendall Creek. In the Site reach samples in May 2005, the concentrations ranged from non-detect to 0.38 mg/L, with all detectable concentrations occurring in the locations adjacent to the west bank (i.e., SW-003A, SW-004A, and

SW-007A). TPH was also detected in the Dresser Outfall at 0.12 and 0.49 mg/L in May 2005 and August 2006, respectively. In August 2006, the TPH concentrations in the Site reach samples ranged from non-detect to 0.20 mg/L, a decrease of a factor of two since May 2005.

The relevance of the May 2005 exceedances is described in Section 6.0.

Table 5.47 presents those compounds detected at concentrations less than or equal to their respective criteria and the concentration range for each compound. In summary, 13 metals (total and dissolved), 3 SVOCs (including naphthalene which is also listed under VOCs in Table 5.47), and 7 VOCs are listed in Table 5.47.

5.7.2 SEDIMENT

The available data for EU7 sediment are provided in Table AI.2 of Appendix AI. A summary of those compounds which exceeded their respective residential direct contact criteria are provided in Table 5.48. Sediment samples were collected from up to 38 locations along the Creek. These data were also compared to the data available from up to 9 background (upstream) locations.

As shown in Table 5.48, arsenic exceeded its criteria in 5 of the 9 background locations. For the on-Site locations, two metals exceeded the Act 2 residential criteria. These were arsenic (25 of 38) and iron (3 of 30). The locations with exceedances are shown on Figures 5.22, 5.23, and 5.24 for the Main Refinery, Crude Tank Farm/Packaging Plant, and Foster Brook Facility, respectively. The maximum concentrations were 10 and 1.3 times their respective criteria. For arsenic which had exceedances at both background and on-Site locations, the on-Site maximum concentration was 4 times greater than the background maximum. The relevance of these exceedances is described in Sections 7.0 (HRA) and 8.0 (ERA).

No SVOCs or VOCs were detected at concentrations in exceedance of their residential Act 2 criteria.

Table 5.49 presents those compounds detected at concentrations less than or equal to their criteria and the concentration range for each compound. In summary, 15 metals, 17 SVOCs (including naphthalene which is also listed as a VOC in Table 5.49), and 16 VOCs are listed in Table 5.49.

5.7.3 SUMMARY

Comparison of the compounds which exceeded their criteria in the surface water and sediment media of EU7 described above show the following:

i) iron and manganese were historically the principal metals with exceedances in the surface water and in both the background and on-Site locations. Total iron and manganese had no exceedances in the May 2005 surface water samples. For the August 2006 samples, total manganese had exceedances at all Site reach locations and total iron in the sample from SW-10C (immediately downstream of the Bolivar Road bridge). The background concentrations were less than the on-Site concentrations;

ii) three PAHs were in exceedance in Tunungwant Creek in May 2005 with the upstream concentrations less than the Site reach concentrations. The exceedances occurred in the sample transect located just upstream of the confluence with Bolivar Run;

iii) in August 2006, eight PAHs were in exceedance in the upstream locations and five PAHs were in exceedance in the Site reach at the sample location downstream of the Kendall Avenue Bridge. The upstream sample concentrations were greater than the Site reach concentrations;

iv) in May 2005 only one PAH was in exceedance in Kendall Creek and Bolivar Run with the upstream concentrations being greater than the concentrations at the mouth of the tributaries. In August 2006, no PAHs were in exceedance at any of these four locations;

v) the CTF tributary had no SVOC exceedances in May 2005. In August 2006, the CTF tributary had four SVOCs in exceedance. These SVOCs were not detected in the downstream area of Tunungwant Creek;

vi) Foster Brook had no SVOC exceedance in May 2005. In August 2006, the upstream location and the mouth each had four SVOCs with exceedances at with similar concentrations. This shows that the exceedances are not Site related;

vii) in May 2005 the Dresser Outfall discharge had 8 SVOCs with exceedances and the concentrations ranged from 2 to 3 times greater than those in the Site reach samples. In August 2006, only pentachlorophenol was in exceedance;

viii) no VOCs, other than chlorinated organics, had exceedances in the surface water samples;

ix) the surface water samples with chlorinated organics were primarily located adjacent to the right bank adjacent to or downstream of the north portion of the CTF;

x) arsenic and iron were the two metals with exceedances in the sediment; and

xi) no VOCs or SVOCs were detected at concentrations above their criteria in the sediments.

5.8 NATIONAL TRANSIT PROPERTY (EXPOSURE UNIT 8)

This section provides the analytical results for the National Transit property. While the National Transit property is not part of the Site, the data are included to allow evaluation of the potential impact of chemical presence on the NT property to the adjacent ARG property and vice versa. Due to the industrial nature of the National Transit property and upgradient railway property, the data for these areas have been compared to non-residential criteria. Even though it has been identified that the two structures on Bolivar Drive are being used for commercial purposes, residential criteria were used for these properties.

5.8.1 GROUNDWATER

The available data for the EU8 groundwater are provided in Tables AJ.1 and AJ.2 of Appendix AJ for the two residential properties and for the remainder of EU8, respectively. Because PQS is preparing the SCR for the National Transit property, this evaluation will focus on the residential and upgradient areas. The on-Site results, not including the 2004 and 2005 results obtained by PQS, will be briefly described to allow comparison with the upgradient results.

With regard to the residential properties, two metals were in exceedance of their respective residential criteria, iron (2 of 2) and manganese (2 of 2) (see Table 5.50). No SVOCs were in exceedance of their criteria. Six VOCs had exceedances of their respective criteria. Five VOCs were related to petroleum products 1,2,4-TMB (2 of 2), 1,3,5-TMB (2 of 2), benzene (3 of 4), ethylbenzene (1 of 4), naphthalene (1 of 4), and total xylenes (1 of 4). The maximum concentrations were 320, 120, 24, 10, and 1.5 times greater than their respective criteria. The remaining VOC is the chlorinated organic tetrachloroethene (1 of 4) locations with a concentration only slightly greater than its criteria (i.e., 0.0061 vs 0.005 mg/L).

Table 5.51 presents those compounds for the residential property samples detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.51 are those petroleum related

compounds which were not analyzed for in the EU8 residential property groundwater but may be present based on their detection in another exposure unit. In summary, 8 metals, 3 SVOCs, and 9 VOCs were listed in Table 5.51.

A summary of those compounds which exceeded their respective non-residential SHS MSC for the upgradient area is provided in Table 5.52. There are analytical results for up to 14 locations. As shown in Table 5.52, two total metals (iron and manganese) exceeded their Act 2 criteria in 2 of 2 upgradient locations. The maximum concentrations were 8 and 4 times greater than their respective criteria. Four dissolved metals (aluminum, iron, lead, and manganese) exceeded their Act 2 criteria in 1 of 6, 5 of 6, 1 of 8, and 5 of 8 upgradient locations, respectively. The maximum concentrations were 38, 160, 9, and 12 times greater than their respective criteria.

For the SVOCs in the upgradient locations, ten compounds had exceedances with all compounds having two or fewer exceedances except for benzo(a) pyrene which had 4 of 12. The maximum concentrations ranged from 1.2 (pyrene) to 1500 (benzo(a) pyrene) times greater than their respective criteria.

With regards to the VOCs in the upgradient locations, three compounds had exceedances, 1,2,4-TMB (6 of 11), 1,3,5-TMB (7 of 11), and benzene (4 of 14). The maximum concentrations were 26, 7, and 50 times greater than their respective criteria.

Table 5.53 presents those compounds for the upgradient samples detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.53 are those petroleum related compounds which were not analyzed for in the EU8 upgradient groundwater but may be present based on their detection in another exposure unit. In summary, 3 metals, 2 SVOCs, and 10 VOCs are listed in Table 5.53.

Table 5.54 lists the on-Site compounds with exceedances of their respective non-residential SHS MSC. For the on-site samples, three dissolved metals exceeded their respective Act 2 criteria. These were aluminum (1 of 3), iron (3 of 3), and manganese (3 of 3). The maximum on-site concentrations were 1.7, 180, and 50 times greater than their respective criteria. The maximum background iron concentration was slightly less than the on-site maximum concentration (47.4 vs. 53.1 mg/L) whereas the maximum background manganese concentration was slightly greater than the maximum on-site concentration (3.76 vs. 2.55 mg/L). The iron and manganese

exceedances are shown on Figure 5.8. The remaining metal with an exceedance (i.e., aluminum) is shown on Figure 5.9.

For the on-site locations, one SVOC (chrysene) was detected at concentrations up to 1.8 times its Act 2 criteria at 3 of 37 locations. The locations of the exceedances are shown on Figure 5.10.

Five VOCs were detected at concentrations in exceedance of their Act 2 criteria in the on-site samples. The three petroleum related compounds were 1,2,4-trimethylbenzene (36 of 43), 1,3,5-trimethylbenzene (26 of 43) and benzene (27 of 53) with maximum concentrations 50, 30, and 1080 times greater than their respective criteria. The other two VOCs were the chlorinated organics 1,1,2,2-tetrachloroethane (1 of 39) and tetrachloroethene (2 of 39) with maximum concentrations 20 and 1.2 times their respective criteria. The locations of the petroleum related VOC exceedances are shown on Figure 5.11 and the chlorinated VOC exceedances are shown on Figure 5.12.

5.8.2 SURFACE SOIL

The available data for the EU8 surface soil for the residential properties are provided in Table AJ.3 of Appendix AJ. As shown on Table AJ.3, no VOCs or SVOCs were detected. Metals were not analyzed for the residential locations.

The available data for the EU8 on-Site and upgradient surface soil are provided in Table AJ.4 of Appendix J.

For the upgradient locations, metals were not analyzed and no SVOCs or VOCs were detected above their respective non-residential SHS MSC.

Table 5.55 presents those compounds detected at the upgradient locations at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. In summary, 8 VOCs are listed in Table 5.55. Also shown in Table 5.55 are those petroleum related compounds which were not analyzed for in the EU8 upgradient surface soil but may be present based on their detection in another exposure unit. In summary, 8 VOCs are listed in Table 5.55.

A summary of those compounds which exceeded their respective non-residential SHS MSC for on-Site locations is provided in Table 5.56. Analytical results for up to 52 on-Site locations are available. Metals were not analyzed for the on-Site locations.

As shown in Table 5.56, no SVOCs were detected at concentrations in exceedance of their criteria.

Three VOCs were detected at concentrations in exceedance of their criteria. The three compounds were 1,2,4-trimethylbenzene (4 of 48), 1,3,5-trimethylbenzene (5 of 48), and benzene (1 of 52). The maximum concentrations were 2.7, 5, and 15 times their respective criteria. The locations of these exceedances are shown on Figure 5.14. As shown on Figure 5.14, the exceedances are spread throughout EU8.

5.8.3 UNSATURATED SOIL

The available data for the EU8 unsaturated soil are provided in Table AJ.5 of Appendix AJ. No unsaturated soil samples for the residential properties were collected.

A summary of those compounds which exceeded their respective non-residential SHS MSC for the on-Site and upgradient locations is provided in Table 5.57. Analytical results are available for up to 47 on-Site locations. Metals were not analyzed for the on-Site locations.

As shown in Table 5.57, no SVOCs were detected at concentrations in exceedance of their criteria.

Two VOCs were detected at two on-Site locations at concentrations in exceedance of their criteria. These were 1,3,5-trimethylbenzene (2 of 44) and benzene (2 of 47). The maximum concentrations were 1.3 and 1.5 times their respective criteria. The locations of these exceedances are shown on Figure 5.13.

5.8.4 SATURATED SOIL

The available data for the EU8 residential property saturated soil are provided in Table AJ.6 of Appendix AJ. Metals were not analyzed for the residential property saturated soil. No SVOCs or VOCs were detected in exceedance of their respective criteria. Table 5.58 presents those compounds detected at concentrations less than or equal to their respective SHS MSC and the concentration range for each compound. Also shown in Table 5.58 are those petroleum related compounds which were not analyzed for in the EU8 residential property saturated soil but may be present based on their detection in another exposure unit. In summary, 4 VOCs are listed in Table 5.58.

The available data for the EU8 on-Site and upgradient locations are provided in Table AJ.7 of Appendix AJ.

For the upgradient area, no VOCs were in exceedance of their respective criteria (see Table 5.59). Arsenic had exceedances in 2 of 5 samples and lead in 3 of 5 samples. One SVOC was in exceedance of its criteria, benzo(a)pyrene in 1 of 9 samples. Table 5.60 presents those compounds detected at concentrations less than or equal to their respective SHS MSC and the range of concentrations for each compound. Also shown in Table 5.60 are those petroleum related compounds which were not analyzed for in the EU8 upgradient saturated soil but may be present based on their detection in another exposure unit. In summary, 18 metals, 19 SVOCs,and 13 VOCs are listed in Table 5.60.

A summary of those compounds which exceeded their respective non-residential SHS MSC for the on-Site locations is provided in Table 5.61. Analytical results are available for up to 33 on-Site locations. Metals were not analyzed for these locations.

As shown in Table 5.61, no SVOCs were detected at concentrations in exceedance of their criteria.

Three VOCs were detected in on-Site saturated soil in exceedance of their criteria. These were 1,2,4-trimethylbenzene (6 of 16), 1,3,5-trimethylbenzene (3 of 16) and benzene (1 of 33). The maximum concentrations were 13, 6.8, and 1.1 times greater than their respective criteria. The locations of these exceedances are shown on Figure 5.14. As shown on Figure 5.14, the exceedances are spread throughout EU8.

5.8.5 SUMMARY

Comparison of the compounds which exceeded their criteria in the groundwater and soil media of EU8 described above show the following.

Residential Properties (Residential Criteria)

i) iron, manganese, and six VOCs were in exceedance in the groundwater;

ii) no SVOCs or VOCs were in exceedance in the surface soil or the saturated soil; and

iii) based on the soil gas survey performed by Shell, vapor intrusion into the Strouss building was not a concern at the time of sampling.

Upgradient Area (non-Residential Criteria)

i) four metals, 10 SVOCs, and 11 VOCs were in exceedance in the groundwater;

ii) no SVOCs or VOCs were in exceedance in the surface soil or unsaturated soil; and

iii) two metals and one SVOC were in exceedance in the saturated soil.

On-Site (Non-Residential Criteria)

i) this area has been minimally impacted;

ii) iron and manganese were the principal metals with exceedances in the groundwater and in both the background and on-Site locations. The iron background concentration was less than the on-Site concentrations whereas the manganese background concentrations were greater than the on-Site concentrations;

iii) only one SVOC (chrysene in 3 of 37 locations) was detected in the groundwater;

iv) no SVOCs were detected at concentrations above their criteria in the soil media; and

v) the primary VOCs detected in the groundwater and soil media were 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and benzene.

5.9 TRENDS IN GROUNDWATER CONCENTRATION WITH TIME

To obtain current information on the quality of the groundwater at/near the Site's boundaries that could be migrating off the Site and provide an indication of potential trends in the groundwater quality with time, 22 historic wells were sampled in the September and November/December 2003 sampling events. The historic wells sampled from each exposure unit were:

EU1	EMW-11, EMW-17, EMW-25, EMW-55, MW-26, MW-50, MW-63, MW-68, MW-69, MW-70, MW-73, MW-76, MW-78, MW-82, and MW-94
EU2	MW-2
EU3	MW-CR22
EU4	MW-TF18, MW-TF22, MW-TF23, and MW-TF44
EU8	MW-CR17

The discussion in the following subsections focuses on the trends in chemical concentrations over time; typically between 2000 and 2003. The discussions regarding off-site chemical flux are presented in Section 6.0. The trend with time evaluations are discussed for those parameters for which either one or more exceedances were detected or which have detected concentrations for two or more different years of sampling.

5.9.1 EXPOSURE UNIT-1 (MAIN REFINERY)

Analytical results for the EU1 area wells are available for four sampling events dating from June 2000 to November 2003.

5.9.1.1 MEK UNIT

Four historic wells were sampled in the MEK Unit, three along the downgradient boundary of the MEK Unit (MW-68, MW-69, and MW-70), and one at the upgradient boundary (MW-63).

For the upgradient well, aluminum concentrations decreased from 280 to ND50 µg/L between June 2000 and November 2003. The concentrations for arsenic, iron, and manganese fluctuated within the following ranges, with no apparent trend with time.

Parameter	*Concentration Range (µg/L)*
Arsenic	48 to 58.5
Iron	43,500 to 65,500
Manganese	2,230 to 3,050

No SVOCs or VOCs were detected for more than one year in the background well. Thus, no trend could be observed from these results, except that the chemical presence is typically minimal.

For the downgradient wells, a summary of the observed trends is provided below.

Well	*Parameter*	*Concentration (µg/L)/Trend*
MW-68	Aluminum	11,800 decreasing to 504
	Cadmium	12 decreasing to 3.6
	Iron	2,180 increasing to 3,140
	Manganese	28,300 decreasing to 21,600
	Nickel	240 decreasing to 38.4
	Zinc	2,360 decreasing to 326
MW-69	Arsenic	9 increasing to 106
	Iron	26,500 increasing to 66,000
	Manganese	20,700 decreasing to 7,130
	Benzo(a)pyrene	14 decreasing to ND0.19
	Benzo(k)fluoranthene	3.95 decreasing to ND0.19
	Chrysene	4.71 decreasing to 0.07
	Toluene	ND5 increasing to 49
MW-70	Iron	3,350 increasing to 24,600
	Manganese	38,800 decreasing to 21,600
	Benzo(a)pyrene	1.06 decreasing to ND0.19
	Benzo(k)fluoranthene	1.58 decreasing to ND0.19

These results show that for the MEK Unit, the groundwater iron concentrations are increasing with time whereas the manganese concentrations are decreasing. For the other metals listed above, some concentrations are increasing (e.g., arsenic) whereas others are decreasing (e.g., aluminum). With regard to the PAH compounds, the concentrations are decreasing. In contrast, the toluene concentrations at the one well where it was present are increasing.

5.9.1.2 ROSE® UNIT

Four historic wells were sampled in the ROSE® Unit, three along the downgradient boundary (EMW-11, MW-73, and MW-94) and one at the upgradient boundary (MW-50).

For the upgradient well, iron and manganese concentrations for both parameters decreased with time from 31,900 to ND100 µg/L for iron and from 4,540 to 12.3 µg/L for manganese. No SVOCs or VOCs were detected for more than one year. Thus, no trend could be observed from these results except that the chemical presence for these parameters is minimal.

For two of the downgradient wells (MW-73 and MW-94), only data for September and November 2003 are available. This time period is too short to comment upon a trend. Data from the 2000 to 2003 period are available for the third downgradient well, EMW-11. A summary of the observed trends in EMW-11 are provided below.

Well	*Parameter*	*Concentration (µg/L)/Trend*
EMW-11	Arsenic	Fluctuates between 74 and 85
	Iron	Fluctuates between 25,100 and 36,500
	Manganese	Fluctuates between 1,310 and 1,690

The above results show that the concentrations for these metals are relatively constant with time.

5.9.1.3 DUBBS UNIT

One historic well (EMW-17) was sampled at the downgradient boundary of the Dubbs Unit. A summary of the observed trends is provided below.

Parameter	*Concentration (µg/L)/Trend*
Iron	59,300 decreasing to 23,500
Manganese	2,320 decreasing to 570
2-Methylnaphthalene	20.2 decreasing to 11
Benzene	195 decreasing to 63
Ethylbenzene	117 decreasing to 3
Xylenes (total)	1,730 decreasing to 8.7

As shown, the concentrations for these six parameters are all decreasing with time.

5.9.1.4 ERIE WYE UNIT

One historic well (MW-82) was sampled at the downgradient boundary of the Erie Wye Unit. A summary of the observed trends is provided below.

Parameter	*Concentration (µg/L)/Trend*
Arsenic	Fluctuates between 40 and 79.5
Iron	Fluctuates between 94,000 and 106,000
Manganese	Fluctuates between 1,890 and 2,500
Benzene	341 decreasing to 82
Ethylbenzene	20 decreasing to 3.3
Toluene	11 decreasing to 3
Xylene	41 decreasing to 6.9

These results show that for the metals, concentrations are holding relatively constant with time, whereas the BTEX concentrations are decreasing with time.

5.9.1.5 CRUDE UNIT AND CRUDE UNIT UPPER YARD

Five historic wells were sampled in the Crude Unit/Crude Unit Upper Yard, three along the downgradient boundary (EMW-25, EMW-55, and MW-26) and two along the upgradient boundary (MW-76 and MW-78). For EMW-25 and EMW-55, only data for September and November 2003 are available. This time is too short to comment upon a trend. Data are available from 2000 through 2003 for the remaining wells. A summary of the trends is provided below.

Well	*Parameter*	*Concentration (µg/L)/Trend*
MW-76	Iron	Fluctuates between 21,300 and 26,700
	Manganese	Fluctuates between 1,060 and 1,220
	Fluorene	Fluctuates between 4.1 and ND10
	Ethylbenzene	Fluctuates between 35 and 79
	Toluene	Fluctuates between ND5 and 5.9
	Xylenes (total)	Fluctuates between 30 and 82
MW-78	Arsenic	95 decreasing to 23.9
	Iron	53,300 decreasing to 12,200
	Manganese	1,800 decreasing to 237
	Benzo(a)pyrene	0.398 decreasing to ND (0.19)
	Benzo(k)fluoranthene	1.62 decreasing to ND (0.19)

MW-26	Arsenic	Fluctuates between 10.7 and 21 with a spike of 82.3 in September 2003
	Iron	Fluctuates between 12,700 and 27,400
	Manganese	Fluctuates between 1,160 and 1,570 with a spike of 4,360 in September 2003

These results show that in the area upgradient of the Crude Unit Upper Yard (MW-76), the concentrations are holding relatively constant whereas in the area upgradient of the Crude Unit (MW-78) the concentrations are decreasing with time. For the downgradient well (MW-26) the concentrations are holding relatively constant with time.

5.9.2 EXPOSURE UNIT 2

One historic well (MW-2) was sampled at the downgradient boundary of this exposure unit. Analytical results are available from June 2000 to November 2003. A summary of the observed trends is provided below.

Parameter	*Concentration (µg/L)/Trend*
Arsenic	61 increasing to 86
Iron	20,600 increasing to 24,000
Manganese	2,670 increasing to 3,450
Benzene	ND5 increasing to 15
Ethylbenzene	ND5 increasing to 18
Toluene	Fluctuating between ND5 and 0.41
Xylenes (total)	ND5 increasing to 170
Cis-1,2-Dichloroethene	456 decreasing to 170
Trichloroethene	7 decreasing to 1.8
Vinyl Chloride	38 decreasing to 16

These results show that the concentration of the VOCs potentially attributable to the petroleum refining operations and metals are increasing with time, although the concentrations are low. In contrast, the concentrations for the chlorinated VOCs, which are believed sourced from the upgradient Pure Seal property, are decreasing with time. This may be indicative that the source chlorinated VOCs from the Pure Seal site has been stopped for a sufficiently long enough period of time that groundwater with lower level concentrations is now migrating from the Pure Seal site thereby decreasing the concentrations in the groundwater beneath the ARG Site.

5.9.3 EXPOSURE UNIT 3

One historic well (MW-CR22) was sampled in close proximity to the downgradient boundary of the Crude Tank Farm. Analytical results are available from July 2001 to November 2003. A summary of the observed trends is provided below.

Parameter	*Concentration (µg/L)/Trend*
Iron	ND2 increasing to 1,060
Manganese	Fluctuates between 5,000 and 5,260

These results are self-explanatory.

5.9.4 EXPOSURE UNIT 4

5.9.4.1 BULK LOADING AREA

One historic well (MW-TF18) was sampled at the downgradient boundary of the Bulk Loading Area. Analytical results are available from April 1999 to December 2003. A summary of the observed trends is provided below.

Parameter	*Concentration (µg/L)/Trend*
Arsenic	Fluctuates between 27 and 79
Iron	75,700 decreasing to 48,100
Manganese	Fluctuates between 6,050 and 7,430

These results show that the arsenic and manganese concentrations are relatively constant with time whereas the iron concentrations are decreasing.

5.9.4.2 LIGHT END TANK FARM

One historic well (MW-TF44) was sampled at the downgradient boundary of the Light End Tank Farm. Analytical results are available from June 2000 to December 2003. A summary of the observed trends is provided below.

Parameter	*Concentration (µg/L)/Trend*
Iron	Fluctuates between 250 and 340, possibly decreasing
Manganese	Fluctuates between 2,320 and 2,700

These results show that the iron and manganese concentrations are relatively constant with time, with the possibility that the iron concentrations are decreasing.

5.9.4.3 FORMER IMPOUNDMENT AREA

Two historic wells (MW-TF22 and MW-TF23) were sampled along the downgradient boundary of the Former Impoundment Area. Analytical results are available from June 2000 to December 2003. A summary of the trends is provided below.

Well	*Parameter*	*Concentration (µg/L)/Trend*
MW-TF22	Arsenic	43 increasing to 143
	Iron	Fluctuates between 71,200 and 97,700
	Manganese	Fluctuates between 1,970 and 2,190
	2-Methylnaphthalene	Fluctuates between 100 and 151
	Acenaphthalene	11.9 decreasing to 0.8
	Phenanthrene	Fluctuates between 14.7 and 17
	Benzene	128 decreasing to 86
	Ethylbenzene	Fluctuates between 3.6 and ND50
	Toluene	Fluctuates between 0.8 and ND5
MW-TF23	Aluminum	210 decreasing to ND50
	Iron	160,000 decreasing to 29,100
	Manganese	11,400 decreasing to 2,070
	2-Methylnaphthalene	27.6 decreasing to ND9.5
	Naphthalene	111 decreasing to 34
	Benzene	7,880 decreasing to 670
	Ethylbenzene	1,260 decreasing to 90
	Toluene	362 decreasing to 96
	Xylenes (total)	8,902 decreasing to 1,380

These results for MW-TF22 show that the concentrations for the metals (except arsenic), phenanthrene, ethylbenzene, and toluene are relatively constant with time. Arsenic concentrations are increasing with time whereas acenaphthalene and benzene concentrations are decreasing with time.

The results for MW-TF23 show that the concentrations for all of the parameters listed above are decreasing with time.

5.9.5 EXPOSURE UNIT 7

The results for surface water samples collected at different times in close proximity to each other are summarized below.

Historic				*Recent Dates*		
Location	*Parameter*	*Date*	*Concentration (µg/L)*	*Location*	*May 2005 Concentration (µg/L)*	*August 2005 Concentration (µg/L)*
TCBKGMR	Iron	8/8/00	420 to 650	SW-002	324 to 363	138 to 143
	Mn	8/8/00	70		58 to 102	70 to 97
TCBKGPP	Iron	8/8/00	350 to 910	SW-007	330 to 869	268 to 272
	Mn	8/8/00	60 to 120		103 to 347	64 to 84
TCFB8	Iron	8/8/00	460 to 600	SW-013	311 to 372	210 to 219
	Mn	8/8/00	70 to 80		82 to 96	75 to 102

The iron results suggest that iron concentrations have decreased between August 2000 and May 2005. With regard to the manganese results, no pattern with time is apparent because the concentration ranges for each pair of locations is similar.

5.9.6 EXPOSURE UNIT 8

One historic well (MW-CR17) was sampled downgradient of the SPL plume in the southern portion of EU8. Analytical results are available from April 1999 to December 2003. A summary of the trends is provided below.

Parameter	*Concentration (µg/L)/Trend*
Aluminum	ND100 increasing to 340
Iron	Fluctuates between 19,300 and 37,900
Manganese	Fluctuates between 1,190 and 2,010

These results show that aluminum concentrations are increasing whereas the iron and manganese concentrations are relatively constant with time.

5.10 SPL CHARACTERIZATION

Over the years of operations at this Site, there have been releases of oil and oil-derived products from the storage, transfer, and handling of these products. In general terms, once an oil product has been released, expectations are that the release will either be collected/contained in the immediate area, flow along the ground surface to a drainage feature (creek/ditch or sewer), or infiltrate into the subsurface regime. Over the past couple of decades with the evolution of heightened environmental awareness, more immediate and complete actions have typically been taken to address identified spills/releases. However, there are still a number of subsurface type releases that take longer to detect (e.g., leaks from tank bottoms and underground pipelines), which consequently are not so promptly identified or addressed.

Releases from recent ongoing sources and historical operations have contributed to the environmental conditions present at the Site today. As one would expect, the recent and historical surficial releases have either been collected or have dissipated into the environment through various pathways (e.g., biodegradation, volatilization, and migration to available surface water routes, etc.) or have reduced in thickness so as to no longer be mobile. Releases have accumulated in the subsurface soils beneath the Site primarily as oil product layers floating upon the top of the capillary fringe of the groundwater table. Over time, these lenses of accumulated floating oil products will migrate along the top of the groundwater table in the general direction of the predominant groundwater flow. In the case of this Site, the general flow direction is toward Tunungwant Creek and its tributaries. The rate at which these accumulated lenses of SPL migrate toward the surface water courses is dependent upon the following factors:

i) the volume of SPL present;

ii) the physical characteristics of the SPL (viscosity, specific gravity, etc.);

iii) the physical characteristics of the soil (grain size, hydraulic conductivity, layering effects, etc.);

iv) the slope of the groundwater table;

v) relative permeability of the water wetted formation for SPL; and

vi) presence of the capillary zone and its rise height from groundwater.

The recent studies that have been conducted at the Site have resulted in the identification of numerous SPL plumes across the Site. As part of the effort to characterize the SPL, all of the available data concerning the various SPL lenses have

been compiled and tabulated for inclusion in this SCR. The areas of SPL presence have been delineated into distinct plumes associated with each SPL lens. Based on the available data, a total of 31 individual areas have been identified where SPL is present on the surface of the upper aquifer groundwater. These 31 areas may each represent SPL from a different source or sources at the Site or from non-Site sources. Accordingly, each of the SPL areas is discussed separately in the following subsections. The locations of the SPL areas are provided on Figures 4.10 a, b, and c for the December 2003 SPL monitoring event (updated to include findings in the Shell March 2005 SCR). The isopach contours depicting the apparent thicknesses of the SPL in each area are also shown on these figures. The majority of these SPL areas, especially the largest SPL areas, are concentrated in the Main Refinery and Foster Brook Facility South.

The apparent thickness of SPL measured in the groundwater monitoring wells located throughout the Site have historically ranged up to 10 feet, although recent SPL recovery programs have significantly reduced these thicknesses. As of December 2003, there are only eleven wells in which more than 1 foot of SPL has been measured with the thickest apparent SPL measured being 6 feet at well MW-103. Other than this one well, no apparent SPL thickness in excess of 3 feet has been observed. The efforts of the SPL recovery programs are summarized in Table 9.1. Measured apparent SPL thicknesses have been corrected using available specific gravity information and the results of the bail down tests. The apparent SPL thickness, static method, is the SPL thickness measured in a well under near-static conditions. It can be many times the actual mobile SPL thickness in the surrounding soil formation based on a variety of reasons. The corrected SPL thickness provides a better estimate of the mobile SPL thickness in the surrounding soils and is determined by the difference between the SPL density and the density of water multiplied by the apparent SPL thickness. However, the mobile thickness of SPL (the portion of the SPL which is capable of migrating) may also be significantly less than the corrected thickness because corrected thickness does not account for the capillary rise of groundwater. The mobile SPL thickness can also be measured using the bail-down test. For further details regarding apparent versus corrected SPL thickness the reader should refer to Appendix T. Unless otherwise noted, the SPL thicknesses discussed in the following sections are apparent thicknesses.

Samples of the SPL analyzed as part of the 2003/2004 SSD activities have shown that the specific gravities of the various SPL areas range between 0.75 and 0.92. Similarly, the dynamic viscosities of the various SPL areas range between 0.78 and 1,140 centipoises. Measurements of product thickness for the March/April, April, and December 2003 monitoring events, and specific gravity, and viscosity are provided in Tables 3.13, 3.14, and 3.15, respectively. SPL apparent and corrected volume calculations are summarized

in Tables 5.62 and 5.63, respectively. The following subsections discuss each SPL area on an individual basis.

5.10.1 SPL-1

SPL-1 is located in the southwest corner of the Main Refinery Area (Exposure Unit 1) adjacent to ASTs which are part of the MEK Unit. In SPL-1, a single monitoring well, EMW-01, has been identified as containing SPL. The current extent of the SPL in SPL-1 is delineated by the following monitoring wells that do not contain SPL: MW-68 and MW-68B to the southwest, MW-100 to the southeast, and MW-101 to the northwest. SPL was first detected in EMW-01 in November 1998. R.E. Wright did not identify SPL in this portion of the Site during their 1994 investigation.

Apparent SPL thicknesses of 0.83 feet, 0.56 feet, and 0.07 feet were measured via the static method at EMW-01 in March, April, and December 2003, respectively. A total of approximately 0.45 gallons of SPL were removed from EMW-01 between February 2003 and February 2004.

A sample of SPL collected from EMW-01 in January 2004 contained hydrocarbons in the n-pentadecane (C-15) to n-octacosane (C-28) range and predominantly in the n-eicosane (C-20) to n-docosane (C-22) range. The SPL collected from EMW-01 had a specific gravity of 0.862, and a dynamic viscosity of 10.15 centipoises. A sample of SPL collected from EMW-01 by ESI in 2002, had a specific gravity of 0.84 which is similar to that for the January 2004 sample. In 2002, ESI described the SPL at EMW-1 as being primarily K-61, which is a solvent distillate known as Kensol 61.

5.10.2 SPL-2

SPL-2 is located near the southwestern end of the Main Refinery (Exposure Unit 1), within the MEK Unit. R.E. Wright did not identify SPL in this portion of the Site during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in the area of SPL-2 during their 1997 AST integrity investigation. SPL was first identified in SPL-2 in April 2001 in MW-69.

Originally identified as separate areas, SPL-2 and SPL-3 now appear to be a contiguous plume. This identification follows the discovery of 6 feet of SPL in monitoring well MW-103, which was installed between the two areas in July 2003 as part of the SSD program to better delineate SPL-2 and SPL-3 in this area. Despite the fact that SPL-2 and

SPL-3 are a single plume, there appears to be two distinct source areas based upon the physical thicknesses of the SPL present, i.e., two separate peak thicknesses. SPL-2 and SPL-3 are therefore described separately. In SPL-2, monitoring well MW-103 has been identified as currently containing SPL. SPL-2 originally also included monitoring well MW-69, which contained 0.07 feet of SPL on October 1, 2001. However, SPL has not been detected at MW-69 since October 2002. The current extent of the SPL in SPL-2 is delineated by the following monitoring wells that do not contain SPL: MW-69 and MW-102 to the south; MW-70 and MW-143 to the east; and MW-64, which is located some distance to the west. To the north, SPL-2 is commingled with SPL-3.

An apparent SPL thickness of 5.96 feet was measured via the static method at MW-103 in December 2003. As MW-103 was only installed in August 2003, no earlier data exist for this monitoring well. A total of 7.4 gallons of SPL was removed from MW-103 between December 2003 and February 2004.

The composition of the SPL in SPL-2 is as follows. In October 2002, ESI reported a specific gravity of 0.82 for the SPL in MW-69.

5.10.3 SPL-3

SPL-3 is located near the southwestern end of the Main Refinery Area (Exposure Unit 1), within the MEK Unit. During their 1994 investigation, R.E. Wright identified SPL thicknesses of between 0.12 and 4 feet at temporary monitoring wells in the area of SPL-3. Brown and Caldwell installed a number of temporary monitoring wells in the area of SPL-3 in 1997, in an effort to evaluate the integrity of ASTs 407, 416, 421, and 430 in this area of the Site. Brown and Caldwell installed temporary wells TW-407 (PZ-1), TW-416 (PZ-2), TW-421 (PZ-3), and TW-430 (PZ-4). SPL apparent thicknesses of 0.02 feet and 0.08 feet were measured at TW-407 and TW-421, respectively. A strong petroleum odor was noted in both wells containing SPL. No SPL was evident in the sample from TW-416 and a small, non-measurable amount of SPL was evident in the sample from TW-430.

In SPL-3 three monitoring wells, MW-62, MW-104, and EMW-79, have been identified as currently containing SPL. SPL-3 historically included monitoring wells EMW-2, EMW-3, EMW-4, and RW-10, each of which contained SPL during either the 1998 or 2001 SPL monitoring rounds, which were conducted by ESI and R.E. Wright, respectively. SPL has not been detected in any of these wells during the 2003 monitoring rounds. The current extent of the SPL in SPL-3 is delineated by the following monitoring wells that do not contain SPL: MW-70 and MW-144 to the east;

MW-64, some distance to the west; and EMW-2 and RW-10 to the north. As noted above, the southern edge of SPL-3 is commingled with SPL-2.

SPL-3 appears to be centered around EMW-79. SPL apparent thicknesses at EMW-79 increased from 1.43 feet in November 1998 to 4.06 feet in October 2001, which may indicate the occurrence of a release in this area between the two measurement dates. CRA is not aware of any specific gravity, viscosity, or hydrocarbon typing samples having been collected from EMW-79 or MW-62. In 2002, ESI described the SPL at EMW-79 as being primarily MN, which is a medium neutral base oil called Kendex 0150.

SPL apparent thicknesses of 0.13 feet, 0.12 feet, and 0.03 feet were measured via the static method at MW-62 in March, April, and December 2003, respectively. Although recovery efforts have been made, no SPL has been removed from MW-62.

SPL apparent thicknesses of 1.23 feet, 0.89 feet, and 0.83 feet were measured via the static method at EMW-79 in March, April, and December 2003, respectively. A total of 0.9 gallons of SPL were removed from EMW-79 between February 2003 and February 2004.

An SPL apparent thickness of 0.24 feet was measured via the static method at MW-104 in December 2003. As MW-104 was only installed in August 2003, no earlier data exist for this monitoring well. No SPL has been attempted to be removed from MW-104.

5.10.4 SPL-4

SPL-4 is located immediately south of Mill Street, in the northern portion of the MEK Unit of the Main Refinery Area (Exposure Unit 1). R.E. Wright did not encounter any SPL in this portion of the Site during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in the area of SPL-4 during their 1997 AST integrity investigation. SPL was first detected in MW-59 by ESI in 1999 and in MW-61 by ESI in 1998.

SPL-4 appears to be centered on MW-59 and includes monitoring well MW-61, which has been identified as currently containing SPL. The current extent of the SPL in SPL-4 is delineated by the following monitoring wells that do not contain SPL: MW-60 to the southwest; MW-58 to the south, and Mill Street to the north. The western edge of the SPL plume has not been completely delineated as there are currently no wells to the west of MW-59; however, as the hydraulic gradient in the area of SPL-4 is to the east, it

is unlikely that the SPL extends much further to the west, unless the source of SPL is located west of MW-59 (i.e., in the area occupied by U.S. Route 219).

CRA is not aware of any specific gravity, viscosity, or hydrocarbon typing samples having been collected from MW-59 or MW-61.

SPL was not detected at MW-59 in 1998; however, 0.01 feet of SPL was present at MW-59 in April 1999. Prior to that date, SPL was not present in this well. SPL apparent thicknesses of 0.41, 0.43, and 0.18 feet were measured at MW-59 in March, April, and December 2003, respectively.

There were isolated and intermittent measurements of 0 to 0.01 feet of SPL at MW-61 in 1998 and 1999. SPL was not detected again at MW-61 until April 2003, when an apparent SPL thickness of 0.41 feet was measured. SPL was present in December 2003 at an apparent thickness of 0.07 feet. MW-61 is located southwest and downgradient of MW-59. Based on the SPL thickness noted in 2003, it is likely that the current measurements of SPL at MW-61 arise from the same source as the SPL at MW-59, whereas, the 1998 measurement of SPL at MW-61 may have originated from a different source area.

SPL-4 is downgradient of ASTs 395, 396, and 397, and the overhead pipe rack. There are no documented releases from this area.

5.10.5 SPL-5

SPL-5 is located immediately north of Mill Street, in the central portion of the Main Refinery Area (Exposure Unit 1), in the area of buildings and ASTs, which are part of the ROSE® Unit. R.E. Wright measured an SPL thickness of 0.07 feet in a temporary monitoring well installed in SPL-5 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in the area of SPL-5 during their 1997 AST integrity investigation.

SPL-5 currently appears to be centered on EMW-07, adjacent to the degreasing and dewaxing unit, and SPL is present in five other monitoring wells, EMW-08, EMW-09, MW-56, MW-71, and MW-121. The current extent of the SPL in SPL-5 is delineated by the following monitoring wells that do not contain SPL: MW-55 to the south; MW-57 to the west; and MW-54 to the north. To the east, SPL-5 has historically been commingled with SPL-6; however, the eastern edge of the SPL plume is separated from the western

edge of the SPL-6 plume by wells EMW-09 and RW-9 which currently do not contain SPL.

A sample of SPL collected from EMW-07 in October 2003 contained hydrocarbons spread relatively evenly through all ranges between n-hexane (C6) and n-tetratetracontane (C44), the largest carbon chain fraction measured. The sample collected from EMW-07 had a specific gravity of 0.868, and a dynamic viscosity of 21.59 centipoises. ESI reported specific gravities of 0.84 and 0.82 for the SPL in EMW-07 and EMW-08, respectively, in October 2002. In 2002, ESI described the SPL at EMW-08 as being primarily HN and secondarily MN. HN is a finished heavy neutral ARG base oil called Kendex 0750.

The SPL at MW-71 is very viscous and has been described as "paraffinic" by CRA field staff.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-5 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-07	1.65	0.97	0.19	43
EMW-08	0.58	0.03	0.46	1.6
EMW-09	0.22	0.30	NP	0.2
MW-56	1.19	1.07	0.51	29
MW-71	0.02	NP	0.17	13
MW-121	NI	NI	0.41	2.4

NP - Not present
NI - Not Installed at time of measurement

As shown above, the apparent SPL thicknesses appear to be decreasing with time since March 2003. In total, approximately 89 gallons of SPL have been removed from SPL-5 between February 2003 and February 2004, inclusive.

5.10.6 SPL-6

SPL-6 is located immediately north of Mill Street, in the central portion of the Main Refinery Area (Exposure Unit 1), in the area of buildings and ASTs, which are part of the ROSE® Unit. R.E. Wright measured an SPL thickness of 0.17 feet in a temporary

monitoring well installed in SPL-6 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in the area of SPL-6 during their 1997 AST integrity investigation.

SPL-6 appears to have historically been centered on EMW-10 and includes three other monitoring wells, MW-56, MW-72, and MW-73, which have been identified as containing SPL. Currently, the center of SPL–6 appears to be around MW-72 and MW-73. The current extent of the SPL in SPL-6 is delineated by the following monitoring wells that do not contain SPL: MW-53, MW-54 and MW-74 to the north; MW-145 to the east; and EMW-09 and RW-9 to the west.

ESI reported a specific gravity of 0.79 for the SPL in EMW-10 in October 2002. In 2002, ESI described the SPL at EMW-10 as being primarily HN.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-6 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-10	0.60	0.43	0.05	0.3
MW-53	0.05	0.01	NP	0.0
MW-72	0.85	0.22	0.35	0.1
MW-73	0.77	0.54	0.09	0.3

NP - Not Present

As shown above, the apparent SPL thickness appears to be decreasing with time since March 2003. In total, approximately 0.7 gallons of SPL have been removed from SPL-6 between February 2003 and February 2004, inclusive.

5.10.7 SPL-7

SPL-7 is located in the AST area in the southeast corner of the ROSE® Extraction Unit of the Main Refinery (Exposure Unit 1) adjacent to Tunungwant Creek. R.E. Wright measured an SPL thickness of 0.31 feet in a temporary monitoring well installed in SPL-6 during their 1994 investigation. Brown and Caldwell installed a number of temporary monitoring wells in the area of SPL-7 in 1997, in an effort to evaluate the integrity of ASTs 222, 256, 257, 259, 260, 263, 267, 268, and 400 in this area of the Site. Brown and Caldwell installed temporary wells TW-256 (PZ-5), TW-257 (PZ-6), TW-259, TW-263,

TW-267 (PZ-7), TW-268 (PZ-8), and TW-400 (PZ-10). The measured SPL apparent thicknesses were 0.01 feet at TW-256, 0.13 feet at TW-257, 0.28 feet at TW-259, 0.32 feet at TW-263, and 0.21 feet at TW-267. The free product sampled by Brown and Caldwell from TW-256 was brownish black in color and had a high viscosity, "similar to a resin compound". SPL from wells, TW-257, TW-259, and TW-267, were also brownish black in color but less viscous. All SPL samples collected in SPL-7 had a strong petroleum odor. No SPL was measured in TW-268 and TW-400. SPL was detected in EMW-11 by ESI as early as November 1998.

In SPL-7, seven monitoring wells or locations have been identified as currently containing SPL, EMW-11, EMW-11 Sump, MW-48, MW-80, MW-93, MW-94, and MW-120. The current extent of the SPL in SPL-7 is delineated by the following monitoring wells that do not contain SPL: MW-52 to the south; RW-16 to the north; and Tunungwant Creek to the east, where the SPL is trapped behind the flood control wall.

A sample of SPL collected by CRA from MW-80 in October 2003, contained hydrocarbons in all ranges between n-pentane (C5) and n-tetratetracontane (C44), the largest carbon chain fraction measured. The sample collected had a specific gravity of 0.891, and a dynamic viscosity of 89.01 centipoises. ESI reported a specific gravity of 0.85 for the SPL in EMW-11 in October 2002. In 2002, ESI described the SPL at EMW-11 as being primarily HN and MN.

Measured SPL apparent thicknesses and removal volumes for the monitoring wells within SPL-7 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-11	0.38	0.38	0.50	0.3
EMW-11 Sump	1.00	NM	NM	19.5
MW-48	1.60	0.86	0.34	3.55
MW-80	1.15	4.20	2.03	3.75
MW-93	NP	NP	TR	--
MW-94	0.25	0.32	NP	0.25
MW-120	NI	NI	0.02	1.6

NM - Not Measured
NP - Not Present
NI - Not Installed at time of measurement
TR - Trace amounts
-- - Not Investigated

The apparent SPL thicknesses are decreasing in some wells and increasing in others. In total, approximately 29 gallons of SPL have been removed from SPL-7 between February 2003 and February 2004, inclusive.

5.10.8 SPL-8

SPL-8 is located in the AST area in the southeast corner of the ROSE® Unit of the Main Refinery (Exposure Unit 1) adjacent to Tunungwant Creek. R.E. Wright did not identify SPL in this portion of the Site during their 1994 investigation. In 1997, Brown and Caldwell installed a temporary monitoring well (TW-222/PZ-9) in the area of aboveground storage Tank 222 in SPL-8, in an effort to evaluate the integrity of Tank 222. Brown and Caldwell measured an SPL thickness of 0.01 feet. There was not enough SPL within TW-222 for Brown and Caldwell to collect a sample; however, they did note that the SPL had a strong petroleum odor.

In SPL-8, one monitoring well, RW-12, has been identified as currently containing SPL. The current extent of the SPL in SPL-8 is delineated by the following monitoring wells that do not contain SPL: RW-16 to the south; EMW-12 to the west; MW-127 to the north; and Tunungwant Creek to the east, where the SPL is trapped behind the flood control wall. SPL-8 has historically been commingled with SPL-7, however during the December 2003 SPL monitoring round SPL-7 and SPL-8 appear as two distinct plumes with RW-16 (which currently does not contain SPL) located between the two plumes.

ESI identified several seeps into Tunungwant Creek downgradient of SPL-8 in 2002. Downgradient of SPL-8 product discharge from the flood control wall weep holes along the section of the wall east of the storage shed, reactor, and flare was observed in 2004.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-8 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
RW-12	NM	0.90	0.15	1.0
RW-16	NP	0.10	NP	0.0

NP - Not Present
NM - Not Measured

The apparent SPL thicknesses in RW-12 appear to be decreasing.

5.10.9 SPL-9

SPL-9 is located beneath the northeastern half of the Dubb's Unit in the Main Refinery (Exposure Unit 1) adjacent to Tunungwant Creek. R.E. Wright did not identify SPL in this portion of the Site during their 1994 investigation; however, they did encounter 1.90 feet of SPL in a temporary monitoring well installed to the south of SPL-9. In 1997, Brown and Caldwell installed a temporary monitoring well (TP-225/PZ30) in the area of Tank 225, which is located within SPL-9, in an effort to evaluate the integrity of this AST. Brown and Caldwell identified an SPL apparent thickness of 0.01 feet with a sheen visible on the sample collected. A strong petroleum odor was also noted.

SPL-9 is currently centered on MW-92 and also includes three other monitoring wells, EMW-17, MW-131, and RW-13, all of which have historically contained several feet of SPL. The current extent of the SPL in SPL-9 is delineated by the following monitoring wells that do not contain SPL: MW-124 to the south; and MW-122 to the west. Tunungwant Creek is located along the eastern edges of the SPL plume and the plume is likely trapped behind the flood control wall, however there are isolated product seeps into the Creek along the concrete bench near the Drive Bridge.

On May 4, 2001, ARG reported to PADEP that they had discovered a release of an unknown quantity from AST 248, which is located within the limits of SPL-9. Tank 248 historically contained naphtha and appeared to have been leaking product from holes in the tank bottom.

ESI installed monitoring well MW-92 approximately 30 feet to the north of Tank 248 in October 2001 and measured an SPL apparent thickness of 0.68 feet at that time. ESI also measured an apparent SPL thickness of 0.5 feet in monitoring well EMW-17, which is located southeast and approximately downgradient of MW-92. In October 2002, MACTEC measured an apparent SPL thickness of 1.35 feet in EMW-17 and an apparent SPL thickness of 0.05 feet in MW-92, both via the static method. A corrected SPL thickness of 0.05 feet in MW-92 was estimated by MACTEC via the bail down method.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-9 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*

EMW-17	NP	0.47	0.09	--
MW-92	0.71	0.12	0.79	0.2
MW-131	NI	NI	0.08	--
RW-13	0.13	0.13	NP	0.3

NP - Not Present
NI - Not Installed
-- - Not Investigated

5.10.10 SPL-10

SPL-10 is the largest SPL plume in terms of areal extent as it covers much of the Crude Unit Upper Yard and portions of the Crude Unit Loading Rack within the Main Refinery (Exposure Unit 1) adjacent to Tunungwant Creek. R.E. Wright identified several isolated pockets of SPL with thicknesses between 0.55 and 0.78 feet in SPL-10 during their 1994 investigation. Brown and Caldwell installed a number of temporary monitoring wells in the area of SPL-10 in 1997, in an effort to evaluate the integrity of ASTs in this area of the Site. Brown and Caldwell identified SPL adjacent to tanks in temporary wells TW-112 (PZ-22), TW-149 (PZ-17), TW-157 (PZ-24), TW-158 (PZ-23), TW-178 (PZ-18), TW-312 (PZ-15), TW-313 (PZ-19), TW-314 (PZ-14), TW-324 (PZ-13), TW-349 (PZ-21), TW-103 (PZ-29), TW-155 (PZ-26), TW-156 (PZ-25), TW-167 (PZ-28), and TW-180 (PZ-27). No SPL was evident in wells TW-326 (PZ-12) and TW-329 (PZ-11). A sheen of SPL was present in well TW-327. SPL sampled from the wells was brownish black in color, had a viscosity similar to that of water, and had a strong petroleum odor. Apparent SPL thicknesses in the wells measured by Brown and Caldwell in 1997 are listed below.

Monitoring Well	*Apparent SPL Thickness (feet)*
TW-112	1.04
TW-149	0.19
TW-157	0.08
TW-158	0.11
TW-178	0.15
TW-312	0.44
TW-313	1.16
TW-314	0.01
TW-324	0.45
TW-349	0.03
TW-103	0.02
TW-155	1.10

TW-156	>0.50
TW-167	1.40
TW-180	1.12
TW-326	None
TW-329	None
TW-327	<0.01

The majority of the SPL plume in SPL-10 is very thin (less than one foot apparent thickness). The core of SPL-10 was historically centered on EMW-82 and also includes EMW-25, EMW-30, and MW-32, all of which have historically contained several feet of SPL. Following the removal of significant quantities of SPL from wells within SPL-10 during 2003 and 2004, no obvious core SPL area remains in SPL-10. Numerous other monitoring wells are currently or have historically been within SPL-10 but outside of the core SPL area, and these wells are listed in the table below. The current extent of the SPL in SPL-10 is delineated by the following monitoring wells that do not contain SPL: MW-38 to the south; MW-75 to the southeast; and EMW-29 to the north. Tunungwant Creek is located along the western edges of the SPL plume, where the plume is trapped behind the flood control wall and collected by the horizontal well system. The minor amount of SPL that discharges from the flood control wall weep holes is manually collected. SPL discharges are mainly along the Creek bank west of tanks 158 and 160, west of tanks 177, 78, and 311, and west of tanks 328 and 330. There is also SPL discharge on the east and west sides of the Platformer Bridge (Bridge #4). To the northeast, SPL-10 is frequently commingled with SPL-11; however, wells EMW-33 and EMW-83, which only intermittently contain SPL, do provide some delineation between SPL-10 and SPL-11. The presence of SPL at monitoring well MW-77 to the east of SPL-10 was not measured during 2003 so the full eastern extent of the SPL in this area is uncertain.

Given the large areal extent of SPL-10 and the presence of numerous large ASTs in the area, the SPL has probably been contributed by a number of sources. The limits of the SPL-10 plume vary considerably between monitoring rounds due to the relative thinness of the SPL layer at the extremities of the plume, fluctuations within the water table, and ongoing SPL removal activities in this area.

A sample of SPL collected by CRA from MW-32 in October 2003, contained hydrocarbons in all ranges between n-heptane (C7) and n-dotetracontane (C42); however, the hydrocarbons fall predominantly within the n-unecane (C11) and n-tricosane (C22) range. The sample collected from MW-32 had a specific gravity of

0.852, and a dynamic viscosity of 4.44 centipoises. ESI reported a specific gravity for MW-32 of 0.85 in October 2002.

ESI collected samples of SPL from EMW-18, EMW-19, EMW-27, MW-37, RW-1, RW-2, RW-3, and RW-14 and reported specific gravities for the SPL from these wells of 0.85, 0.87, 0.85, 086, 0.85, 0.84, 0.86, and 0.84, respectively. The similarity in specific gravities throughout SPL-10 may indicate that the SPL is derived from similar products.

In 2002, ESI described the SPL at MW-37 as being primarily K-61 (solvent distillate, Kensol 61), with LLN (light, light neutral finished ARG base oil Kendex 0060) and HN as secondary constituents. On the same figure, ESI described the SPL at RW-4 as being primarily K-61 and LLN. ESI described the SPL at EMW-21 as being primarily K-51 (solvent distillate, Kensol 51) and LLN. In 2002, ESI described the SPL at EMW-24 as being primarily K-51, K-53 (solvent distillate Kensol 53), and LLN. ESI described the SPL at MW-33 as being primarily K-51 and LLN, with K-50 (solvent distillate, Kensol 50) as a secondary constituent. ESI described the SPL at EMW-26 as being primarily K-50, K-61, and another unknown constituent, and HN and another unknown constituent as secondary constituents. ESI described the SPL at MW-26 as being primarily HN, and another unknown constituent, with K50 and K-61 as secondary constituents. ESI described the SPL at EMW-83 as being primarily K-61, with MN and HN as secondary constituents.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-10 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-18	0.24	0.47	0.20	0
EMW-19	0.01	NP	0.03	0
EMW-21	0.07	0.08	0.23	0
EMW-22	0.27	NP	0.01	0
EMW-23	0.01	NP	NP	0
EMW-24	0.02	0.02	0.29	0.7
EMW-25	NP	0.08	0.10	6
EMW-26	0.13	0.38	0.16	4.5
EMW-27	0.32	0.05	0.23	4.1
EMW-28	0.80	0.73	0.01	69
EMW-29	0.54	0.66	NP	0.3
EMW-83	0.60	0.48	NP	3.3

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
HWMW-02	NP	NP	0.01	--
HWMW-03	NP	NP	0.03	--
JD-01	NM	0.17	0.06	7.3
MW-25	0.89	2.89	NM	132
MW-26	0.99	0.17	0.08	1.7
MW-32	0.25	0.30	0.17	1.2
MW-33	0.55	0.34	0.40	4.6
MW-37	0.16	0.14	0.01	0
MW-125	NI	NI	0.01	--
MW-126	NI	NI	0.10	1.5
RW-1	0.65	2.34	NP	48
RW-2	0.05	0.01	0.35	190
RW-3	0.10	NP	0.33	46
RW-4	0.55	0.55	0.74	3.5
RW-14	1.35	0.57	0.45	79
RW-15	0.20	1.05	0.10	7.8

NP - Not Present
NM - Not Measured
NI - Not Installed at time of measurement
-- - Not Investigated

In general, the apparent SPL thickness is decreasing except in those RW wells being pumped to assist in the SPL removal (i.e. RW-2, 3, 4, 14, and 15 and those monitoring wells in proximity to the pumping wells). The reason for this increase is that the drawdown created by pumping these wells is drawing the SPL towards them. In total, approximately 611 gallons of SPL have been removed from SPL-10 between February 2003 and February 2004, inclusive.

5.10.11 SPL-11

SPL-11 covers portions of the Crude Unit Loading Rack, Crude Unit Barrel House, and Crude Unit portions of the Main Refinery (Exposure Unit 1) adjacent to Tunungwant Creek. R.E. Wright measured SPL thicknesses between 0.7 and 8 feet in temporary monitoring wells installed in SPL-11 during their 1994 investigation. Brown and Caldwell installed a number of temporary monitoring wells in the area of SPL-11 in 1997, in an effort to evaluate the integrity of ASTs 104, 115, and 342 in this area of the Site. Brown and Caldwell identified SPL apparent thicknesses in temporary wells 104

(PZ-31), 115 (PZ-32), and 342 (PZ-33). The SPL apparent thicknesses for wells 104, 115, and 342 were 0.57 feet, 0.43 feet, and >1.75 feet, respectively. SPL sampled from these wells was brownish black in color, had a viscosity similar to that of water, and had a strong petroleum odor.

SPL-11 is centered on EMW-37 and MW-107 and also includes EMW-34, EMW-35, EMW-38, EMW-39, EMW-52, EMW-53, EMW-54, MW-21, MW-22, MW-25, MW-91, and MW-106, all of which have historically contained several feet of SPL, except for MW-106 which was installed in July 2003. CRA has been unable to locate EMW-54 and this well may have been abandoned or destroyed since it was last measured in 2002. Numerous other monitoring wells are within SPL-11 but outside of the core SPL area, and these wells are listed in the table below. The current extent of the SPL in SPL-11 is delineated by the following monitoring wells that do not contain SPL: EMW-33 to the west; EMW-42 to the southeast; and EMW-55 to the northeast. Tunungwant Creek is located along the northwestern edge of the SPL plume where the SPL is trapped behind the flood control walls and captured by the horizontal well system. The minor amount of SPL that discharges from the flood control wall weep holes is manually collected before it can reach the Creek. The limits of SPL-11 fluctuate over time and SPL-11 is frequently commingled with SPL-10 to the south and SPL-12 to the east.

A sample of SPL collected by CRA from MW-25 in October 2003 contained hydrocarbons spread relatively evenly through all ranges between n-butane (C4), the lightest hydrocarbon analyzed, and n-dotetracontane (C42). The sample collected from MW-25 had a specific gravity of 0.860, and a dynamic viscosity of 12.37 centipoises.

ESI reported a specific gravity of 0.86 for the SPL in EMW-37 in October 2002.

In 2002, ESI described the SPL at EMW-35 as being primarily K-61, with MN and HN as secondary constituents. ESI described the SPL at EMW-50 as being primarily HN and K-50, with MN and an unknown product as secondary constituents. ESI described the SPL at EMW-52 as being primarily K-51, K-53 and HN, with two additional unknown products as secondary constituents. ESI described the SPL at EMW-54 as being primarily K-51, with HN and an unknown product as secondary constituents. ESI described the SPL at EMW-85 as being primarily K-61, with MN and HN as secondary constituents. ESI described the SPL at MW-21 as being primarily HN, with two unknown products as secondary constituents.

On April 11, 2001, ARG reported to PADEP that they had discovered a release of 84 gallons from Tank 22, which is located within the limits of SPL-11 in the Crude Unit

Loading Rack Area. Tank 22 is a 110,000-gallon diesel fuel storage tank, which appeared to have been leaking from a hole in the tank bottom.

Monitoring well MW-21 is located approximately 25 feet to the north of Tank 22. MW-21 did not contain SPL when measured by ESI in October 2001; however, by October 2002, MACTEC measured an apparent SPL thickness of 6.19 feet at MW-21. ESI installed MW-91 approximately 5 feet to the east of Tank 22. ESI measured an apparent SPL thickness of 6.39 feet in MW-91 in October 2001. The apparent SPL thickness measured by MACTEC at MW-91 in March 2002 was 7.10 feet. MACTEC conducted bail down testing at MW-91 in October 2002 and determined a corrected SPL thickness of 2.0 feet.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-11 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-34	1.20	0.89	0.83	0.2
EMW-35	0.88	0.36	0.39	1.7
EMW-37	1.25	1.23	0.76	1,512
EMW-50	0.22	0.20	0.07	0.1
EMW-51	0.21	0.73	0.09	1.9
EMW-53	0.07	0.18	0.59	0.4
EMW-84	0.60	0.37	0.12	1.0
EMW-85	0.76	0.86	0.86	4.5
MW-21	0.50	0.26	0.30	6.3
MW-22	0.33	0.36	0.31	20
MW-23	0.20	NP	NP	--
MW-24	3.95	0.66	0.45	26
MW-25	0.89	2.89	NM	132
MW-86	NM	NM	0.32	--
MW-90	NM	NM	NM	0.3
MW-91	0.95	0.27	NM	7.8
MW-105	NI	NI	0.55	23
MW-106	NI	NI	2.40	143
MW-107	NI	NI	1.56	91

NM - Not Measured
-- - Not Investigated
NI - Not Installed at time of measurement

In general, the apparent SPL thicknesses are decreasing with time since March 2003. In total, approximately 1,970 gallons of SPL have been removed from SPL-11 between February 2003 and February 2004, inclusive, most of which was recovered from well EMW-37 (1,512 gallons).

5.10.12 SPL-12

SPL-12 covers a portion of the Crude Unit Barrel House of the Main Refinery (Exposure Unit 1) near the railroad property. R.E. Wright did not install any temporary monitoring wells in SPL-12 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in the area of SPL-12 during their 1997 AST integrity investigation.

The core of SPL-12 is centered around EMW-44, EMW-45, EMW-46, and EMW-47, and also includes MW-15 and RW-11. The current extent of the SPL in SPL-12 is delineated by the following monitoring wells that do not contain SPL: EMW-42 to the southwest; and MW-78 to the south. To the north, SPL-12 is commingled with SPL-13. However, as SPL-12 and SPL-13 appear to have distinct source areas based on historic SPL thicknesses, they are described separately. SPL-12 may also be commingled with SPL-14 to the east.

A sample of SPL collected by CRA from EMW-46 in October 2003, contained hydrocarbons spread through all ranges between n-hexane (C6) and n-dotetracontane (C42) and predominantly in the n-heptadecane (C-17) to n-heneicosane (C-21) range. The sample collected from EMW-46 had a specific gravity of 0.864, and a dynamic viscosity of 10.28 centipoises. ESI reported a specific gravity of 0.86 for the SPL in EMW-46 in October 2002. In 2002, ESI described the SPL at RW-11 as being primarily MN, with HN as a secondary constituent. ESI described the SPL at EMW-47 as being primarily HN and K-53, with MN and K-61 as secondary constituents.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-12 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-44	1.43	7.77	2.65	70
EMW-46	1.73	0.62	3.89	26
EMW-47	0.28	0.91	0.38	22
MW-15	1.60	0.92	0.73	51
RW-11	0.43	1.30	0.10	16

In total approximately 185 gallons of SPL have been removed from SPL-12 between February 2003 and February 2004, inclusive.

5.10.13 SPL-13

SPL-13 covers portions of the Crude Unit and Crude Unit Barrel House of the Main Refinery (Exposure Unit 1) adjacent to Tunungwant Creek. R.E. Wright measured SPL thicknesses between 0.7 and 9 feet in temporary monitoring wells installed in SPL-13 during their 1994 investigation. Brown and Caldwell installed one temporary well TW-102 (PZ-34) to investigate the integrity of AST 102, in the SPL-12 area. The apparent thickness in the well was measured to be 0.04 feet. SPL sampled from these wells was brownish black in color and had a strong petroleum odor.

SPL-13 is centered around MW-19 and EMW-60, and also includes CAWS-2, EMW-57, EMW-58, EMW-59, EMW-62, EMW-87, MW-16, and MW-22, all of which have historically contained several feet of SPL. Numerous other monitoring wells are within SPL-13 but outside of the core SPL area. These wells are listed in the table below. The current extent of the SPL in SPL-13 is delineated by the following monitoring wells that do not contain SPL: MW-20 and EMW-55 to the northwest; and EMW-62 and MW-13 to the east. To the south, SPL-13 is commingled with SPL-12. Wells MW-90 and EMW-61 separate SPL-13 from the Creek. These two wells do not contain SPL. Thus, Tunungwant Creek is located beyond the northern tip of the SPL plume.

A sample of SPL collected by CRA from MW-19 in October 2003, contained hydrocarbons in all ranges between n-hexane (C6) and n-tetratetracontane (C44), the largest carbon chain fraction measured, and predominantly in the n-octadecane (C-18) to n-dotetracontane (C-42) range. The sample collected from MW-19 had a specific gravity of 0.880, and a dynamic viscosity of 46.31 centipoises.

ESI described the SPL at MW-19 as being primarily K-53, with HN, MN, and K-61 as secondary constituents. ESI described the SPL at EMW-58 as being primarily HN and K-61, with K-51 and an unknown product as a secondary constituent. ESI described the SPL at MW-16 as being primarily HN and an unknown product, with K-51, K-50, and MN as secondary constituents.

R.E. Wright reported specific gravities of 0.839, 0.837, and 0.848 for the SPL in EMW-58, EMW-59, and EMW-60, respectively, in 1996. ESI reported specific gravities of 0.85, 0.84, 0.83, 0.85, 0.83, and 0.83 for the SPL present in monitoring wells EMW-57, EMW-58, EMW-59, EMW-60, MW-7, and MW-16, respectively.

On October 24, 2000, ARG reported to PADEP that a routine inspection had discovered a potential release of unknown volume from Tank 173. Tank 173 is a crude oil storage tank, which failed the routine (out-of-service) inspection due to a hole in the tank bottom and there were other bottom thicknesses less than the allowance of 0.01 feet.

Monitoring well MW-90 is located approximately 10 feet to the northwest of Tank 173. No apparent SPL thickness was measured in MW-90 by ESI in October 2001. MACTEC measured an apparent SPL thickness of 0.49 feet in MW-90 in October 2002.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-13 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
CAWS-2	NM	NP	0.02	1.5
EMW-57	0.24	0.22	0.03	0
EMW-58	0.93	0.62	0.27	2.3
EMW-59	0.01	0.38	NP	0
EMW-60	1.78	1.52	1.30	11
EMW-61	1.38	0.48	NM	--
MW-7	0.58	0.57	0.02	0.4
MW-10	0.04	0.04	NP	--
MW-12	NM	0.06	NP	--
MW-16	NM	NM	0.10	--
MW-19	0.93	3.54	0.36	26.6
MW-90	NM	NM	NM	0.3
MW-108	NI	NI	0.01	4.5

NP - Not Present
NM - Not Measured

– - Not Investigated
NI - Not Installed at time of measurement

In general, the apparent SPL thicknesses appear to be decreasing with time since March 2003. In total, approximately 47 gallons of SPL have been removed from SPL-13 between February 2003 and February 2004, inclusive.

5.10.14 SPL-14

SPL-14 covers parts of the Crude Unit and Crude Unit Barrel House of the Main Refinery (Exposure Unit 1) and the Administration/Research and Development Area (Exposure Unit 2) adjacent to Tunungwant Creek. R.E. Wright measured SPL thicknesses between 0.01 and 0.71 feet in temporary monitoring wells installed in SPL-14 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in the area of SPL-14 during their 1997 AST integrity investigation.

The core of SPL-14 is centered around MW-79, and also includes a number of other wells, which are listed in the table below. The current extent of the SPL in SPL-14 is delineated by the following monitoring wells that do not contain SPL: EMW-80 to the west; EMW-63 to the northwest; EMW-67 to the north; MW-05, MW-04, and MW-08 to the east; and MW-88 to the south. SPL-14 may also be commingled with SPL-12 to the west. Given the multi-lobed shape of SPL-14, the SPL may have been contributed from a number of sources.

In 2002, ESI described the SPL at RW-7 as being primarily K-51 and K-53, with K-61 and two unknown products as secondary constituents. ESI described the SPL at EMW-67 as being primarily HN and an unknown product, with K-51 as a secondary constituent. ESI described the SPL at MW-7 as being primarily HN, K-51, and two unknown products, with K-53 as a secondary constituent. In 2002, ESI reported a specific gravity of 0.84 for the SPL from EMW-64.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells/structures within SPL-14 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-64	0.28	0.12	NP	0
EMW-65	NP	NP	0.14	0
EMW-69	0.34	0.35	0.11	0

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
EMW-71	0.73	0.46	0.23	0.3
MW-6	0.47	0.37	0.18	0.3
MW-7	0.58	0.57	0.02	0.4
MW-10	0.04	0.04	NP	--
MW-12	NM	0.06	NP	--
MW-79	5.80	3.34	0.49	11
RW-6	0.05	NM	NP	4.5
RW-7	0.15	NM	0.03	0.3
BA2E	NM	0.21	NM	0

NM - Not Measured
NP - No Product
-- - Not Investigated

The apparent SPL thicknesses are decreasing with time since March 2003. In total, approximately 17 gallons of SPL have been removed from SPL-14 between February 2003 and February 2004, inclusive.

5.10.15 SPL-15

SPL-15 is located within the AST area in the northeast corner of the Erie Wye Unit of the Main Refinery (Exposure Unit 1) and appears to extend under Kendall Avenue to the northeast. R.E. Wright did not identify any SPL in the four temporary monitoring wells they installed in SPL-15 during their 1994 investigation. Brown and Caldwell installed a temporary monitoring well TW-202 (PZ-35) in the area of SPL-15 in 1997, in an effort to evaluate the integrity of AST 202. Brown and Caldwell identified SPL with an apparent thickness of 0.32 feet in TW-202. SPL sampled from the well was brownish black in color and had a strong petroleum odor.

SPL-15 appears to be centered on MW-28 and includes ten additional monitoring wells/structures, ERIE-CLAY, ERIE-CON, JD-02, JD-03, MW-29, MW-82B, MW-85, RW-5, RW-18, and RW-20, which have been identified as containing SPL. The current extent of the SPL in SPL-15 is delineated by MW-30 to the west and Tunungwant Creek to the south and east where SPL would be trapped behind the flood control walls. A horizontal well has been installed in this area to intercept SPL before it could reach the Creek. There are no monitoring wells present to the north to provide delineation of the northern limits of SPL-15; however, given that the hydraulic gradient beneath this

portion of the Site is to the east and Tunungwant Creek, it is unlikely that the plume extends too far to the north.

ESI collected samples of SPL from ERIE-CLAY, MW-28, and RW-5 and reported in October 2002 a specific gravity for the SPL from three wells of 0.80. A sample of SPL collected by CRA from MW-28 in October 2003, contained hydrocarbons spread through all ranges between n-hexane (C6) and n-dotetracontane (C42) and predominantly in the n-nonane (C-9) to n-tetracosane (C-20) range. The sample collected had a specific gravity of 0.827, and a dynamic viscosity of 2.29 centipoises.

The similarity in specific gravities throughout SPL-15 may indicate that the SPL is derived from the same source. ESI described the SPL at RW-5 as being primarily HN and two unknown products, with K-51 as a secondary constituent. ESI described the SPL at MW-28 as being primarily two unknown products, with K-53 as a secondary constituent.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-15 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
ERIE-CLAY	0.01	0.07	0.51	2.8
ERIE-CON	0.15	0.15	0.04	469
JD-02	NM	4.30	2.27	14
JD-03	NM	0.23	0.12	--
MW-28	1.53	0.73	0.82	3.6
MW-82B	0.21	0.18	NP	--
MW-85	NM	NM	0.05	--
RW-5	1.02	0.28	NP	4.5
RW-18	0.82	0.83	0.05	1.3

NP - Not Present
NM - Not Measured
-- - Not Investigated

In general, the apparent thickness is decreasing with time since March 2003, except for the Erie-Clay location. A reason for this increase has not been identified. In total, approximately 495 gallons of SPL have been removed from SPL-15, primarily from the ERIE-CON location between February 2003 and February 2004, inclusive.

5.10.16 SPL-16

SPL-16 is located in the south corner of the Crude Tank Farm (Exposure Unit 3). R.E. Wright did not identify any SPL in the monitoring well that they installed in SPL-16 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in SPL-16 during their 1997 AST integrity investigation. The investigations conducted by Brown and Caldwell in the area to the southwest of SPL-16 focused on two tanks, Tank 709 (TW-709/PZ-36) and Tank 710 (TW-710/PZ-37). The results of the investigation indicated that minor amounts of SPL (thickness of less than 0.01 feet) were evident on the groundwater in TW-710. No free product was evident in temporary well TW-709. The SPL sample from well TW-710 had strong petroleum-related odors. Water from well TW-709 appeared to be clear and had minor petroleum-related odors.

In SPL-16, two monitoring wells, MW-416 and MW-CR03, were identified as containing SPL in 2003. Historically, there have been isolated observations of SPL at other wells in the vicinity of MW-416, including MW-CR21 (October 2000) and MW-CR05 (October 2001). SPL was observed at MW-CR03 by ESI as early as December 1998. The lateral extent of SPL-16 is defined by the following wells that do not contain SPL: MW-415 to the southwest; MW-CR04 to the west; MW-CR23/23A/23B to the north; and MW-CR21 to the southeast.

SPL apparent thicknesses of 0.20 and 0.05 feet were measured via the static method at MW-416 in April and December 2003, respectively. No SPL was measured in MW-416 during the March 2003 SPL monitoring round. No SPL has been removed from MW-416.

An SPL apparent thickness of 0.22 feet was measured via the static method at MW-CR03 in December 2003. No SPL was detected in MW-CR03 during the March or April 2003 SPL monitoring rounds. No SPL has been removed from MW-CR03.

A sample of SPL collected by CRA from MW-416 in October 2003 contained hydrocarbons spread relatively evenly through all ranges between n-butane (C4) and n-tritetracontane (C43). The sample had a specific gravity of 0.818 and a dynamic viscosity of 3.49 centipoises.

In January 2004, ARG reported a release of crude oil from a pipeline adjacent to monitoring well MW-CR05. Prior to January 2004 no SPL was measured at MW-CR05. On February 10, 2004 an SPL apparent thickness of 1.2 feet was measured. On February 11, 2004, 2 gallons of oil were removed from MW-CR05. On February 20, 2004,

0.25 gallons of oil were removed. The last three measurements taken in April 2004, all indicated an SPL apparent thickness of 0.01 feet at MW-CR05.

5.10.17 SPL-17

SPL-17 is located in the central area of the Crude Tank Farm (Exposure Unit 3). R.E. Wright did not identify any SPL in the monitoring well that they installed in SPL-17 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in SPL-17 during their 1997 AST integrity investigation. The investigations conducted by Brown and Caldwell in the Crude Tank Farm area to the north of SPL-17 focused on Tank 723 (TW-723/PZ-38). The results of the investigation indicated that minor amounts of SPL (SPL thickness of less than 0.01 feet) were evident on the groundwater in the vicinity of Tank 723. The SPL sample from TW-723 had strong petroleum-related odors.

Currently a single monitoring well, MW-CR06, has been identified as containing SPL in SPL-17. SPL was detected at MW-CR06 by ESI as early as December 1998. The lateral extent of SPL-17 is defined by the following wells that do not contain SPL: MW-CR22/22A/22B to the west; MW-CR12 to the north; MW-CR07 to the northeast; MW-109 and MW-110 to the east; and MW-CR23/23A/23B to the south.

An SPL apparent thickness of 0.01 feet was measured via the static method at MW-CR06 in December 2003. No SPL was detected in MW-CR06 during the March and April 2003 SPL monitoring rounds. No SPL has been removed from MW-CR06.

A sample of SPL collected by CRA from MW-CR06 in January 2004 contained hydrocarbons spread through all ranges between n-hexane (C6) and n-dotetracontane (C42) and predominantly in the n-decane (C-10) to n-octacosane (C-28) range. The sample had a specific gravity of 0.874, and a dynamic viscosity of 17.54 centipoises.

On November 4, 1999, ARG reported to PADEP that a release of 42,000 gallons of crude oil had occurred due to overfilling of Tank 721, which is located north of the limits of SPL-17. ARG stated that the spill was entirely contained within the earthen-bermed emergency containment area surrounding the tank and was recovered by ARG.

Monitoring well MW-CR20 is located approximately 15 feet to the northwest and hydraulically downgradient of Tank 721. MW-CR20 did not contain SPL when measured by ESI in October 2001, and SPL has not been detected at MW-CR20 since that time.

5.10.18 SPL-18

SPL-18 is located in the north corner of the Crude Tank Farm (Exposure Unit 3) and extends into the National Transit Property (Exposure Unit 8). R.E. Wright did not report SPL results for SPL-18 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in SPL-18 during their 1997 AST integrity investigation.

In SPL-18, three monitoring wells, MMW-C, MW-CR10, and MW-CR18 have been identified as containing SPL. The extent of the SPL in SPL-18 is delineated by the following monitoring wells that do not contain SPL: MW-CR11 to the south; MMWB and MMWA to the west; MWCR17 to the northwest; MW-NT-04 to the north, MW-NT-05 to the southeast, and MW142 to the east.

ATC Associates Inc. installed 26 monitoring wells (MW-NT01 to MW-NT26) in 2001 on National Transit Property which are the locations of the current SPL-18 and SPL-19 plumes. Apparent SPL thicknesses were measured in May, June, July, and November 2001, and in January 2002. Wells MW-NT03, MW-NT07, MW-NT08, MW-NT09, MW-NT20, MW-NT22, MW-NT25, and MW-NT26 contained SPL. The SPL distribution appears to be predominantly near the former AST No. 118, in the southeast area of the National Transit Property. The apparent SPL thicknesses ranged from 0.03 to 0.39 feet with the exception of MW-NT22 with a measurement of 1.22 feet. Manual bailing of SPL began by ATC in April 2002 as an interim remedial measure. As of June 2002 approximately 12 gallons of SPL had been removed. Physical inspection of the SPL samples from monitoring wells MW-NT20, MW-NT22, MW-NT26, and MW-CR10 showed SPL that had low viscosity, was black in color, and had a petroleum odor. SPL from MW-CR18 had similar characteristics except for a higher viscosity. SPL from MW-NT25 was amber-colored and had a strong solvent-like odor. ATC reported that SPL in MW-NT20, MW-NT-22, and MW-NT25 consisted of low-end distillation cuts that were minimally to moderately degraded, whereas SPL from MW-NT26, MW-CR10, and MW-CR18 consisted of severely weathered crude oil with exposure times of twenty years or more.

A sample of SPL collected by CRA from MW-CR10 in October 2003 contained hydrocarbons spread through all ranges between n-pentane (C5) and n-tritetracontane (C43). The majority, greater than 50 percent, of the hydrocarbons present in the SPL from MW-CR10 are in the n-heptane (C7) to n-unecane (C11) range. The sample had a specific gravity of 0.816 and a dynamic viscosity of 2.23 centipoises. In 1999, ESI reported that the SPL in MW-CR10 contained predominantly C6 to C12 hydrocarbons,

with a minor amount of C12 to C20 hydrocarbons, and had a specific gravity of 0.7904. ESI concluded that the source of the SPL in MW-CR10 was indeterminate. A sample of SPL from MW-CR10 was submitted for laboratory identification in 2001 by ATC Associates.

As discussed above, the SPL at MW-CR10 originally consisted of severely weathered crude oil as reported by ATC in 2001. However, the 2003 sample contained predominantly light end hydrocarbons in the C7 to C11 range.

MMW-C was not measured in March 2003. No SPL was present at MMW-C during April 2003. An apparent SPL thickness of 3.16 feet was measured via the static method at MMW-C in December 2003.

SPL apparent thicknesses of 0.22 feet, 0.13 feet, and 0.02 feet were measured via the static method at MW-CR10 in March, April, and December 2003, respectively. A total of approximately 0.5 gallons of SPL were removed from MW-CR10 between February 2003 and February 2004.

SPL apparent thicknesses of 0.17 feet and 0.05 feet were measured via the static method at MW-CR18 in April and December 2003, respectively. SPL was not detected in MW-CR18 in March 2003. No SPL has been removed from MW-CR18.

In May 2004, ARG reported a spill of diesel fuel where the diesel pipeline crosses beneath the railroad south of MMW-C. This release is consistent with the finding in the March 2005 PQS SCR that the SPL in SPL-18 consists of a mixture of refined products and moderately to severely degraded crude oil with fresh diesel due to the May 2004 ARG spill. Furthermore, the PQS SCR reported a SPL area located within SPL-18 on the NT property in the vicinity of former NT AST 118. According to PQS's SCR, the SPL in this area consisted of crude oil. Potential sources for the older components of this SPL are:

i) the NT property crude oil operations; and

ii) the ARG refinery crude oil and refined product pipelines.

ARG has submitted an NIR and is preparing the SCR for the diesel fuel release. It is noted that in addition to the remedial actions performed by ARG, Chemtura implemented a supplemental SPL recovery program and removed approximately 4,400 gallons of SPL from this area by December 2004.

5.10.19 SPL-19

SPL-19 is located in the northern portion of the National Transit Property (Exposure Unit 8). R.E. Wright did not report SPL results for SPL-19 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in SPL-19 during their 1997 AST integrity investigation.

In SPL-19 a single monitoring well, MW-133, has been identified as containing SPL at an apparent thickness of 0.02 feet. The extent of the SPL in SPL-19 is delineated by monitoring wells MW-132 to the west, MW-NT10 and MW-NT23 and conduit test holes TH-3 and TH-5 to the south, MW-TF40 and TP02-06 to the north, and MW-140 and MW-141 to the east that do not contain SPL. An SPL apparent thickness of 0.02 feet was measured via the static method at MW-133 in December 2003. As MW-133 was installed in August 2003, no earlier data are available.

According to the March 2005 SCR prepared by PQS, the SPL in this area consisted of refined products. The closest possible refined product source to this SPL area is the refined product pipelines that run along the west side of the railroad tracks. However, all of these refined product pipelines have been above grade for many years and no leaks have been reported. In 2002, ARG tested these active lines and found them to be of sound integrity. To determine if a leak could have occurred from one of the historic underground refined product pipelines (which are now all out of service), these abandoned pipelines were inspected in 2004 and 2005 at the request of PADEP and were found to have been cleaned and no product remained within them. One other upgradient source of refined products into this area is the former Custer City Oil Site that is located on Bolivar Drive just east of the railroad tracks. Further investigations are planned for this SPL plume. The investigations will be a co-operative effort by Chemtura, ARG, PQS, and Custer City Oil.

5.10.20 SPL-20

SPL-20 is located in the central area of the Packaging Plant (Exposure Unit 6). R.E. Wright did not report SPL results for SPL-20 during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in SPL-20 during their 1997 AST integrity investigation. SPL was first identified in SPL-20 in June 2000, when approximately 2 feet of SPL was measured in MW-PP03.

In SPL-20, two monitoring wells, MW-PP03, and MW-PP04 have been identified as containing SPL. The extent of the SPL in SPL-20 is delineated by the following monitoring wells that do not contain SPL: MW-PP05 to the east; MW-117 to the southeast; and MW-119 to the northeast.

The apparent SPL thicknesses measured in MW-PP03 in 2000 and 2001 ranged from 1.77 to 8.52 feet. SPL apparent thicknesses of 1.08 feet, 0.87 feet, and 0.25 feet were measured via the static method at MW-PP03 in March, April, and December 2003, respectively. A total of approximately 11 gallons of SPL was removed from MW-PP03 between February 2003 and February 2004, inclusive. In general, the SPL thickness at MW-PP03 appears to be decreasing in response to the SPL removal activities completed by CRA in 2003/2004.

An SPL apparent thickness of 0.18 feet was measured via the static method at MW-PP04 in December 2003. MW-PP04 was not measured in March or April 2003. A total of approximately 0.5 gallons of SPL were removed from MW-PP04 between February 2003 and February 2004, inclusive. Only one measurement of SPL was taken prior to 2003. No SPL was present in MW-PP04 during the October 2001 monitoring event. There is currently insufficient data for MW-PP04 to identify any trends toward increasing or decreasing SPL thicknesses.

A sample of SPL collected by CRA from MW-PP03 in October 2003 contained hydrocarbons spread relatively evenly through all ranges between n-decane (C10) and n-dotetracontane (C42). The sample collected from MW-PP03 had a specific gravity of 0.884, and a dynamic viscosity of 91.05 centipoises.

5.10.21 SPL-21

SPL-21 is located along the western boundary of the Packaging Plant (Exposure Unit 6). In SPL-21, a single monitoring well, MW-116 has been identified as containing SPL.

An SPL apparent thickness of 0.46 feet was measured via the static method at MW-116 in December 2003. As MW-116 was only installed in July 2003, no earlier data exists for this monitoring well. A total of approximately 1.85 gallons of SPL has been removed from MW-116 between February 2003 and February 2004, inclusive.

5.10.22 SPL-22

SPL-22 is located in the southwest corner of the Foster Brook South Facility (Exposure Unit 4) in the Light End Tank Farm Area. R.E. Wright identified SPL thicknesses between 0.26 and 1.28 feet in three of the approximately 12 monitoring wells they installed in the area of SPL-22 in 1994. Brown and Caldwell installed 16 temporary monitoring wells in the area of SPL-22 in 1997 to investigate the integrity of Tanks 534, 538, 555, 565, 569, 600, 609, 611, 615, 618, 622, 625, and 626, and mixing kettles K1, K2, K3, and K4. Wells that contained SPL included TW-534 (PZ-39), TW-538 (PZ-40), TW-565 (PZ-44), TW-569 (PZ-45), TW-600 (PZ-47), TW-611 (PZ-51), TW-618 (PZ-53), TW-622 (PZ-54), TW-625 (PZ-55), and TW-626 (PZ-56). The apparent SPL thicknesses of these wells are shown in the table below.

Monitoring Well	*Apparent SPL Thickness (feet)*
TW-534	0.09
TW-538	0.14
TW-565	0.19
TW-569	1.07
TW-600	0.20
TW-611	0.01
TW-618	0.10
TW-622	0.11
TW-625	0.51
TW-626	2.30

Wells TW-609 (PZ-50) TW-K1 (PZ-61), TW-K2 (PZ-62), TW-K3 (PZ-63), and TW-K4 (PZ-64) did not contain SPL. Wells 555 (PZ-43) and 615 (PZ-52) had apparent SPL thicknesses of less than 0.01 feet. Most of the wells that contained SPL had SPL that was brownish black in color and a viscosity slightly higher than water. The SPL in well TW-618 was described as weathered with an odor similar to that of gasoline or kerosene. SPL in wells TW-622, TW-625, and TW-626 were black in color and very viscous.

In SPL-22, nine monitoring wells, HG-417A, MW-420, MW-TF10, MW-TF14, MW-TF28, MW-TF29, MW-TF35 MW-TF37, and MW-TF50 have been identified as currently containing SPL. There appears to be two distinct source areas based on the physical thicknesses of the SPL present, one in the area of MW-TF37 and the other in the area of MW-TF29. The extent of the SPL in SPL-22 is delineated by the following monitoring wells that do not currently contain SPL: MMW-01 and MW-TF36 to the south; MW-TF18, MW-TF13, MW-TF09, and MW-TF19 to the west; MW-TF34 and MW-TF32 to

the east. MW-TF14 and MW-TF28 at the northern limit of SPL-22 contain SPL intermittently and, thereby, provide some indication of the northern extent of SPL-22.

In 1999, ESI reported that the SPL in MW-TF10 contained predominantly C8 to C32 hydrocarbons and had a specific gravity of 0.844. ESI concluded that the SPL in MW-TF10 was gasoline or diesel fuel based. ESI reported that the SPL in MW-TF14 contained predominantly C6 to C10 hydrocarbons and had a specific gravity of 0.7365. ESI concluded that the SPL in MW-TF10 was gasoline based.

On May 11, 1998, ARG reported to PADEP a suspected release due to a failed routine (out-of-service) inspection of Tank 603. Tank 603 is a 217,266 gallon unleaded gasoline tank.

TW-600 and TW-611 (installed in 1997 by Brown and Caldwell and subsequently abandoned) were historically the closest wells to Tank 603. In 1997, they contained SPL at 0.20 feet and 0.01 feet, respectively. In 2002, ESI installed monitoring well MW-TF50 approximately 20 feet to the south and upgradient of Tank 603. An apparent SPL thickness in MW-TF50 of 0.09 feet was measured by ESI in October 2002. A monitoring event conducted by ESI in October 2002 indicated that groundwater flow was to the northwest and that a significant plume of SPL existed to the north of Tank 603. SPL measurements were taken at wells MW-TF29, MW-TF31, MW-TF19, HG-417, MW-TF50, and MW-TF34 in October 2002. SPL was present in all the wells, with the exception of MW-TF19 and MW-TF34, which did not contain any SPL. The apparent SPL thicknesses ranged from 0.09 to 2.15 feet. Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-22 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*				*SPL Removed (gal)*
Measurement Date	*October 2002*	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
HG-417A	1.05	NM	0.06	0.01	30.1
MW-420	NI	0.50	1.04	0.56	4.5
MW-TF10	NI	0.15	0.16	0.21	5.0
MW-TF14	NI	NP	NP	0.01	0
MW-TF28	NI	0.27	NP	0.14	0.8
MW-TF29	2.15	NP	1.72	1.58	8.0
MW-TF35	NI	0.43	2.02	0.22	0
MW-TF37	NI	0.27	1.44	0.76	6.4
MW-TF50	1.25	0.10	0.65	0.30	0

NP - Not Present
NM - Not Measured
NI - Not Investigated

As shown above, the apparent SPL thicknesses are decreasing in about half of the wells and increasing in the other half. In total, approximately 55 gallons of SPL have been removed from SPL-22 between February 2003 and February 2004, inclusive.

A sample of SPL collected by CRA from MW-TF37 in September 2003, contained hydrocarbons spread through all ranges between n-pentane (C5) and n-hentetracontane (C41) and predominantly in the n-tridecane (C-13) to n-heptacosane (C-27) range. The sample had a specific gravity of 0.873, and a dynamic viscosity of 10.48 centipoises. ESI reported a specific gravity of 0.844 for the SPL in MW-TF10 in 1999. The similarity in specific gravities throughout this portion of SPL-22 and the proximity of MW-TF10 and MW-TF37 may indicate that the SPL is derived from the same source or similar products.

A sample of SPL collected by CRA from MW-TF28 in October 2003, contained hydrocarbons spread through all ranges between n-butane (C4) and n-nonacosane (C29) and predominantly in the n-pentane (C-5) to n-dodecane (C-12) range. MW-TF28 is located in close proximity to MW-TF29. The sample had a specific gravity of 0.750, and a dynamic viscosity of 0.96 centipoises. ESI reported a specific gravity of 0.737 for the SPL in MW-TF14 in 1999. The difference in specific gravities and dynamic viscosities for the portion of SPL-22 in the proximity of MW-TF10 and MW-TF37 and that in the proximity of MW-TF28 may indicate that the SPL is derived from a different source.

5.10.23 SPL-23

SPL-23 is located in the southeast corner of the Foster Brook South Facility (Exposure Unit 4) in the Barrel House Area. R.E. Wright did not identify SPL in the monitoring well they installed in the area of SPL-23 in 1994. Brown and Caldwell installed three temporary monitoring wells in the area of SPL-23 in 1997 to investigate the integrity of Tanks 553, 554, and 572. Well TW-554 (PZ-42) contained an apparent thickness of 0.01 feet of SPL, while TW-572 contained 2.78 feet of SPL. Observations showed that the SPL sample was brownish black in color and had a viscosity slightly higher than water. Well 553 (PZ-41) did not contain SPL.

In SPL-23, a single monitoring well, MW-TF07 has been identified as currently containing SPL. The extent of the SPL in SPL-23 is delineated by the following monitoring wells that do not contain SPL: MWTF-11 to the south; MW-TF39 to the north and MW-TF45 to the east.

A sample of SPL collected by CRA from MW-TF07 in January 2004, contained hydrocarbons spread relatively evenly through all ranges between n-butane (C4) and n-hentetracontane (C41). The SPL from MW-TF07 contained two small peaks, at n-decane (C10) and n-eicosane (C20), respectively, which may be evidence of at least two different sources of the SPL in this area. The sample had a specific gravity of 0.886, and a dynamic viscosity of 35.07 centipoises.

SPL apparent thicknesses of 0.20 feet, 0.63 feet, and 0.02 feet were measured via the static method at MW-TF07 in March, April, and December 2003, respectively. A total of approximately 0.1 gallons of SPL was removed from MW-TF07 between February 2003 and February 2004, inclusive.

5.10.24 SPL-24

SPL-24 is located in the southwest area of the Foster Brook South Facility (Exposure Unit 4) in the Light End Tank Farm Area. R.E. Wright did not identify SPL in the monitoring wells they installed near the area of SPL-24 in 1994. Brown and Caldwell installed two temporary monitoring wells in the area of SPL-24 in 1997 to investigate the integrity of Tanks 602 and 608. Well TW-602 (PZ-42) contained an apparent thickness of 6.57 feet of clear, yellow, low viscosity SPL, which Brown and Caldwell described as gasoline. Well TW-608 contained 0.02 feet of SPL. There was insufficient SPL in TW-608 to characterize.

In SPL-24, a single monitoring well, MW-TF27 has been identified as currently containing SPL. The extent of the SPL in SPL-24 is delineated by the following monitoring wells that do not contain SPL: MW-TF09 to the south; MW-TF44 to the west; MW-TF08 to the northwest; and MW-TF19 to the east.

SPL apparent thicknesses of 1.55 feet, 0.52 feet, and 0.41 feet were measured via the static method at MW-TF27 in March, April, and December 2003, respectively. A total of approximately 0.8 gallons of SPL was removed from MW-TF27 between February 2003 and February 2004, inclusive. SPL thicknesses at MW-TF27 declined throughout 2003, likely due to the removal of SPL from the well.

5.10.25 SPL-25

SPL-25 is located along the west boundary of the Foster Brook South Facility (Exposure Unit 4) in the Light End Tank Farm Area. R.E. Wright did not identify SPL in the two

monitoring wells they installed near the area of SPL-25 in 1994. Brown and Caldwell did not install any temporary monitoring wells in the area of SPL-25 in 1997.

In SPL-25 a single monitoring well, MW-TF26, has been identified as currently containing SPL. The extent of the SPL in SPL-25 is delineated by the following monitoring wells that do not contain SPL: MW-TF08 to the southeast; MW-TF44 to the south; and MW-TF06 to the north.

An apparent SPL thickness of 0.75 feet was measured via the static method at MW-TF26 in March 2003. SPL was not present in MW-TF26 in April and December 2003. No SPL was removed from MW-TF26 between February 2003 and February 2004, inclusive.

5.10.26 SPL-26

SPL-26 is located in the central area of the Foster Brook South Facility (Exposure Unit 4) in the Former Impoundment Area and Garage/Shed Area. R.E. Wright did not identify SPL in the five monitoring wells they installed near the area of SPL-26 in 1994. Brown and Caldwell installed four temporary monitoring wells in the area of SPL-26 in 1997 to investigate the integrity of Tank 632 and to investigate conditions in the garage area. Well TW-602 (PZ-42) contained an apparent thickness of 6.57 feet of clear, yellow, low viscosity SPL, which Brown and Caldwell described as gasoline. Wells TW-632, TW-G2, and TW-G4 contained 0.01, 0.01, and 0.02 feet of SPL, respectively. Well TW-G1 did not contain SPL. SPL in TW-632 and TW-G4 was brown/black in color with a viscosity slightly higher than that of water. There was insufficient SPL in TW-G2 to characterize.

In SPL-26, five monitoring wells, MW-TF02, MW-TF03, MW-TF04, MW-TF17, and MW-TF25 have been identified as currently containing SPL. The extent of the SPL in SPL-26 is delineated by the following monitoring wells that do not contain SPL: MW-TF42 to the east, MW-TF32 to the south; MW-TF24 and MW-22 some distance to the west; and MW-TF01 and MW-TF20 to the northeast.

A sample of SPL collected by CRA from MW-TF02 in October 2003 contained hydrocarbons spread through all ranges between n-butane (C4) and n-hentriacontane (C31) and predominantly in the pentane (C5) through n-tridecane (C13) range. The sample had a specific gravity of 0.760, and a dynamic viscosity of 3.25 centipoises. ESI reported specific gravities of 0.737 and 1.004 for the SPL in MW-TF02 and MW-TF03, respectively in 1999. The large difference in specific gravities between MW-TF02 and MW-TF03 may indicate that the SPL in these two wells is from different sources. An SPL specific gravity greater than unity is suspect as this implies that the material has a

density greater than that of water and should, therefore, sink through the water column. However, depending on the salinity of the groundwater in this area, the density of the water may be greater than 1.0 mg/L or the difference in densities between the water and the product may not be sufficiently great to overcome the wetting angle and capillary pressures.

In 1999, ESI reported that the SPL in MW-TF02 contained predominantly C6 to C10 hydrocarbons and ESI concluded that the SPL in MW-TF10 was gasoline based. ESI reported that the SPL in MW-TF03 contained predominantly C6 to C10 hydrocarbons, with minor amounts of C10 to C28 hydrocarbons and concluded that the SPL in MW-TF10 was primarily gasoline based.

A spill of crude oil occurred on May 13, 1998 to the north of SPL-26 along the railway lines in the Crude Rail Unloading Area, south of Foster Brook. Monitoring wells MW-A, MW-B, and MW-C were installed on March 15, 1999. The average depth to static water in each monitoring well was approximately 7.9 feet bgs. Each well was purged and SPL was observed in each monitoring well. SPL samples were taken on March 19, 1999 from the wells. The apparent SPL thicknesses ranged from 0.02 to 0.05 feet in each well. MW-A was not measured in March and April 2003 and did not contain any SPL in December 2003. MW-B was not measured in 2003. MW-C was measured and did not contain any SPL in 2003.

Measured SPL apparent thicknesses and removed volumes for the monitoring wells within SPL-26 are summarized below.

Monitoring Well	*Apparent SPL Thickness (feet)*			*SPL Removed (gal)*
Measurement Date	*March 2003*	*April 2003*	*December 2003*	*February 2003 – February 2004*
MW-TF02	2.55	1.81	1.25	30.3
MW-TF03	1.07	1.41	0.11	< 0.1
MW-TF04	NM	NM	0.05	0
MW-TF17	1.07	1.41	0.11	0.7
MW-TF25	0.43	0.20	0.20	0.7

NM - Not Measured

The apparent thickness appears to generally be decreasing with time since March 2003. In total, approximately 32 gallons of SPL have been removed from SPL-26 between February 2003 and February 2004, inclusive.

5.10.27 SPL-27

SPL-27 is located in the east corner of the Foster Brook South Facility (Exposure Unit 4) in the Garage/Shed Area and Bauxite Fill Area. R.E. Wright did not identify SPL in the three monitoring wells they installed near the area of SPL-27 in 1994. Brown and Caldwell did not install any monitoring wells in the area of SPL-27 in 1997.

In SPL-27, a single monitoring well, MW-TF21 has been identified as currently containing SPL. The extent of the SPL in SPL-27 is delineated by the following monitoring wells that do not contain SPL: MW-TF05 to the east, MW-TF41 to the southwest, and MW-TF42 to the west. SPL was historically detected at MW-TF05 and MW-TF42; however, SPL was not measured in these wells during 2003.

A sample of SPL collected by CRA from MW-TF21 in October 2003 contained hydrocarbons spread through all ranges between n-pentane (C5) and n-hentetracontane (C41). The SPL from MW-TF21 was predominantly (56 percent) in the nonane (C9) through onecane (C11) range with a second smaller peak predominantly in the tricosane (C-23) to hexatriacontane (C-36) range. The sample collected from MW-TF21 had a specific gravity of 0.845, and a dynamic viscosity of 11.33 centipoises.

In 1999, ESI reported that the SPL in MW-TF05 contained predominantly C8 to C13 hydrocarbons and had a specific gravity of 0.9999. ESI concluded that the SPL in MW-TF05 was gasoline based.

SPL apparent thicknesses of 2.45 feet, 1.96 feet, and 0.85 feet were measured via the static method at MW-TF21 in March, April, and December 2003, respectively. A total of approximately 6.7 gallons of SPL were removed from MW-TF21 between February 2003 and February 2004, inclusive.

5.10.28 SPL-28

SPL-28 is located in the northwest region of the Foster Brook South Facility (Exposure Unit 4), west of the Former Burn Pit Area and adjacent to Route 219. R.E. Wright did not identify SPL in the two monitoring wells they installed near the area of SPL-28 in 1994. Brown and Caldwell did not install any monitoring wells in the area of SPL-28 in 1997.

In SPL-28, two monitoring wells, MWRW-02 and FBMW-02 have been identified as currently containing SPL. The extent of the SPL in SPL-28 is delineated by the following

monitoring wells that do not contain SPL: MW-128 to the south; MWRW-03 to the northwest; and MW-TF48 to the southeast.

A sample of SPL collected by CRA from MW-RW02 in October 2003, contained hydrocarbons spread relatively evenly through all ranges between n-heptane (C7) and n-dotetracontane (C42). The sample collected had a specific gravity of 0.923, and a dynamic viscosity of 1,140 centipoises.

Due to the highly viscous nature of the SPL present in MWRW-02, it was not possible to accurately measure the thickness of the SPL during the March, April, or December 2003 SPL monitoring rounds. No SPL has been removed from MWRW-02.

SPL apparent thicknesses of 12.97 feet, 1.26 feet, and 0.65 feet were measured via the static method at FBMW-02 in March, April, and December 2003, respectively. It is believed that the March 2003 apparent thickness is a false thickness due to the very viscous SPL adhering to the interface probe after it passed through the SPL/water interface and continued downward through the underlying water column in the well. No SPL has been removed from FBMW-02.

5.10.29 SPL-29

SPL-29 is located in the center of the Platformer Unit within the Main Refinery (Exposure Unit 1). R.E. Wright identified SPL in this portion of the Site during their 1994 investigation. Brown and Caldwell did not install any monitoring wells in the area of SPL-29 during their 1997 AST integrity investigation.

In SPL-29, a single monitoring well, EMW-13, has been identified as currently containing SPL. The current extent of the SPL in SPL-29 is delineated by the following monitoring wells that do not contain SPL: MW-135 and MW-43 to the southwest, RW-08 to the northwest; EMW-14 to the north; and MW-42 to the northeast.

Apparent SPL thicknesses of 0.01 feet, and 0.01 feet were measured via the static method at EMW-13 in April, and December 2003, respectively. SPL was not present at EMW-13 during the March 2003 SPL monitoring round. Due to the small amount of SPL in EMW-13, it was not possible to remove any SPL from EMW-13 between February 2003 and February 2004.

5/10.30 SPL-30

SPL 30 is located in the Foster Brook South Facility at the northern end of the railroad loading/unloading facility. As a result of a railroad car loading spill reported by ARG in May 1998, a series of seven groundwater monitoring wells were installed in this area. The wells were identified as MW-A through MW-G. One monitoring well on each side of the railroad tracks was identified to have SPL present (well MW-A on the east side and MW-G on the west side).

5.10.31 SPL-31

SPL-31 is located upgradient of the National Transit property, south of Bolivar Drive. Subsequent to the work performed by Chemtura, PQS installed 3 more wells in 2004 (MW-NT33, MW-NT34, and MW-NT36) in the northern portion of the railway property adjacent to the NT property. No SPL has been observed in MW-NT34 and MW-NT36. However, SPL with apparent thicknesses of 0.02 and 2.62 feet were observed in MW-NT33 in September and December 2004, respectively. Wells in close proximity to MW-NT33 (e.g., MW-140 located approximately 35 feet south of MW-NT33) did not contain SPL. This is a new SPL plume which was just identified in 2004.

Manual SPL recovery was initiated in 2005 and, after the recovery of 39 gallons of SPL, the apparent thickness had decreased to 0.9 feet by May, 2006. The SPL was identified to be light end distillate cut of crude oil similar to the SPL identified in MW-NT22. Well MW-140, installed by Chemtura in February 2004, is located 35 feet south of MW-NT33 and well MW-NT34, installed in 2004 by PQS, is located approximately 60 feet northwest of MW-NT33. SPL has not been detected in these wells. The absence of SPL in both of these wells was reconfirmed in October 2005 and April 2006.

Review of the groundwater levels in this area show that MW-NT33 is generally 2 feet hydraulically upgradient of any of the ARG refined pipelines that are located on the west side of the railway property. The SPL is unlikely to be attributable to the refined product pipelines that were located on the western side of the railway tracks considering it would have to have migrated approximately 80 feet in an upgradient direction. Furthermore, the abandoned refined product underground pipelines on the western side of the railway tracks in this area were checked in 2004 and 2006 and were found to have been cleaned and without product, thereby supporting that the historical refined pipelines have not contributed to this SPL area. Furthermore, six test holes were excavated (three each along the west and east pipelines) at the locations shown on

Figure 2.6. No visual or olfactory evidence of a release was observed at these six locations.

To further investigate the presence of this SPL, three test pits (TP02-06, TP03-05, and TP04-06) were excavated in the vicinity of MW-NT33. The test pits are located approximately 40 feet to the northeast (toward Bolivar Drive), 20 feet to the east, and 60 feet to the west. These locations were placed as close as possible to the B&P Railroad tracks while maintaining compliance with the B&P Railroad requirements regarding excavations [i.e., no test pits within 12 feet of the centerline of the closest track, no monitoring wells within 18 feet of the centerline of the closest track, and no excavations beneath the "influence line" (i.e., a line running 1:1.5 vertical to horizontal starting 10 feet from the centerline of the closest track)]. Additional details of these test pits are provided in Section 3.2.15.

No SPL was observed in the three test pits and no SPL has been observed in wells MW-140 or MW-NT34, both of which are located within 60 feet of MW-NT33. Consequently, no route of SPL migration to this location has been identified based upon the results of the field work. However, because field conditions limited the depth of test pit excavations, the target depth for the investigation could not be achieved in all cases. The only other evidence of petroleum products in this investigation area was the sheen seen on the surface of the water table at TP 03-05 and the petroleum odor noted in the soil around the pipeline at this same test pit. However, it is unlikely that this is the source area for MW-NT33 because no SPL was observed and the soil sample collected at this location had no exceedance of SHS MSCs except for a low level exceedance of benzo(a)pyrene (0.15 J/5.8 J vs. 4.6 mg/kg) and lead (35.4/48.7 vs. 45 mg/kg) in the duplicate sample only. The average concentrations for both parameters in this duplicate pair are less than their SHS MSC.

Given the above, it is believed that:

i) the SPL is in a very localized area; and

ii) the SPL may be a new SPL area.

5.10.32 SPL-CC01

SPL-CC01 is located on the north side of Bolivar Drive on the Custer City Oil property. According to the January 2002 Custer City Oil SCR, the SPL was:

i) a mixture of 55% crude oil and 45% refined lubricant; and

ii) the crude oil was severely biodegraded with an exposure time of twenty years or more.

Based on the known operations and pipeline locations, potential sources for the SPL underlying the Custer City Oil property are:

i) the Custer City Oil operations (refined portion); and

ii) the ARG refinery pipelines (crude and refined portions).

It is noted that the area of the 1991 pipeline crude oil release is in close proximity to SPL-CC01. Based on the information provided in Section 3.2.15, it is believed that the 1991 release did not contribute to SPL-CC01.

5.11 AREAL DISTRIBUTION OF CHEMICALS IN GROUNDWATER

The primary environmental impacts of the SPL releases on the Site are related to the chemical concentrations that then result in the groundwater flow regime and have the potential to discharge to the Tunungwant Creek. To evaluate the potential impact on the groundwater beneath the Site, the areal distribution of chemicals in the groundwater has been determined.

The chemicals in the groundwater have been consolidated into the following groups of chemicals and summed and plotted to facilitate discussion and to help interpret the impacts, if any:

i) benzene, toluene, ethylbenzene, and xylenes (BTEX);

ii) PAHs; and

iii) chlorinated VOCs.

The first two groups were selected because they are representative of chemicals potentially attributable to refinery operations and spills and releases of products used, stored, or produced at the refinery. The third group, chlorinated VOCs, were selected because they are present in the groundwater beneath the Site. The areas with elevated concentrations of chlorinated VOCs are believed to be sourced from other sites, even though they are present beneath the ARG Site.

For many of the parameters, the concentrations were non-detect, either on all occasions or in some cases only for certain sampling events. In order to make as accurate an assessment of areal distribution as possible, the following procedure was used for the inclusion of non-detect analytical results in the summations:

i) if a compound was never detected at a location, a concentration of 0 was used at that location; and

ii) if a compound was detected one or more times at a location, a value of one-half the detection limit was used at that location.

Furthermore, for locations with results for multiple dates, only the most recent results were used.

The summed BTEX concentrations are shown on Figures 5.28, 5.29, and 5.30. The summed PAH concentrations are shown on Figures 5.31, 5.32, and 5.33, and the summed chlorinated VOC concentrations are shown on Figures 5.34, 5.35, and 5.36.

5.11.1 MAIN REFINERY

5.11.1.1 MEK UNIT

As shown on Figure 5.28, approximately one quarter of the groundwater underlying the MEK Unit has BTEX concentrations of 10 µg/L and greater. The highest BTEX concentrations are in the area of RW-10 and south thereof, whereas the highest PAH concentrations are located west (upgradient) of RW-10 with lower PAH concentrations south of RW-10 (see Figure 5.31). The area south of RW-10 corresponds to the area in which SPL-3 is located (see Figure 4.10a). As shown on Figures 5.3 and 5.4, seven PAHs and pentachlorophenol are the only SVOCs and benzene is the only VOC in exceedance of their SHS MSCs in this area.

An area with lower BTEX concentrations is present in the northwest corner of the MEK Unit. This area corresponds to SPL-4. As shown on Figure 5.3 and 5.4, no SVOCs or VOCs were in exceedance of their SHS MSC in this area.

With respect to the chlorinated VOCs there are only four locations with low level concentrations to a maximum of 2.5 µg/L. None were in exceedance of their SHS MSCs.

5.11.1.2 ROSE® UNIT

As shown on Figure 5.28, there is one area with relatively elevated BTEX concentrations located in the vicinity of temporary well RW-56 which historically had 1,300 µg/L. This area is immediately upgradient of SPL-7 (see Figure 4.10a). A second smaller area with lower level BTEX concentrations (i.e., 15 µg/L) is located in the vicinity of RW-9/ESI-7. As shown on Figure 5.4, no BTEX compounds are currently in exceedance of their SHS MSC in either area.

With respect to PAHs, there are two areas with detected PAHs, RW-9/ESI-7 (552 µg/L) and MW-94 (34 µg/L). The RW-9/ESI-7 PAH area corresponds to SPL-5 and SPL-6 whereas SPL-7 is located upgradient of MW-94 (see Figure 4.10a). As shown on Figure 5.3, two PAHs exceeded their SHS MSC in the RW-9/ESI-7 area.

Similar to the MEK Unit, chlorinated VOCs were detected only at low level concentrations (maximum 3.5 µg/L) and only at three locations (see Figure 5.34). As shown on Figure 5.4, no chlorinated VOCs exceeded their SHS MSC.

5.11.1.3 PLATFORMER UNIT

As shown on Figure 5.28, BTEX were detected at elevated concentrations in only one area (MW-135) of the Platformer Unit at a concentration of 1,520 µg/L. As shown on Figure 5.4, benzene is the only VOC which exceeded its SHS MSC in this area. Elevated PAH and chlorinated VOCs concentrations were not detected in the Platformer Unit. The highest detected concentrations were only a maximum summed concentration of 13 µg/L for PAHs at MW-43 (see Figure 5.31) and maximum chlorinated VOC concentration of 25 µg/L at MW-135. A second area with detected PAH concentrations is present in the MW-42 area (16 µg/L). As shown on Figure 5.3, two PAHs exceeded their SHS MSC in well EMW-14 which is located in this area. A small SPL plume is present in the area of EMW-13 which is in close proximity to MW-135 (see Figure 4.10a).

As shown on Figure 5.34, chlorinated VOCs were detected at one location with a low level concentration (MW-135 at 25 µg/L). None of the chlorinated VOCs exceeded their SHS MSCs (see Figure 5.4).

5.11.1.4 DUBBS UNIT

As shown on Figure 5.28 and 5.31, the majority of the groundwater beneath the Dubbs Unit has detectable concentrations of BTEX and PAHs. The maximum BTEX concentration is 729 µg/L at VW-2 whereas the maximum PAH concentration is 158 µg/L at EMW-16. Both the BTEX and PAH areas correspond to the area of SPL-9 (see Figure 4.10a). As shown on Figures 5.3 and 5.4, seven PAHs and one VOC (benzene) exceeded their SHS MSCs in the Dubbs Unit groundwater.

As shown on Figure 5.34, there are two locations in the Dubbs Unit with low level concentrations (maximum of 2 µg/L) for the summed chlorinated VOCs. None were in exceedance of their SHS MSC.

5.11.1.5 ERIE WYE

As shown on Figure 5.28 and 5.31, the groundwater beneath the northeast portion of the Erie Wye has detectable concentrations of BTEX (maximum of 167 µg/L at MW-28) and PAHs (maximum of 18 µg/L at MW-85). Both the BTEX and PAH areas correspond to the area of SPL-15 (see Figure 4.10a). As shown on Figure 5.3, no SVOCs were in exceedance of their SHS MSCs whereas, as shown on Figure 5.4, benzene was in exceedance of its SHS MSC.

As shown on Figure 5.34, there are two locations with low level concentrations (maximum 8.4 µg/L) for the summed chlorinated VOCs. As shown on Figure 5.4, methylene chloride and trichloroethene were in exceedance of their SHS MSCs.

5.11.1.6 CRUDE UNIT UPPER YARD

As shown on Figure 5.28, there are two areas with detectable BTEX concentrations in the vicinity of RW-4 (historic maximum of 2,400 µg/L) and of MW-33 (maximum of 21 µg/L). As shown on Figure 5.4, no BTEX compounds exceeded their SHS MSC in this area. The groundwater in the MW-33 area also has detectable concentrations of PAHs with a maximum of 196 µg/L at EMW-24 which is located downgradient of MW-33 (see Figure 5.31). As shown on Figure 4.10a, both the RW-4 and MW-33 areas are within the area of SPL-10. As shown on Figure 5.3, three PAHs exceeded their SHS MSC in this area.

For the chlorinated VOCs, there are two areas with low level concentrations, MW-40 (0.8 µg/L) and EMW-25 (0.5 µg/L) and two areas with slightly higher concentrations (MW-37, 16 µg/L) and EMW-3 (84 µg/L). As shown on Figure 5.4, trichloroethene exceeded its SHS MSC at one location.

5.11.1.7 CRUDE UNIT/BARREL HOUSE UNIT

As shown on Figures 5.28 and 5.31, the majority of the groundwater underlying the Crude Unit/Barrel House has detectable BTEX and PAH concentrations with higher concentrations detected in the central area of these units. The highest BTEX and PAH concentrations are detected at EMW-87 (660 µg/L for BTEX and 50 µg/L for PAHs). There is also a second small area with higher concentrations in the area of temporary well RW-29 (240 µg/L) for the PAHs.

As shown on Figure 4.10a, much of the groundwater in these units is overlain with SPL (i.e., SPL-11 through SPL-14). As shown on Figure 5.3, five PAHs exceeded their SHS MSC in this area while, as shown on Figure 5.4, only benzene exceeded its SHS MSC in this area.

As shown on Figure 5.34, low level concentrations of chlorinated VOCs are present throughout the groundwater in these units. The highest concentration of 8.2 µg/L was detected at EMW-55, which is located within the area of elevated BTEX concentrations. None of the chlorinated VOCs exceeded their SHS MSC.

5.11.1.8 MAIN REFINERY SUMMARY

Based on the descriptions provided in the preceding sections, the areas of groundwater with elevated BTEX and/or PAH concentrations generally are located within or downgradient of the areas where SPL is also present. For the chlorinated VOCs, low level concentrations (<10 µg/L) are present randomly throughout the Main Refinery except for one area in the Platformer Unit and two areas within the Crude Unit Upper Yard where higher concentrations were detected, with a maximum of 84 µg/L in the Upper Yard.

5.11.2 ADMINISTRATION/RESEARCH AREA

As shown on Figure 5.28, the groundwater in the southwest portion of this area has detectable BTEX concentrations with a maximum of 150 µg/L in temporary well RW-24. This area corresponds to the area of SPL-14 (see Figure 4.10a). Lower level concentrations (maximum of 30 µg/L at MW-134) were also detected in the groundwater in the northern portion of this area (see Figure 5.29). As shown on Figures 5.4 and 5.11, benzene was the only BTEX compound which exceeded its SHS MSC. As shown on Figure 5.3 and 5.10, no SVOCs exceeded this SHS MSC. For the PAHs, low level concentrations were detected in the northeast corner of this area with a maximum concentration of 25 µg/L in MW-1, which is located approximately 60 feet southwest of MW-134.

For the chlorinated VOCs, the groundwater beneath the northern portion of this area has elevated concentrations with a maximum of 990 µg/L at MW-134 followed by MW-1 (620 µg/L) and MW-83 (518 µg/L). All three wells are located in close proximity of the upgradient boundary of this area. As shown on Figure 5.12, three chlorinated VOCs exceeded their SHS MSCs in this area. Considering no processes or storage of chemicals have occurred in this area, and the trend of higher upgradient concentrations and lower downgradient concentrations (see Figure 5.35), these chlorinated organics were not sourced by activities related to the Site.

5.11.3 CRUDE TANK FARM

As shown on Figure 5.29 there are four small areas located within the Crude Tank Farm with detectable BTEX concentrations in the groundwater. The area with the highest BTEX concentrations is MW-CR23 with a concentration of 229 µg/L. As shown on Figure 5.11, benzene is the only BTEX compound exceeding its SHS MSC. For the PAHs, Figure 5.32 shows three small areas with detectable concentrations. These three areas coincide with three of the areas with detectable BTEX. The area with the highest PAH concentration is MW-414 with 32 µg/L. As shown on Figure 5.10, no SVOCs exceeded their SHS MSCs in this area.

Figure 4.10b shows two small areas with SPL (SPL-16 and SPL-17). Two of the BTEX and one of the PAH areas with detectable concentrations coincide with the locations of these SPL areas.

With regard to the chlorinated VOCs, low level concentrations were detected at a few locations in the southern half of the CTF (maximum of 2.5 µg/L, none exceeded SHS

MSC), whereas elevated concentrations were detected in the northern half (see Figure 5.35). The highest concentrations were detected in wells MW-CR14 (2,360 µg/L) and MW-111 (1,480 µg/L). As shown on Figure 5.35, the pattern of the chlorinated VOCs is higher concentrations along the upgradient Site boundary and decreasing concentrations with distance from the upgradient boundary downgradient toward Tunungwant Creek. This pattern shows that these chlorinated organics were not sourced by activities related to the Site.

5.11.4 NATIONAL TRANSIT PROPERTY

As shown on Figures 5.29 and 5.32, the groundwater in the eastern (upgradient) third of the NT property had detectable concentrations of BTEX and PAHs. The area with the detected BTEX concentrations extends approximately 50 feet south into the Independent Production Area South of the CTF and approximately 150 feet north into the Foster Brook Facility whereas, the area with PAHs extends only a few feet onto the CTF and approximately 50 feet onto the Foster Brook Facility. The highest concentrations of 10,200 µg/L for BTEX and of 55 µg/L for PAHs were detected in MW-NT35 and SB-16 (IT), respectively. As shown on Figures 5.10 and 5.11, one PAH and one BTEX compound (benzene) exceeded their SHS MSCs in this area. Also shown on Figure 5.29, the area with BTEX presence extends upgradient to the Custer City Oil property. Being upgradient, the BTEX in the groundwater underlying the Custer City Oil property is a source of BTEX not attributable to the ARG Site.

With regard to the chlorinated organics, a portion of the CTF plume is present in the southwest corner of the NT property. Also, two wells in the eastern half have low level concentrations with a maximum of 6.2 µg/L in SB-64 (IT). As shown on Figure 5.12, two chlorinated VOCs exceeded their SHS MSC.

5.11.5 PACKAGING PLANT

As shown on Figure 5.29, BTEX was detected in only one location and at low levels (MW-116 at 0.9 µg/L for BTEX), which did not exceed its SHS MSC. PAHs were also detected at low level concentrations (0.7 µg/L at MW-116) and at higher concentrations in MW-PP04 and MW-PP05 (0.7 and 10 µg/L, respectively). As shown on Figure 5.10, no SVOCs exceeded their SHS MSC. The MW-116 area coincides with SPL-21 and the MW-PP04/MW-PP05 area coincides with SPL-20 (see Figure 4.10b).

With regard to the chlorinated VOCs, there is an area of elevated concentrations in the groundwater underlying the northern portion of the Packaging Plant (see Figure 5.35). This area coincides with the three chlorinated VOCs that exceeded their SHS MSC, as shown on Figure 5.12 and with the areas of SPL-20 and SPL-21. The concentrations are greatest in the area of SPL-20 and decreases with radial distance outward. The source for these VOCs is unknown.

5.11.6 FOSTER BROOK FACILITY SOUTH

The results on Figures 5.30 and 5.33 show that the majority of the groundwater beneath the Foster Brook Facility South has detectable concentrations of BTEX and PAHs. The increased presence and much greater concentrations of BTEX in this area, compared to other areas of the Site is believed due to the types of products (gasoline, light ends, etc.) handled in this area compared to the predominantly crude oil handled in other parts of the facility. As shown on Figures 5.30 and 5.33, there appear to be three individual areas with BTEX and PAHs:

i) the storage/handling areas;

ii) the Former Burn Pit Area; and

iii) the Crude Rail Unloading Area.

The highest BTEX concentrations are located in the Light End Tank Farm of the storage/handling areas (47,510 µg/L at MW-TF08 and 42,650 µg/L in MW-TF29) and in the Former Burn Pit Area (21,000 µg/L at MWRW-01). As shown on Figure 5.18, all four BTEX compounds exceeded their SHS MSC, with benzene having the greater number of locations with exceedances.

The highest PAH concentrations are located in the Light End Tank Farm (2,510 µg/L at MW-TF29) and in the Former Burn Pit Area (450 µg/L at MWRW-01). As shown on Figure 5.17, eight PAHs exceeded their SHS MSCs, primarily in the Former Burn Pit Area.

As shown on Figure 4.10c, SPL is present throughout much of the Foster Brook South Area (SPL-22 through SPL-28) and coincide with the areas of elevated BTEX and PAHs.

With regard to the chlorinated VOCs, there are four areas with higher concentrations, two in the Light End Tank Farm and two in the Garage/Shed Area. As shown on

Figure 5.18, the chlorinated VOC exceeding its SHS MSC in both areas was 1,2-dichloroethane.

5.11.7 FOSTER BROOK FACILITY NORTH

As shown on Figure 5.30 and 5.33, BTEX and PAHs were not detected in the groundwater of the Foster Brook Facility North. Also, as shown on Figure 4.10c, no SPL was detected in this area of the Site.

With regard to the chlorinated VOCs, low level concentrations were detected in three wells with a maximum concentration of 31 μg/L in RAW-28 (see Figure 5.36). Two chlorinated VOCs (methylene chloride and trichloroethene) slightly exceeded their SHS MSCs.

5.11.8 SUMMARY

Based on the descriptions provided in the preceding sections, the areas of groundwater with elevated BTEX and/or PAH concentrations generally are located within or downgradient of areas where SPL is also present. With respect to BTEX, the increased presence and concentrations in the Foster Brook Facility South are attributable to the types of products (e.g., gasoline, light ends, etc.) stored and handled in this area compared to other areas of the facility which principally store/handle/process crude oil.

With regard to the chlorinated VOCs, they are present in the groundwater at many locations throughout the Site at low level concentrations (generally <10 μg/L) except for the three areas:

i) the northern part of the Administration/Research Area;

ii) the northern part of the CTF; and

iii) the northern part of the Packaging Plant.

For the first two areas, the trend of greater concentrations at the upgradient Site boundary with decreasing downgradient concentrations show that the chlorinated VOCs in these areas are not sourced by activities related to the Site.

For the Packaging Plant, the downgradient concentrations are greater than the upgradient boundary concentrations. As stated in Section 5.6.1, it is believed that the

electronics facility located upgradient of the refinery is the likely source of these chlorinated organics. The most likely scenario is that the releases occurred sufficiently in the past such that the center core of the plume with the greatest concentrations has migrated past the upgradient Site boundary to its current location.

5.12 FOSTER BROOK FACILITY – 5 SPECIFIC AREAS

PADEP has identified five specific areas of potential concern in the Foster Brook Facility and has requested that each of these areas be further evaluated and discussed in the SCR. The five areas are: the Bauxite Fill Area, the Fly Ash Area, the Former Burn Pit Area, the Construction Debris Area, and the Refuse/Container Removal Area (see Figure 2.4). Additional characterization sampling and analysis of these five specific areas was performed to determine if these areas have been properly closed in compliance with Pennsylvania laws and regulations or if additional measures are needed to achieve proper closure that are protective of human health and the environment and are consistent with best management practices for waste left in place.

The evaluation of the characteristics of each area and the remedial alternatives evaluated are presented in Appendix AN. This SCR section summarizes the characteristics of each area and the measures that would be necessary to close these five areas in accordance with the requirements of the Pennsylvania laws and regulations. Pennsylvania differentiates between unpermitted disposal areas at which disposal ended before and after September 7, 1980. Those that received no waste after that date must be remediated under Act 2. Those that received waste after that date must be remediated under the Solid Waste Management Act if waste is to be left in place. None of the five areas addressed in this section received waste after September 7, 1980. Therefore, they are to be closed under Act 2.

The Pennsylvania Land Recycling Program Technical Guidance Manual states that closing a fill area in place "may be accomplished by covering the non-media solids with a suitable cover and using any combination of Act 2 standards for soil and groundwater outside the perimeter of the cover under Section 250.9(a) (relating to interaction with other environmental statutes). The covering, grading, revegetation, and related closure activities for waste left in place are to be consistent with best management practices to prevent pollution, odor, and other public nuisances". Further, liability protection afforded under Act 2 "would be provided upon approval of the final report by the Department".

The basic objectives of these regulations in closing an uncontrolled disposal area are:

i) to ensure that the waste is properly covered
   (a) to prevent direct contact with humans or wildlife,
   (b) to prevent erosion by stormwater or wind, and
   (c) to limit infiltration of precipitation through the waste and into the groundwater; and

ii) to minimize the impact of the fill material on the groundwater.

In cases where these objectives are not met, corrective action could be necessary. These corrective actions could include:

i) removal;
ii) covering with soil or an engineered layered system;
iii) grading (3% preferred) to promote runoff;
iv) vegetative planting to stabilize the cover material;
v) gas controls;
vi) groundwater controls; and
vii) monitoring.

The following subsections summarize:

i) the existing conditions in each of these five potential areas of concern; and
ii) their closure status and needs.

It is noted that where the existing cover includes imported soil (fill) appropriate for use as a cover (e.g., silty sands, silts, clays), the thickness of this imported soil (fill) has not been included in the "Thickness of Fill" figures because it is deemed not to be a waste.

5.12.1 BAUXITE FILL AREA

Description of Site: The Bauxite Fill Area is an approximately 2-acre area located on the eastern side of the Foster Brook Facility directly to the south of Foster Brook as shown on Figure 5.37. Bauxite (Fuller's Earth), which had historically been used to filter aromatic and odor bodies from the operations that formerly occupied the Crude Unit

Loading Rack area, was historically placed in this area. The bauxite fill is visible at the ground surface, is friable in nature, and has been transported by stormwater runoff to the ditch at the northern edge of the area. There is no vegetative cover over the bauxite fill. The lateral extent and thickness of the bauxite fill is shown on Figure 5.37.

The average thickness of the bauxite is approximately 6 feet. The Bauxite Fill Area is mounded in the middle to a height of 3 to 4 feet sloping down from the middle on all sides. The surface topography along with the lateral extent of the area of Bauxite Fill is shown on Figure 5.37.

Results of Previous and Present Investigation: Twenty-six unsaturated soil samples have been collected from 14 locations to investigate the Bauxite area. The soil analytical results show that there has only been a minor impact on soil quality in the Bauxite Fill Area. No COCs were detected that exceed the SHS MSCs for the soil samples with the following minor exceptions: benzene and ethylbenzene in the unsaturated soil and arsenic in the saturated soil. Three of the 26 soil samples (two from MW-TF47 and one from BF-1A) had a concentration of benzene that exceeded the SHS MSCs of 0.5 mg/kg. The concentrations ranged from 0.53 to 2.46 in MW-TF4-7 and was 4.0 mg/kg in BF-1A. One of the 26 soil samples (BF-1A) had a concentration of 85 mg/kg for ethylbenzene which exceeded the SHS MSCs of 70 mg/kg. MW-TF47 and BF-1 are approximately 280 feet apart. The few number of parameters with exceedances (i.e., three) at only two locations shows a very limited impact to the soil in two small localized areas.

Seven monitoring wells have been installed and sampled in this area. No COCs were detected that exceeded the SHS MSCs for the groundwater samples with the exception of benzene, arsenic, iron, and manganese. Three of the seven wells have concentrations of benzene that exceed the SHS MSCs of 0.005 mg/L, ranging from 0.008 to 1.64 mg/L. Two of the seven wells have concentrations of arsenic that slightly exceed the SHS MSCs of 0.050 mg/L, ranging from 0.076 to 0.54 mg/L. All seven wells have concentrations of iron that exceed the SHS MSCs of 0.300 mg/L, ranging from 4.75 to 68.7 mg/L. All seven wells also have concentrations of manganese that exceed the SHS MSCs of 0.050 mg/L, ranging from 3.45 to 7.75 mg/L. With the exception of one benzene concentration of 1.64 mg/L found in monitoring well MW-TF43 in June 2000, the exceedances of benzene and arsenic are relatively minor. As shown on Figure 5.30, the benzene in the groundwater underlying the Bauxite fill area is part of the larger BTEX plume underlying the majority of the Foster Brook South area. Furthermore, the Bauxite Fill area is located in the upgradient portion of the Foster Brook South area. Thus, groundwater potentially impacted by the bauxite fill would continue to migrate into the larger BTEX plume. The concentrations of iron and manganese are expected to be slightly elevated due to the presence of anaerobic conditions in the groundwater in the

general area. However, iron and manganese concentrations at the facility are also known to be elevated due to background conditions.

The Bauxite Fill Area is within Exposure Unit 4 (EU4). The Human Health Risk Assessment (HHRA) for EU4 identified no health risks above the target cumulative risk of 10^{-4} and HI of 1 for the soil exposure pathways except for the outdoor worker (inhalation of vapors from exposed subsurface soils) and the construction worker exposed to subsurface soils (ingestion, inhalation, and dermal). Exceedances of the targets were found for the soil gas to indoor worker pathway and the groundwater and SPL to construction worker pathways.

The groundwater underlying the Bauxite Fill area is being addressed by the SPL recovery program as described in Appendix AM of the SCR, and there is no potential for direct contact with the groundwater unless it is exposed by construction activities. For a construction worker exposed to subsurface soil, groundwater, and SPL HIs of 2500, 5.8, and 130, respectively, were calculated for the Reasonable Maximum Exposure (RME) scenario primarily due to the presence of 1,2,4-TMB and 1,3,5-TMB in soil and benzene in soil, groundwater, and SPL. However, any construction activities or subsurface work in this area will be performed following appropriate health and safety procedures, thereby eliminating this potential exposure pathway. The procedures to ensure appropriate H&S measures are implemented are presented in Appendix AP.

The Act 2 MSCs for iron and manganese are based on aesthetic concerns (not human health concerns). Furthermore, the groundwater from this area is not used, and there are no applicable soil to groundwater MSCs for these two metals.

With regard to the soil gas to indoor worker pathway, there are no structures subject to this pathway on the Bauxite Fill Area and none are planned for the future. Thus, this pathway is incomplete for this area. The one building in the light end tank farm at the Foster Brook Facility which occasionally has indoor workers has been addressed by the installation of passive soil gas vents beneath the building.

Based on the HHRA and Bauxite Fill Area conditions, the only potential exposure pathway of concern in the Bauxite Fill Area are the outdoor worker exposed to subsurface soil; the construction worker exposed to soil, groundwater, and SPL; and limited impact to subsurface soil and groundwater.

Requirements of Close Bauxite Fill Area Under Act 2: The bauxite fill is uncovered and friable. The material can be transported by wind or water from the area, and water can infiltrate into and through the fill. A demonstration under Act 2 must show that the

fill material has been adequately covered and revegetated and that there are no off-Site impacts.

Closure Assessment: Due to the presence of elevated benzene concentrations at two locations in the soils and in the one groundwater sample, it appears that a related impact has occurred. In order to properly close the Bauxite Fill Area, the following technologies are the most appropriate for consideration for the Bauxite Fill Area:

i) excavation and off-site treatment/disposal;

ii) in-situ treatment;
   a) solidification/stabilization;
   b) soil vapor extraction; and
   c) bioremediation; and

iii) cover and institutional controls.

Based on the evaluations described in Appendix AN, the estimated costs for these technologies are:

	Estimated Costs	
Alternative	*Capital*	*Annual O&M*
Excavation and Off-Site Disposal 6-inch crushed limestone cover	$1,460,000	$1,000
Solidification/Stabilization 6-inch crushed limestone cover	$350,000	$3,800
Soil Vapor Extraction 6-inch crushed limestone cover	$487,000	$117,000
Biosparging 6-inch crushed limestone cover	$272,000	$55,800
24-inch Vegetated Soil Cover	$89,000	$3,700
6-inch Crushed Limestone Cover	$45,000	$3,800

Minor exceedances of the SHS MSCs are present in isolated areas of the Bauxite Fill Area. Therefore, this area will be closed under a combined SHS MSC and Site-Specific Standard (SSS).

The closure alternative selected for the Bauxite Fill Area involves:

i) regrading of the area to achieve compliance with the slope requirements, to the extent practical;

ii) placement of a 6-inch thick crushed limestone cover on the western portions of the area;

iii) placement of a 6-inch thick crushed limestone cover with a geotextile on the slopes adjacent to the railroad;

iv) implement deed restrictions to restrict land and groundwater use and operating procedures to ensure appropriate H&S measures are implemented for subsurface activities (language is included in SCR Appendices AO and AP); and

v) submittal of the appropriate forms and reports to close the area using a combined SHS MSC and Site Specific Standard for the soils and groundwater based on the existing data.

This alternative was selected based on its ability to:

i) further reduce the already acceptable pathway of direct contact with humans;

ii) further reduce the already acceptable pathway of direct contact with wildlife;

iii) control erosion to the surface water drainage swales leading to Foster Brook;

iv) limit infiltration of precipitation through the fill into the groundwater by removing any depressions that could retain precipitation for infiltration; and

v) continue use of the area by ARG for plant operations,

Figure AN.2.1 of Appendix AN shows the area to be covered.

Post-Closure Monitoring And Maintenance

Because this is an active area of the refinery, the integrity of the cover will be subject to visual observation on all days that the refinery is in operation. However, to ensure the integrity of the cover remains intact, it will be "officially" inspected on a semi-annual basis. Any observations of erosion in the cover will be addressed as soon as practical by removing the eroded cover material from where it has migrated to and replacing it into the eroded areas, if possible. Should the erosion result in transporting materials into the surface water drainage swales adjacent to the railroad, measures (e.g., replacing/adding more geotextile, use of gravel/riprap, etc.) will be taken to prevent such erosion.

Groundwater monitoring will be performed at two wells semi-annually. The samples will be analyzed for benzene, arsenic, iron, and manganese.

Additional details will be provided in the Site Cleanup Plan.

5.12.2 FLY ASH AREA

Description of Site: The Fly Ash Area is an approximately 3/4-acre, triangularly shaped area located on the eastern side of the Foster Brook Facility directly to the south of Foster Brook as shown on Figure 5.38. The ground surface is almost flat, with a slope of 1% or less toward Foster Brook to the northeast. The coal ash is covered with grasses (70-80% coverage) and with mature sumac. The lateral extent of the coal ash fill is shown on Figure 5.38. The coal ash ranges in thickness up to 8 feet thick and averages around 6 feet thick. The cover material is primarily clayey soil although slag is present in the cover material. The thickness of the cover over this fill is typically 4 to 6 inches thick, as presented on Figure 5.39.

Results of Present Investigation: The soil analytical results show that there has been no adverse impact on soil quality in the Fly Ash area. Thus, it is expected that there has been no adverse impact on the groundwater quality underlying the Fly Ash area from the coal ash fill and subsequently to groundwater quality underlying adjacent areas. There had been no investigation of the Fly Ash Area previous to the SSD. During the SSD, 15 soil samples were collected from 5 borings drilled in the area. The data show that no COCs were detected in exceedance of the SHS MSCs for the soil samples. There are no groundwater monitoring wells in the Fly Ash area and therefore no groundwater samples were collected. However, considering that the 15 soil samples did not exceed any of the soil to groundwater SHS MSCs, it is unlikely that the groundwater underlying the Fly Ash area has exceedances related to the coal ash and subsequently no adverse impact to the groundwater adjacent to the Fly Ash area.

The Fly Ash Area is within Exposure Unit 4 (EU4). The HHRA for EU4 identified no health risks above the target cumulative risk of 10^{-4} and HI of 1 for the soil exposure pathways except for the outdoor worker (inhalation of vapors from exposed subsurface soils) and the construction worker exposed to subsurface soils (ingestion, inhalation, and dermal).

None of the samples of the coal ash or the surrounding soil exhibit concentrations of any parameters that exceed any of the SHSs MSCs. Therefore, this material does not represent an unacceptable risk by direct contact for either human health or wildlife.

Exceedances of the targets for EU4 were found for the soil gas to indoor worker pathway and the soil, groundwater, and SPL to construction worker pathways. There are no structures subject to the indoor air pathway in the Fly Ash Area and none are planned or

would be expected in this isolated area in the future. Thus, this pathway is incomplete in the Fly Ash Area.

For the soil and groundwater to construction worker and subsurface soil to outdoor worker pathways, there is no potential for direct contact with the soil or groundwater unless it is exposed by construction activities. As stated above, because the soil samples did not exceed any of the soil to groundwater SHS MSCs, it is believed that there is no adverse impact to the groundwater underlying the Fly Ash Area attributable to the coal ash. For the SPL to construction worker pathway, no SPL exists in the Fly Ash Area. Thus, this pathway is incomplete.

Based on the HHRA and the Fly Ash Area conditions, there are no complete exposure pathways. Thus, no H&S measures specific to address chemical exposure are needed for the Fly Ash Area.

Based on the Ecological Risk Assessment (ERA), the American brook lamprey (a Pennsylvania endangered fish species) and the Ohio lamprey (a Pennsylvania threatened species) are species of concern in Tunungwant Creek. No plant or federally listed species of concern or their habitats were identified. Bolivar Run is only considered a *habitat of concern* due to the potential occurrence of the American brook lamprey and Ohio lamprey. While there is the possibility that erosion from the coal ash could migrate to Foster Brook, the surface soils in the Fly Ash Area are all below the SHS MSCs and therefore, there is no concern in this regard.

Requirements to Close Fly Ash Area Under Act 2: The Fly Ash Area appears to be relatively uniformly covered with a 4 to 6-inch thick layer of clay/slag material. The ground surface is almost flat, with a slope of 1% or less in a northeasterly direction toward Foster Creek (see Figure 5.2).

Closure Assessment: Based on the evaluation described in Appendix AN, the cover and institutional controls technology is the most appropriate for consideration for the Fly Ash Area.

The estimated costs for the two alternatives considered (i.e., 24-inch and 12-inch thick cap) are:

Alternative	*Estimated Costs*	
	Capital	*Annual O&M*
24-inch Vegetated Soil Cover	$11,000	$560

12-inch Vegetated Soil Cover	$6,000	$590

No exceedances of the SHS MSCs are present in the Fly Ash Area. Thus, this area will be closed under the SHS MSCs.

The closure alternative selected for the Fly Ash Area involves:

i) perform isolated, minor regrading of the Fly Ash Area cover material from the railroad tracks toward Foster Brook to enhance precipitation runoff from the Fly Ash Area to the Brook;

ii) place 6 to 8 inches of topsoil in select locations to further enhance the continuity of the surface slopes and vegetation;

iii) revegetate the regraded portions of the Fly Ash Area with grasses and herbaceous seed mix to enhance the ecological habitat value of the area; and

iv) submit the appropriate forms and report to close the Area using SHS MSCs for the soils and groundwater based on the existing data.

This alternative was selected based on its ability to:

i) further reduce the already acceptable pathway of direct contact with humans;

ii) further reduce the already acceptable pathway of direct contact with wildlife;

iii) further control erosion to the surface water drainage swales leading to Foster Brook;

iv) limit infiltration of precipitation through the coal ash into the groundwater; and

v) provide sufficient soil to allow the growth of a vegetative cover,

Because the concentrations of parameters do not exceed the soil-to-groundwater SHSs MSCs, the existing cover material appears to be adequate to prevent excessive infiltration through the fill material. However, to assist in controlling future erosion, it is proposed that the graded areas be supplemented with up to 8-inches of topsoil, resulting in a generally 12-inch thick cover, which will better support vegetation and further reduce the infiltration of water through the fill material.

Removal of the existing vegetation to place additional cover material in areas not to be graded would be more disruptive than the benefit gained from recovering these areas. Consequently, no further work is planned for the areas in which no regrading is needed and in which vegetative ground cover has been established.

Figure AN3.1 of Appendix AN shows the area to be covered.

Post-Closure Inspection And Maintenance

To ensure the cover remains effective, post-closure inspection and maintenance activities will be performed upon completion of construction of the cover for a period of two years. This will include semi-annual inspections and repair/maintenance of the soil and vegetative cover should the inspections identify the need for such.

Any observation of a lack or sparsity of vegetative cover and/or erosion in the soil cover will be addressed as soon as practical. Potential corrective measures for sparse vegetation include:

i) reseeding; and

ii) adding more topsoil and reseeding.

For the soil cover, potential corrective measures include:

i) removing the eroded cover material from where it has migrated to, when practical, and replacing into the eroded areas and reseeding; and

ii) replacement of the eroded soils with additional soils and reseeding.

Additional details will be provided in the Site Cleanup Plan.

5.12.3 FORMER BURN PIT AREA

Description of Site: The Former Burn Pit Area is an approximately 3 acre area located on the western edge of the Foster Brook Area just to the south of Foster Brook as shown in Figure 5.40. Historically, the Burn Pit Area was used from the mid-1950s to 1971 for the treatment of various types of hydrocarbon waste materials. The area is divided into two distinct areas: the Burn Pit and the Burn Pile. The Burn Pit was the northernmost feature and measured approximately 150 feet by 50 feet and was several feet deep. The Burn Pile was located immediately south of the Burn Pit and was approximately 200 feet in diameter. The ground surface of the Former Burn Pit Area is currently sloped at approximately a 2% grade to the northeast toward Foster Creek and to the west toward the drainage swale of State Route 219. The maximum elevation of the area is 1421 feet amsl. By contrast Foster Brook at this location has an elevation of 1407 feet amsl. The

vegetation in this area is classified as Old Field consisting of grasses and goldenrod. The vegetative coverage is virtually 100% with the exception of small, isolated bare spots. The lateral extent and vertical thickness of the burn pit fill are shown on Figure 5.40. The depth of cover is shown in Figure 5.41.

Results of Previous and Present Investigation: The soil and groundwater analytical results show that there has been a moderate to significant impact on soil and groundwater quality in the Former Burn Pit area. However, the extent of off-Site impact to the groundwater is low level and limited in areal extent. A total of 53 soil samples have been collected from 34 locations in this area. Exceedances of the SHS MSCs were detected in soil samples for benzene and other aromatic hydrocarbons, chlorinated hydrocarbons, naphthalene, lead, and selenium. For the unsaturated soils, the exceedances were:

Parameter	*No. of Exceedances*	*Standard (mg/kg)*	*Lowest to Highest Exceedances (mg/kg)*
1,1,1-Trichloroethane	1 of 33	20	35
1,1-Dichloroethane	1 of 33	11	30
1,2-Dichloroethane	1 of 33	0.5	4.8
1,2,4-Trimethylbenzene	5 of 8	20	29 - 202
1,3,5-Trimethylbenzene	5 of 8	6.2	12 - 92
Benzene	6 of 33	0.5	1.3 – 6.5
Ethylbenzene	2 of 33	70	77 - 105
Toluene	1 of 33	100	100
Chloromethane	2 of 33	0.3	0.31 – 1.4
Naphthalene	1 of 33	25	109
Benzo(a)pyrene	1 of 33	11	23.3
Lead	3 of 33	450	459 – 1110
Selenium	8 of 33	26	29 - 38

For the saturated soils, the exceedances were:

Parameter	*No. of Exceedances*	*Standard (mg/kg)*	*Lowest to Highest Exceedances (mg/kg)*
Benzene	2 of 16	0.5	0.5 - 16
Naphthalene	2 of 16	10	16 - 50

Seventeen monitoring wells have been installed and sampled in the Former Burn Pit area. Exceedances of the SHS MSCs were detected in groundwater samples for benzene and other aromatic hydrocarbons, chlorinated hydrocarbons, naphthalene and other polynuclear hydrocarbons, arsenic, and manganese. A summary of exceedances of the standards is presented below:

Parameter	*No. of Exceedances*	*Standard (mg/L)*	*Lowest to Highest Exceedances (mg/L)*
cis-1,2-Dichloroethene	1 of 17	0.07	0.180
Benzene	9 of 17	0.005	0.015 – 2.79
Ethylbenzene	3 of 17	0.7	0.85 – 2.74
Vinyl Chloride	1 of 17	0.002	0.016
Naphthalene	2 of 17	0.1	0.120 – 0.433
Benzo(b)fluoranthene	2 of 17	0.0012	0.0059 - 0.0092
Benzo(g,h,i)perylene	3 of 17	0.00026	0.00055 – 0.0013
Benzo(k)fluoranthene	2 of 17	0.00055	0.00097 – 0.0023
Chrysene	2 of 17	0.0019	0.012 - 0.025
Dibenzo(a,h)anthracene	2 of 17	0.00036	0.0008 – 0.0072
Pyrene	2 of 17	0.013	0.013 – 0.017
Arsenic	2 of 17	0.05	0.06 – 0.0827
Manganese	13 of 17	0.05	0.13 – 17.8

In addition, SPL has historically been documented to be present in the some of the wells at thicknesses of up to 1.85 feet.

As shown on Figure 5.30, the BTEX concentrations decrease rapidly from 21,000 µg/L in MWRW-01 to 15 µg/L in MWRW-05 located approximately 300 feet downgradient of MWRW-01. Furthermore, the BTEX concentrations in wells adjacent to Foster Brook range from non-detect to 5 µg/L. The pattern for PAHs shown on Figure 5.33 is similar to that for BTEX. This rapid decrease in concentrations within a relatively short distance shows that natural attenuation is effectively preventing the migration of BTEX and PAHs from the Former Burn Pit Area to Tunungwant Creek and Foster Brook. Due to the presence of SPL in the area, it is uncertain whether the noted groundwater impacts are related to the SPL or to continuing releases from the impacted soils.

As shown above, 13 compounds were detected above their SHS MSC in the subsurface unsaturated soil samples and two compounds were detected in exceedance of their SHS MSC in the saturated soil. In the groundwater, 13 compounds were detected above their SHS MSC.

Because the soil samples with exceedances are located at depths greater than 1.5 feet bgs, there is limited potential for direct contact with these soils for humans or wildlife, other than for humans if the materials are exposed by maintenance or construction activities. In such cases, an appropriate health and safety plan would be in place to protect the workers from these potential exposure pathways.

The Former Burn Pit Area is within Exposure Unit 4 (EU4). The HHRA for EU4 identified no health risks above the target cumulative risk of 10^{-4} and HI of 1 for the soil exposure pathways except for the outdoor worker (inhalation of vapors from exposed subsurface soils) and the construction worker exposed to subsurface soil (ingestion, inhalation, and dermal). Exceedances of the targets were found in EU4 for the soil gas to indoor worker pathway and the soil, groundwater, and SPL to construction worker pathways. There are no structures subject to the indoor air pathway in the Former Burn Pit Area and none are planned. Thus, this pathway is incomplete in this Area.

The impacted groundwater underlying the Former Burn Pit area extends only a relatively short distance beyond the refinery boundary showing that natural attenuation is effectively preventing the migration of the BTEX and PAHs from the Area to Tunungwant Creek and Foster Brook. Also, there is no potential for direct contact with the soil, groundwater, and SPL unless it is exposed by construction activities. Such construction activities would be performed following appropriate health and safety procedures, thereby eliminating this potential exposure pathway. The procedures to ensure appropriate H&S measures are implemented are presented in Appendix AP.

Based on the HHRA and Former Burn Pit Area conditions, the exposure pathways of concern are:

i) inhalation of vapors from impacted subsurface soil (outdoor worker and construction worker);

ii) direct contact with/ingestion of impacted soil (construction worker);

iii) direct contact with/ingestion of SPL (construction worker);

iv) impacted soil/SPL to groundwater pathway (construction worker); and

v) direct contact with/ingestion of impacted groundwater (construction worker).

The findings of the ERA with regard to species and habitats of concern are the same as for the Fly Ash Area with regard to proximity of the Area to Foster Brook and its associated wetlands.

Requirements to Close Burn Pit Area Under Act 2: The Former Burn Pit Area is covered in most areas with between 2 and 4 feet of yellowish brown clayey silt (see Figure 5.41). The permeability of the cover material has been determined to range between 1.3×10^{-4} to 3.1×10^{-7} cm/second. There are only small, isolated bare spots with little or no vegetation cover over this area. The thickness of the fill material below this cover varies from approximately 1 foot to 11 feet. This fill material is primarily comprised of clayey to sandy silt and silty sand containing traces of cinders, bricks, coal, and wood fragments. Some locations had a gray sludge material (TB-6B, TB-23, TB-33, TB-40, and TB-46) present. The ground surface currently is sloped at approximately a 2% grade in a northeasterly direction toward Foster Creek and westerly toward State Route 219 (see Figures 5.40 and 5.41).

Closure Assessment: Based on the evaluation described in Appendix AN, the technologies that are most appropriate for consideration for the Former Burn Area are:

i) excavation and off-site treatment/disposal;

ii) in-situ treatment:

   a) solidification/stabilization,

   b) soil vapor extraction, and

   c) bioremediation; and

iii) cover and institutional controls.

The estimated costs for these technologies are:

Alternative	*Estimated Costs*	
	Capital	*Annual O&M*
Excavation and Off-Site Disposal 6-inch vegetated soil cover	$865,000	$5,900
Solidification/Stabilization 6-inch vegetated soil cover	$279,000	$5,900
Soil Vapor Extraction 6-inch vegetated soil cover	$429,000	$131,500
Biosparging 6-inch vegetated soil cover	$219,000	$60,500
24-inch Vegetated Soil Cover	$14,000	$5,600
12-inch Vegetated Soil Cover	$6,000	$5,600

Exceedances of SHS MSCs are present throughout the Former Burn Pit Area. Thus, this area will be closed under a combined SHS MSC and Site-Specific Standard.

The closure alternative selected for the Former Burn Pit Area involves:

i) moderate regrading of the area to promote surface water runoff to the northeast toward Foster Brook and to the west toward the State Route 219 drainage swale;

ii) placement of up to an additional 6 inches of topsoil over those areas with less than one foot of cover;

iii) revegetation of the regraded areas with grasses and herbaceous seed mix to enhance the ecological habitat value of the area;

iv) implementation of deed restrictions to restrict groundwater use and operating procedures to ensure appropriate H&S measures are implemented for subsurface activities for both the Site (draft language is provided in SCR Appendices AO and AP) and downgradient off-Site property (i.e., PennDOT) (procedures are presented in Appendix AM); and

v) submittal of appropriate forms and report to close the area using a combined SHS MSC and SSSs for the soil and groundwater based on the existing data.

This alternative was selected based on its ability to:

i) further reduce the already acceptable pathway of direct contact with humans;

ii) further reduce the already acceptable pathway of direct contact with wildlife;

iii) further control erosion to Foster Brook;

iv) limit infiltration of precipitation through the waste into the groundwater; and

v) provide sufficient soil to allow the growth of a vegetative cover,

Figure AN4.2 of Appendix AN shows the area to be covered.

Post-Closure Monitoring And Maintenance

To ensure the cover remains effective, post-closure monitoring and maintenance activities will be performed upon completion of construction of the cover. This will include semi-annual inspections and repair/maintenance of the soil and vegetative cover should the inspections identify the need for such.

Any observation of a lack or sparsity of vegetative cover and/or erosion in the soil cover will be addressed as soon as practical. Potential corrective measures for sparse vegetation include:

i) reseeding; and

ii) adding more topsoil and reseeding.

For the soil cover, potential corrective measures include:

i) removing the eroded cover material from where it has migrated to, where practical, and replacing into the eroded areas and reseeding; and

ii) replacement of the eroded soil and reseeding.

Groundwater monitoring will be performed at four wells semi-annually. The samples will be analyzed for VOCs, PAHs, arsenic, and manganese.

Additional details will be provided in the Site Cleanup Plan.

5.12.4 CONSTRUCTION DEBRIS AREA

Description of Site: The Construction Debris Area is an approximately 14-acre area located at the northern end of the Foster Brook Facility as shown in Figure 5.42. The southern end of this area received fill prior to 1980 and is elevated approximately 4 feet above the area to the north. The transition between these two areas is evidenced by a steep drop-off out of which old equipment and other wastes are visible. The southern portion is vegetated with Herbaceous-Old Field vegetation and the coverage of vegetation is approximately 70%. There is a wetland in this area also. The northern portion of this area consists of 50 to 70 year old deciduous forest with the exception of an open area adjacent to State Route 219 that is 90% covered with Old Field growth. Based on elevation and boring log data, the area and thickness of fill are shown on Figure 5.42. Fill was observed to be present in 4 areas, a larger one connected to fill in the Refuse Area, and 3 smaller areas. In the smaller areas, the maximum fill thickness ranged from 2 to 6 feet and in the larger area was up to 8 feet thick. Generally, the fill is exposed at ground surface. Where cover exists, it is patchy and generally less than 1-foot thick (see Figure 5.43). The types of fill material encountered included a matrix composed of clay, silt, and sand with brick, coal, cinders, glass and metal fragments, unspecified debris/organic debris, and roofing shingles within the matrix.

Results of Previous Investigation: The soil and groundwater analytical results show that there has been a very minor impact on the soil and groundwater quality in the Construction Debris Area. No adverse impact to off-Site groundwater was detected. Prior to 2003, two geophysical surveys were performed and test pits were excavated in the Construction Debris Area. At that time, soil samples were collected from 38 locations. In 2003, 8 additional borings were installed and 23 additional soil samples were collected and analyzed. In all of the unsaturated soil samples, no COCs in exceedance of SHS MSCs were detected with the following exceptions:

i) PCE in one sample (RAS-6 at 35 mg/kg vs a standard of 0.5 mg/kg); and

ii) Arsenic and lead in one sample in borehole FBCD-11 (lead at 1,120 mg/kg vs a standard of 450 mg/kg and arsenic at 69 vs a standard of 53 mg/kg).

For the saturated soil samples, the following parameters had exceedances:

Parameter	*SHS MSC (mg/kg)*	*Location*	*Concentration (mg/kg)*
Arsenic	15	FBCD-11B	37
		FBCD-3B	29
		FBCD-4B	20
		DBCD-5B	25
Cadmium	3.8	FBCD-11B	15
Lead	45	FBCD-11B	462
		FBCD-5B	81
Mercury	1.0	FBCD-11B	3.4J
Nickel	65	FBCD-11B	106
Benzene	0.013	FBCD-5B	0.035J

Based upon this information, there is essentially no organic chemical presence in the soils of the Construction Debris Area. Only one location had exceedances of one organic parameter at approximately three times its criteria. This shows a very limited impact in one localized area.

Six groundwater monitoring wells have also been installed and sampled in this area including one background location (MW-RA-02). Only a few SHS MSC exceedances were measured. One well (MW-RA03) exceeded the SHS MSC for TCE (0.006 and 0.047 mg/L vs a standard of 0.005 mg/L) in two earlier sampling events but did not exceed the SHS MSC in the third sampling event. Monitoring well RAW28 exceeded the SHS MSC for TCE in one sampling event (0.024 mg/L vs a standard of 0.005 mg/L. Both wells are located in the same general area. Thus, currently, only one well (RAW-28) has an exceedance of one parameter and that exceedance is less than five times its criteria. Well MW-RA4 located downgradient of MW-RA03 and RAW-28 did not have any organic compounds detected and thus there is no off-Site groundwater impact due to the on-Site organic compounds.

As shown in Appendix AN, the exceedances of the aluminum, beryllium, cadmium, lead, and nickel standards detected in the groundwater samples are minor. Iron and manganese exceeded their SHS MSC in the majority of the samples. However, this could be a result of the groundwater being in an anaerobic condition rather than as a result of a release from the Site. In fact, given the low iron and manganese concentrations in the soil, it is likely that the iron and manganese presence in the groundwater is due to the existing Site conditions and unrelated to any release/spill at the Site, a condition that is natural in many areas. The only parameters exceeding criteria at the downgradient well MW-RA4 were iron and manganese.

The Construction Debris Area is within Exposure Unit 5 (EU5). The HHRA for EU5 identified no health risks above the target cumulative risk of 10^{-4} and HI of 1 for all of the complete exposure pathways except for soil and groundwater for the construction worker (ingestion, inhalation, and dermal).

As shown above, no compounds were detected above their SHS MSC in the surface soil samples. Arsenic and lead were detected in exceedance of their SHS MSC in only one location in the subsurface unsaturated soil. For the saturated soil, benzene and 5 metals were detected in exceedance of their SHS MSC. In the on-Site groundwater, 2 organic compounds and 7 metals were detected above their SHS MSC. No exceedances were detected in the off-Site downgradient groundwater.

Because the soil samples with exceedances are located at depths greater than 6 feet bgs, there is no potential for direct contact with these soils for humans or wildlife, other than for humans if the materials are exposed by maintenance or construction activities. Also, there is no potential for direct contact with the groundwater unless it is exposed by maintenance or construction activities. Such activities will be performed following

appropriate health and safety procedures, thereby eliminating these potential exposure pathways. The procedures to ensure appropriate H&S measures are implemented are presented in Appendix AP.

The Act 2 MSCs for iron and manganese are based on aesthetic concerns (not human health concerns). Furthermore, the groundwater from this area is not used, and there are no applicable soil to groundwater MSCs for these two metals.

Based on the HHRA and Construction Debris Area conditions, there are no complete exposure pathways of concern and only limited impact to the on-Site saturated soil and groundwater.

The findings of the ERA with regard to the species and habitats of concern are the same as for the Fly Ash Area with regard to proximity to Foster Brook and its associated wetlands. In addition, a wetland is located within the Construction Debris Area.

Requirements to Close Construction Debris Area Under Act 2: A demonstration under Act 2 must show that the fill material has been adequately covered where exposed, and revegetated, and that there are no off-site impacts.

Closure Assessment: The technologies that are most appropriate for consideration for the Construction Debris Area are:

i) excavation and off-site treatment/disposal;
ii) in-situ treatment
   a) solidification/stabilization; and
iii) cover and institutional controls.

The estimated costs for these technologies were:

Alternative	*Estimated Costs*	
	Capital	*Annual O&M*
Excavation and Off-Site Disposal 6-inch vegetated soil cover	$1,150,000	$4,000
Solidification/Stabilization 6-inch vegetated soil cover	$284,000	$4,000
24-inch Vegetated Soil Cover	$109,000	$4,000
12-inch Vegetated Soil Cover	$22,000	$3,600

Minor exceedances of the SHS MSCs are present in isolated areas of the Construction Debris Area. However, there is no impact of these exceedances in off-Site areas. Therefore, this Area will be closed under a combined SHS MSC and Site-Specific Standard.

The closure alternative selected for the Construction Debris Area involves:

i) regrading of uneven areas (such as excavated pit areas) and open, non-vegetated areas to promote drainage toward Foster Brook, where applicable;

ii) covering of all exposed wastes and regraded areas with a 12-inch thick cover consisting of 12 inches of soil capable of supporting vegetation;

iii) revegetation of the regraded/covered areas covered with grasses, and herbaceous seed mix to enhance the ecological habitat value of the area;

iv) implementation of deed restrictions to restrict groundwater use and operation procedures to ensure appropriate H&S measures are implemented for subsurface activities (draft language is provided in SCR Appendices AO and AP); and

v) submittal of the appropriate forms and reports to close the area using a combined SHS MSC and Site Specific Standard for the soils and groundwater based on the existing data.

This alternative was selected based on its ability to:

i) further reduce the already acceptable pathway of direct contact with humans;

ii) further reduce the already acceptable pathway of direct contact with wildlife;

iii) control erosion of the fill;

iv) limit infiltration of precipitation through the fill into the groundwater; and

v) provide sufficient soil to allow growth of a vegetative cover,

Removal of the existing vegetation and cover would be more disruptive than the benefit gained from recovering/regrading some of these areas. Consequently, no further work is planned for the areas that have no exposed wastes, in which no regrading is needed, and in which vegetative ground cover has been established.

The general area to be covered is shown on Figure AN5.2 of Appendix AN.

Post-Closure Monitoring And Maintenance

To ensure the cover remains effective, post-closure monitoring and maintenance activities will be performed upon completion of construction of the cover. This will include semi-annual inspections and repair/maintenance of the soil and vegetative cover should the inspections identify the need for such.

Any observation of a lack or sparsity of vegetative cover and/or erosion in the soil cover will be addressed as soon as practical. Potential corrective measures for sparse vegetation include:

i) reseeding; and

ii) adding more topsoil and reseeding.

For the soil cover, potential corrective measures include:

i) removing the eroded cover material from where it has migrated to, where practical, and replacing into the eroded areas and reseeding; and

ii) replacement of the eroded soil and reseeding.

Groundwater monitoring will be performed at two wells semi-annually. The samples will be analyzed for VOCs and metals.

Additional details will be provided in the Site Cleanup Plan.

5.12.5 REFUSE/CONTAINER REMOVAL AREA

Description of Site: The Refuse/Container Removal Area is an approximately 9-acre, triangular shaped area located on the northern side of Foster Brook as shown in Figure 5.36. An approximately 3-acre cleared area at the northern end of the Refuse/Container Removal Area was used by the refinery as a disposal site for miscellaneous demolition debris and drums of wastes until the early 1970s. This area is elevated approximately 4 feet above the Construction Debris Area that lies to the north. The transition between these two areas is evidenced by a steep drop-off out of which old equipment and other wastes are visible. This area is vegetated with Herbaceous-Old Field vegetation. The coverage of vegetation is approximately 70%. The remaining 6 acres are located to the south and are primarily wooded with relatively new growth forest whose coverage is 100%. The lateral extent of and thickness of the fill in this area

is shown in Figure 5.36. Based on elevation and boring log data, the thickness of cover is shown on Figure 5.37. Aside from a small number of excavated pits and the steep drop-off mentioned above, no fill material was visible at the ground surface.

Summary of Previous Investigation/Remedial Activities: The soil and groundwater analytical results show that there has been a very minor impact on the soil and groundwater quality in the Refuse/Container Removal Area. No adverse impact to off-Site groundwater was detected. The container removal area was investigated through three geophysical surveys. The majority of the survey anomalies were found to be large masses of buried metal with some buried containers observed in the western section of the survey. Groundwater samples collected in this area were non-detect for BTEX. According to the report entitled "Foster Brook Container Removal Activity and Refuse Site Characterization Report" dated March 1998, 3,200 containers and approximately 400 cubic yards of TPH impacted soil were removed in 1997 and disposed off Site. Following the removal, 62 soil samples and 10 groundwater samples from 32 boring locations taken across the entire refuse site were collected and analyzed. The TPH concentrations in the soil samples ranged from non-detect to a maximum of 37,000 mg/kg except for 3 locations (location 11 = 75,000 mg/kg, location 6 = 117,000 mg/kg, and location 21 = 200,000 mg/kg) for the field analyzed samples and from non-detect to 43,000 mg/kg for the laboratory analyzed samples. It is noted that there currently is no SHS MSC for TPH. Rather, the individual compounds included in TPH which are deemed to be of significant concern (e.g., BTEX) have SHS MSCs.

With respect to the compounds analyzed for which there are SHS MSCs, only 1 of the soil samples (RAS-19) had concentrations greater than the SHS MSCs for soil-to-groundwater impact. The soil compounds in exceedance of their SHS MSCs at this one location were reported to be arsenic (59 mg/kg vs a standard of 53 mg/kg for direct contact), lead (490 mg/kg vs 450 mg/kg), and thallium (21 mg/kg vs 14 mg/kg). One other sample (RASS-01) also exceeded the direct contact SHS MSC for arsenic (84 mg/kg vs 53 mg/kg). Given the isolation of these locations from direct contact, there is minimal environmental significance of the Site soils and the chemicals contained therein.

For the saturated soil samples, arsenic exceeded its SHS MSC in locations FBCD-7B and FBCD-8B with a maximum concentration of 44 mg/kg vs a standard of 15 mg/kg.

The two locations described above are randomly located in different areas of the Refuse Area. The few number of parameters with exceedances at only two locations shows a very limited impact to the soil in two small localized areas.

Groundwater samples were collected from 5 monitoring wells including one background well (MW-RA01). The on-Site groundwater dissolved metals in exceedance of their SHS MSCs were reported to be beryllium and nickel and this only occurred at one and two locations, respectively. Beryllium was present in monitoring well RAW-02 at a concentration of 0.007 mg/L vs a standard of 0.004 mg/L. Nickel was present in wells RAW-02 and RAW-31 at concentrations of 0.21 and 0.13 mg/L, respectively, vs a standard of 0.1 mg/L. Given their low exceedances and infrequent presence, the metals are not of environmental concern. These compounds are not attributable to the refinery petroleum products and because no petroleum related compounds (e.g., BTEX) exceeded their SHS MSCs, it is believed that the TPHs are also not a significant environmental issue. Furthermore, no impact to off-Site groundwater or surface water is occurring based on no exceedances detected in downgradient monitoring well RAW-16.

The Refuse/Container Removal Area is within Exposure Unit 5 (EU5). The RA for EU5 identified no health risks above the target cumulative risk of 10^{-4} and HI of 1 for any of the complete exposure pathways except for soil and groundwater for the construction worker (ingestion, inhalation, and dermal).

As shown above, only arsenic, lead, and thallium were detected above their SHS MSC in the surface soil samples. No compounds were detected in exceedance of their SHS MSC in the subsurface unsaturated soil. Only arsenic was detected in exceedance of its SHS MSC in the saturated soil. In the groundwater, only beryllium and nickel were detected above their SHS MSC in the on-site groundwater.

Because the soil samples with exceedances are located in the surficial soils, there is a potential for direct contact with these soils for humans and wildlife. In addition, human exposure may occur if the materials are exposed by maintenance or construction activities. Also, there is no potential for direct contact with the groundwater unless it is exposed by construction activities.

Such construction and maintenance activities will be performed following appropriate health and safety procedures, thereby eliminating these potential exposure pathways. The procedures to ensure appropriate H&S measures are implemented are presented in Appendix AP.

The Act 2 MSCs for iron and manganese are based on aesthetic concerns (not human health concerns). Furthermore, the groundwater from this area is not used, and there are no applicable soil to groundwater MSCs for these two metals.

Based on the HHRA and Refuse/Container Removal Area conditions, there are no completed exposure pathways of concern and only limited impact to the on-Site saturated soil and groundwater.

The findings of the ERA with regard to species and habitats of concern are the same as for the Fly Ash Area with regard to proximity of the Area to Foster Brook and its associated wetlands. In addition, a wetland is located within the Refuse/Container Removal Area. The wetland is not in the area where the currently exposed fill materials are present.

Requirements to Close Refuse/Container Removal Area Under Act 2: A demonstration under Act 2 must show that the fill material has been adequately covered where exposed and revegetated, and that there are no off-site impacts.

Closure Assessment: The technologies that are most appropriate for consideration for the Refuse Area are:

i) excavation and off-site treatment/disposal;

ii) in-situ treatment

   a) solidification/stabilization; and

iii) cover and institutional controls.

The estimated costs for these technologies are:

Alternative	*Estimated Costs*	
	Capital	*Annual O&M*
Excavation and Off-Site Disposal 6-inch vegetated soil cover	$164,000	$3,000
Solidification/Stabilization 6-inch vegetated soil cover	$43,000	$3,000
24-inch Vegetated Soil Cover	$24,000	$3,000
12-inch Vegetated Soil Cover	$11,000	$3,000

All drummed wastes and a considerable amount of other waste and contaminated soil has already been removed from this Area. The remaining concentrations of contaminants in the soil and groundwater, with few minor exceptions, are below the applicable SHS MSCs and no off-Site migration in exceedance of SHS MSCs is occurring.

Because of the minor exceedances, this area will be closed under a combined SHS MSC and Site-Specific Standard.

The closure alternative selected for the Refuse/Container Removal Area involves:

i) minor regrading to improve surface water drainage, where necessary;

ii) cover all exposed wastes and regraded areas with up to a 12-inch thick cover consisting of soil capable of supporting vegetation consistent with surrounding ground elevations;

iii) revegetation of the newly covered areas with grasses and herbaceous seed mix to enhance the ecological habitat value of the area;

iv) implementation of deed restrictions to restrict groundwater use and operating procedures to ensure appropriate H&S measures are implemented for subsurface activities (Draft language is provided in SCR Appendices AO and AP); and

v) submit the appropriate forms and reports to close the area using a combined SHS MSC and Site-Specific Standards for the soils and groundwater based on existing data.

This alternative was selected based on its ability to:

i) further reduce the already acceptable pathway of direct contact with humans;

ii) further reduce the already acceptable pathway of direct contact with wildlife;

iii) control erosion of the fill;

iv) limit infiltration of precipitation through the fill into the groundwater; and

v) provide sufficient soil to allow growth of a vegetative cover,

Removal of the existing vegetation and cover would be more disruptive than the benefit gained from recovering/regrading some of these areas. Consequently, no further work is planned for the areas that have no exposed wastes and have established ground cover.

The general area to be covered is shown on Figure AN5.2 of Appendix AN.

Post-Closure Monitoring And Maintenance

To ensure the cover remains effective, post-closure monitoring and maintenance activities will be performed upon completion of construction of the cover. This will

include semi-annual inspections and repair/maintenance of the soil and vegetative cover should the inspections identify the need for such.

Any observation of a lack or sparsity of vegetative cover and/or erosion in the soil cover will be addressed as soon as practical. Potential corrective measures for sparse vegetation include:

i) reseeding; and

ii) adding more topsoil and reseeding.

For the soil cover, potential corrective measures include:

i) removing the eroded cover material from where it has migrated to, where practical, and replacing into the eroded areas and reseeding; and

ii) replacement of the eroded soil and reseeding.

Groundwater monitoring will be performed at two wells semi-annually. The samples will be analyzed for metals.

Additional details will be provided in the Site Cleanup Plan.

5.13 CHEMICAL CHARACTERIZATION SUMMARY

For the discussions provided in the subsequent sections, the following descriptions are used:

i) low level exceedances are ≤5 times the SHS MSC;

ii) moderate exceedances are >5 to ≤50 times the SHS MSC; and

iii) significant exceedances are >50 times the SHS MSC.

Groundwater locations which had exceedances of different levels on different dates were assigned the higher level in the following discussion.

Entire Site

i) Significant iron and manganese exceedances occur throughout the groundwater underlying and upgradient of the Site. These conditions are believed to be

typical for the area although the Site has resulted in some increases of the iron and manganese concentrations beneath the Site. There are no applicable SHS MSCs for iron or manganese in soil. In general, the groundwater concentrations are holding constant or slowly decreasing with time, indicative of steady-state conditions. These two parameters are not further discussed in the following sections.

Main Refinery

i) Low level exceedances of arsenic occurred throughout the groundwater underlying the Main Refinery. This may be related to the anaerobic conditions that exist beneath the Site. The other nine metals have only six or fewer low level to moderate exceedances except for one significant exceedance for each of aluminum and cadmium.

ii) Low level to moderate exceedances occurred for six PAHs with four or fewer exceedance locations for each PAH. Significant exceedances of three PAHs occurred in the groundwater underlying the MEK Unit, ROSE® Unit, Dubbs Unit, and Crude Unit Upper Yard of the Main Refinery. In general the PAH concentrations are decreasing with time.

iii) Moderate to significant exceedances of benzene also occurred within these three areas, in addition to the Platformer Unit and Crude Unit/Barrel House Area. Depending on the location within the Main Refinery, benzene concentrations are holding constant, or decreasing with time.

iv) Furthermore, an area with three low level exceedances of chlorinated VOCs is present beneath the Crude Unit Upper Yard.

v) The areas with groundwater exceedances are generally located beneath or downgradient of areas where SPL is present.

vi) In the surface soils, only cadmium had one low level exceedance and benzene had one low level exceedance.

vii) In the unsaturated soils, low level and moderate benzene exceedances occurred in the ROSE® Unit, Dubbs Unit, and the Erie Wye Unit. A few low level exceedances of benzo(a)pyrene occurred in the Platformer Unit, Dubbs Unit, Crude Unit Upper Yard, and Barrel House Area.

viii) In the saturated soils, low level exceedances of arsenic occurred throughout the Main Refinery, which is similar to the pattern for groundwater. Low to moderate exceedances of lead also occurred throughout the Main Refinery. A few low level to moderate exceedances for seven PAHs occurred primarily in the

ROSE® Unit and the Platformer Unit. Low level to moderate benzene exceedances occurred in the ROSE® Unit, Dubbs Unit, and Crude Unit.

The above shows that much of the groundwater and saturated soil underlying the Main Refinery has been moderately impacted with the areas of greatest impact being where SPL is present.

Administrative/Research Area

i) Low level exceedances of arsenic occurred throughout the groundwater underlying this area. This may be related to the anaerobic conditions that exist beneath the Site. Arsenic concentrations appear to be increasing with time. The other metal with an exceedance (aluminum) only slightly exceeds the secondary maximum contaminant level at only one location.

ii) No exceedances of SVOCs occurred in the groundwater.

iii) A low level exceedance of benzene occurred at only one location. This location is beneath an area where SPL is present. Benzene concentrations appear to be increasing with time.

iv) Moderate to significant exceedances of three chlorinated VOCs occurred in the groundwater. These chlorinated VOCs are not attributable to the Site. The chlorinated VOC concentrations appear to be decreasing with time.

v) No exceedances occurred in the surface or unsaturated soils.

vi) In the saturated soil only lead had a low level exceedance and at only one location.

The above shows that the Administration/Research Area has been minimally impacted by Site related activities, except for a small area located adjacent to Kendall Avenue which correlates with the SPL present in this area.

Crude Tank Farm

i) Low level exceedances of arsenic and thallium occurred in the groundwater at only four locations and one location, respectively. No trend with time could be evaluated. The arsenic exceedances may be related to the anaerobic conditions that exist beneath the Site.

ii) No exceedances of SVOCs occurred in the groundwater.

iii) With regard to petroleum related VOCs, groundwater in nine locations had exceedances, six low level exceedances in the southern portion one low level exceedance in the Tank 724 area, and one low level and one significant exceedance in the Former Rendering Area. No trend with time could be evaluated.

iv) The areas with exceedances are generally located beneath or downgradient of areas where SPL is present.

v) Significant exceedances of chlorinated VOCs occurred in the northern portion of the CTF. These chlorinated VOCs are not attributable to the Site. No trend with time could be evaluated.

vi) In the surface soils, arsenic (3 of 20), lead (2 of 20), and benzene (1 of 29) were the only parameters with exceedances. The arsenic and lead exceedances were low level and the benzene exceedance was moderate.

vii) In the unsaturated soil, arsenic (1 of 33), lead (1 of 33), and benzene (2 of 34) were the only parameters with exceedances. The arsenic, lead, and benzene exceedances were low level.

viii) In the saturated soil, arsenic (2 of 11), lead (2 of 11), and benzene (1 of 11) were the only parameters with exceedances. The lead, arsenic, and benzene exceedances were low level.

The above shows that the Crude Tank Farm has been minimally impacted by Site related activities, except for the three areas where SPL is present (i.e., SPL-16, SPL-17, and SPL-18).

Foster Brook Facility South

i) Low level exceedances of arsenic occurred throughout the groundwater underlying the Foster Brook Facility South with one moderate exceedance in the Light End Tank Farm. This may be related to the anaerobic conditions that exist beneath the Site. Arsenic concentrations appear to be increasing with time. The other four metals have only 5 or fewer low level exceedances with a total of 9 exceedances.

ii) Low level to moderate exceedances occurred for seven PAHs at four or fewer locations, except for naphthalene which had exceedances at 11 locations. All exceedances occurred in either the Light End Tank Farm or the Garage/Shed Area. PAH concentrations appear to be constant or decreasing with time.

iii) Significant exceedances of benzene occurred throughout the groundwater underlying the Foster Brook Facility South. Also, moderate to significant

benzene exceedances occurred in the off-Site groundwater downgradient of the Light End Tank Farm. In addition, low level to moderate exceedances for ethylbenzene, toluene, and xylene occurred principally in the Light End Tank Farm, the Garage/Shed Area, and the Former Burn Pit Area. BTEX concentrations appear to be constant or decreasing with time.

iv) Low level to moderate exceedances of 1,2-DCA occurred in the Light End Tank Farm and Garage/Shed Area.

v) The areas with groundwater exceedances are generally located beneath or downgradient of areas where SPL is present.

vi) In the on-Site surface soil, lead and selenium each had three low level exceedances and antimony had two low level and three moderate exceedances and benzene had one low level exceedance. For the off-Site downgradient surface soil, benzo(a)pyrene, benzene, and naphthalene have only one low level exceedance each whereas1,2,4-trimethylbenzene (2 of 4), and 1,3,5-trimethylbenzene (2 of 4) have two moderate exceedances each. Furthermore, two of the three chlorinated VOCs each have one low level exceedance and the other has a moderate exceedance. The one PAH and all the VOC exceedances, except one of the benzene, occurred in the Former Burn Pit Area. The remaining benzene exceedance occurred in the Light End Tank Farm.

vii) In the on-Site unsaturated soil, arsenic (1 of 89), lead (3 of 89), mercury (1 of 89), and selenium (1 of 89) had low level exceedances. Benzo(a)pyrene had only three low level exceedances whereas naphthalene had three low level and one moderate exceedances. Benzene had moderate exceedances throughout the Foster Brook Facility South with 58 percent of the exceedances occurring in the Light End Tank Farm followed by the Garage/Shed Area and the Former Burn Pit Area. Ethylbenzene, toluene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene had 6, 3, 4, and 4 low level to moderate exceedances, again occurring primarily in the Light End Tank Farm. Methylene chloride, a chlorinated VOC had 2 low level exceedances.

viii) In the off-Site downgradient unsaturated soil, lead (1 of 14) and selenium (2 of 14) were low level exceedances. No SVOCs had exceedances. For the VOCs, 1,2,4-TMB (3 of 4), 1,3,5-TMB (3 of 4), benzene (5 of 9), and ethylbenzene (2 of 14) had low to moderate level exceedances.

ix) In the on-Site saturated soil, arsenic (3 of 22) had low level exceedances. Five PAHs had two or fewer low level exceedances whereas naphthalene had 11 low level to moderate exceedances. Benzene had significant exceedances throughout the Foster Brook Facility South whereas ethylbenzene and toluene each had only one low level exceedance. Similar to the unsaturated soil, the areas with the

greatest number of naphthalene and BTEX exceedances were the Light End Tank Farm, Garage/Shed Area, and the Former Burn Pit Area.

x) In the off-Site downgradient saturated soil, lead had one low level exceedance. The benzene (1 of 9) and naphthalene (2 of 9) exceedances were both low level.

The above shows that much of the Foster Brook Facility South has been significantly impacted with the areas of greatest impact being the Light End Tank Farm, Garage/Shed Area, and the Former Burn Pit Area. These three areas correlate with areas where SPL is present. Also, two off-Site areas have been impacted. The first is the groundwater downgradient of the Light End Tank Farm which has been moderately to significantly impacted with benzene. The second is the Former Burn Pit Area soil and groundwater west of the Site boundary. The off-Site soils have been significantly impacted principally with naphthalene, 1,2,4-TMB, 1,3,5-TMB, and benzene whereas the off-Site groundwater has been significantly impacted with benzene.

Foster Brook Facility North

i) One low level exceedance occurred for beryllium and nickel and one significant exceedance occurred for aluminum in the groundwater underlying the Foster Brook Facility North. No trend with time could be ascertained.

ii) One low level exceedance for methylene chloride and one low level and one moderate exceedance of trichloroethene occurred in the groundwater. No trend with time could be ascertained.

iii) No SPL plumes are present in the Foster Brook Facility North.

iv) In the surface soils, the only parameters with exceedances were three metals, arsenic (2 of 28), lead (1 of 28), and thallium (1 of 28). All exceedances were low level (less than 2 times their SHS MSC).

v) In the unsaturated soil, arsenic and lead, were the only parameters with exceedances. Each parameter had only one low level exceedance.

vi) In the saturated soil, arsenic had six low level exceedances. The other four metals with exceedances have two or fewer low level exceedances except for lead which had one moderate exceedance. No SVOCs or VOCs had an exceedance.

The above shows that the Foster Brook Facility North has been minimally impacted by Site related activities.

Packaging Plant

i) The only parameters, other than iron and manganese, with exceedances in the groundwater were three chlorinated VOCs. These three compounds had low level to moderate exceedances in the northern portion of the Packaging Plant. The source for these VOCs is suspected to be the electronics facility located west (upgradient) of the Packaging Plant. No trend with time could be ascertained.

ii) No surface or saturated soil analytical results are available for the Packaging Plant.

iii) For the unsaturated soil, no metals, SVOCs, or VOCs had exceedances.

The above shows that the northern area of the Packaging Plant has been impacted by Site related activities. The area of greatest impact is the two SPL areas.

Tunungwant Creek

i) for the Site reach surface water, only aluminum and iron had low level exceedances in historic samples. No exceedance for total metals were detected in the May 2005 Site reach samples whereas for the August 2006 samples, total manganese had exceedances at all Site reach locations and iron was in exceedance in one Site reach location. The Site reach concentrations were slightly greater than the background concentrations;

ii) four PAHs had a total of 6 moderate level exceedances (6 of 21 samples) in the May 2005 Tunungwant Creek surface water and five PAHs had moderate exceedances at one location in the August 2006 samples. The Site reach concentrations were slightly greater than the background concentrations;

iii) only one PAH had a moderate exceedance in each of Kendall Creek and Bolivar Run in May 2005. The upstream concentrations were greater than the concentrations at the mouth of the tributaries (which were non-detect). In August 2006, no PAHs were in exceedance at any of these four locations. Thus, this is not Site related;

iv) the CTF tributary had no SVOC exceedances in May 2005. In August 2006, the CTF tributary had four SVOCs in exceedance;

v) Foster Brook had no SVOC exceedance in May 2005. In August 2006, the upstream location and the mouth each had four SVOCs with exceedances. The upstream concentrations were similar to the downstream concentrations;

vi) the Dresser Outfall discharge had 8 SVOCs with significant exceedances in May 2005. The concentrations ranged from 2 to 3 times greater than those in the Site reach samples. In August 2006, only pentachlorophenol was in exceedance;

vii) no VOCs, other than chlorinated organics, had exceedances in the surface water samples in May 2005 and August 2006. The chlorinated organics are not Site related;

viii) the surface water samples with chlorinated organics, which were primarily located adjacent to the east bank adjacent to or downstream of the north portion of the CTF, had low level exceedances;

ix) the surface water concentrations have decreased since August 2000;

x) arsenic had low to moderate level exceedances and iron had 3 low level exceedances in the sediment; and

xi) no VOCs or SVOCs were detected at concentrations above their criteria in the sediments.

6.0 FATE AND TRANSPORT EVALUATION

An evaluation was conducted of the potential fate and transport of chemicals detected in groundwater beneath the Site. The organic chemicals detected in groundwater beneath the Site are primarily related to the SPL present on top of the water table in various areas of the Site. Section 6.1 presents an evaluation of the potential migration of SPL chemical constituents to groundwater. Given that the Site is adjacent to Tunungwant Creek, the most significant migration pathway for chemicals present in groundwater is groundwater discharge to surface water. Section 6.2 presents an evaluation of the potential chemical loading from the Site through groundwater discharge to surface water. This evaluation is conducted using the current chemical concentrations that have been detected in groundwater. The analytical results from a surface water sampling program completed in May 2005 have also been used to determine the Site's impact on adjacent surface water bodies. As discussed in Section 5.9, the majority of the chemical concentrations in groundwater are either constant or decreasing with time. Furthermore, with the SPL recovery program that is being implemented, it is expected that the groundwater concentrations will continue to decrease with time as the major chemical source (the SPL) is being removed. Thus, this evaluation is a conservative estimate of any future chemical loading to surface water.

6.1 POTENTIAL MIGRATION OF SPL TO GROUNDWATER

The leaching of chemicals from SPL to the groundwater at the Site was evaluated using available groundwater data collected from areas where SPL was present. The evaluation was based on the assumption that the chemical concentrations in the groundwater directly underneath the SPL are representative of the leaching potential of the SPL. For example, the groundwater beneath a crude oil or a heavy oil SPL is not anticipated to have elevated concentrations of hydrocarbons representative of gasoline. On the other hand, the groundwater beneath a gasoline SPL is anticipated to have elevated levels of dissolved hydrocarbons representative of gasoline.

Sixteen monitoring wells located beneath thirteen identified SPL plumes were selected for the evaluation of the SPL-to-groundwater leaching. Table 6.1 lists the monitoring wells included in the comparison and identifies the exposure units and SPL plumes.

The most recent groundwater data from these monitoring wells show that only 13 VOCs and 11 SVOCs have been detected at least once in the groundwater adjacent to the SPL plumes. Among these, only 5 VOCs (benzene, cis-1,2-dichloroethene, MTBE, naphthalene, and toluene) and 3 SVOCs (benzo(a)pyrene, benzo(k)fluoranthene, and

chrysene) exceeded the Statewide Standard MSCs for groundwater with the following defined conditions: used aquifer, TDS < 2500 mg/L, and non-residential. Table 6.2 lists the chemicals detected in these monitoring wells and those that exceeded the groundwater MSCs.

Table 6.3 lists the chemicals detected in the SPL sample analyses. Comparison of the SPL data in Table 6.3 with the groundwater data in Table 6.2 indicates the following:

i) the number of detected chemicals and the number of exceedances in groundwater reflect the chemical concentrations detected in SPL. For example, the highest concentrations in groundwater for benzene (1.26 mg/L, 2.53 mg/L, and 5.24 mg/L in MW-TF28, MW-TF02, and HG-417 respectively), correspond to the highest concentrations of benzene detected in the SPL samples; and

ii) in general, the concentrations in groundwater were lower than expected considering that these monitoring wells are located directly beneath an SPL plume. For example, the SPL in HG-417 has 5,700 mg/kg benzene, while the groundwater in HG-417 has only 5 mg/L.

Seven additional potential reasons for the lower than calculated concentrations in the groundwater are:

i) infiltrating water does not pass through the SPL but rather over and around it;

ii) the infiltrating water which has contacted the SPL will be diluted by the base flow of the groundwater;

iii) desorption of the chemicals in the groundwater onto the soil particles at some downgradient location;

iv) chemical and biological degradation;

v) losses due to volatilization as the impacted groundwater moves beyond the SPL area;

vi) dispersion caused by groundwater migration; and

vii) much of the SPL is likely highly weathered and has lost some of its leaching potential.

6.2 POTENTIAL MIGRATION IN GROUNDWATER TO SURFACE WATER

The Site-related impacts to soil and groundwater may have an effect on Tunungwant Creek as a result of impacted groundwater discharging to surface water. However, the impacted groundwater does not always reach Tunungwant Creek. For example, in the Main Refinery area, the discharge of impacted groundwater to surface water is greatly reduced due to the operation of the horizontal and vertical extraction groundwater wells which provide containment of the areas of elevated groundwater impacts underlying the Main Refinery. However, impacted groundwater beyond the influence of the extraction wells on the Main Refinery and from other portions of the Site potentially may migrate in groundwater and discharge to Tunungwant Creek.

An evaluation was conducted to evaluate whether the discharge of Site-related parameters contained within groundwater might result in surface water concentrations that potentially could pose risks above acceptable levels to either human health or aquatic life. The assessment involved estimating potential in-stream concentrations for the Site-related parameters detected in groundwater at the Site, and comparing the estimated in-stream concentrations to the applicable PADEP surface water criteria protective of both human health and aquatic life. In-stream concentrations were determined by estimating the potential chemical loading to Tunungwant Creek from the Site associated with groundwater flowing through the impacted depth of the upper aquifer, followed by mixing this chemical loading with the volume of surface water flow in the Creek. Actual monitoring of Tunungwant Creek was performed in May 2005 and the results were used to further refine the modelling efforts.

Tunungwant Creek represents a regional discharge zone for groundwater throughout the entire thickness of the upper aquifer, however only groundwater flowing through the impacted portion of the upper aquifer would contribute chemical loading to surface water. The chemicals associated with the groundwater impact at the Site are predominantly related to the SPL, which, being less dense than water, floats on top of the water table and does not sink vertically downward. As a result, the depth of the groundwater impact associated with the SPL is shallow and is expected to remain so in the future. In addition, with Tunungwant Creek being a regional discharge zone and the Site being located adjacent to the Creek, groundwater flow in the immediate vicinity of the Site is directed upward. Thus, at the Site, the predominantly upward groundwater flow direction essentially eliminates downward migration of Site-related chemicals. Therefore, only groundwater flowing through the shallow portion of the upper aquifer is impacted by Site-related chemicals and contributes chemical loading to surface water. Section 6.2.1 presents the assessment conducted to determine the depth

of impact in the upper aquifer. Groundwater discharge to surface water estimated from this portion of the upper aquifer was used in the chemical loading calculations.

The chemical loading calculations are summarized in Table 6.23, and are described further in Section 6.2.2. The chemical loading calculations identified that there is a total of 1.77 lbs/day of VOCs and 0.09 lbs/day of SVOCs entering Tunungwant Creek from the Site. It is noted that the 1.77 lbs/day of VOCs includes 0.44 lbs/day of chlorinated VOCs that are not related to the Site (see Table 6.23). Excluding the chlorinated VOCs, the following four compounds comprise approximately half (48 percent) of the remaining Total VOC chemical loading of 1.33 lbs/day to Tunungwant Creek, 0.265 lbs/day benzene, 0.165 lbs/day xylenes, 0.125 lbs/day MEK, and 0.087 lbs/day ethylbenzene (see Table 6.23). For Total SVOCs, the following three components comprise approximately 78 percent of chemical loading: 0.0495 lbs/day 2-methylnaphthalene, 0.0121 lbs/day phenanthracene, and 0.0112 lbs/day acenaphthalene (see Table 6.23).

6.2.1 DEPTH GROUNDWATER IMPACT IN THE UPPER AQUIFER

A review was conducted of the groundwater quality data available for monitoring wells screened in the deeper portion of the upper aquifer to evaluate the depth to which groundwater is impacted by Site-related chemicals. Monitoring well installation details were reviewed to determine which monitoring wells were installed at various depths in the upper aquifer. Most of the monitoring wells have been installed into the shallow portion of the upper aquifer, however, a few monitoring wells were installed to greater depths. Three such monitoring wells were identified for which analytical results are available. These deep monitoring wells are listed below. Listed after each deep monitoring well is the closest shallow monitoring well for which analytical results are available.

Monitoring Well	*Screened Interval (ft bgs)*	*Depth to Groundwater (ft bgs)*	*Location*
EMW-50 (D)	13.1 to 39.0	7.10 to 8.00	Main Refinery, Upper Yard
MW-91 (S)	5.0 to 19.0	7.00 to 7.07	Main Refinery, Upper Yard
MW-CR16 (D)	15.0 to 25.0	8.65 to 9.00	CTF
MW-CR15 (S)	5.1 to 15.1	8.63 to 9.86	CTF
BW-418 (D)	51.0 to 76.0	NM	Foster Brook Facility, Light End Tank Farm
	96.0 to 121.0	NM	Foster Brook Facility, Light End Tank Farm
	221.0 to 231.0	NM	Foster Brook Facility, Light End Tank Farm
MW-TF12 (S)	3.0 to 23.0	6.33 to 9.20	Foster Brook Facility, Light End Tank Farm

Notes:
D Deep monitoring well within the upper aquifer.
S Shallow monitoring well within the upper aquifer.
NM Not measured.

An assessment of the depth of groundwater impacts at these locations is presented in the following.

Main Refinery

The deep monitoring well EMW-50 is located in close proximity to Tunungwant Creek in an area with an SPL plume present both in the immediate area of the well and also in the upgradient area. The presence of the upgradient SPL plume would have the greatest potential to act as a source of chemicals to the deeper groundwater in the vicinity of EMW-50 taking into consideration dispersion, push-down by precipitation infiltration, and downward groundwater flow from the water table to the lower elevation of Tunungwant Creek. The saturated interval above the top of the EMW-50 screened interval ranges from 5 to 6 feet.

The only parameters detected in EMW-50 in exceedance of Act 2 criteria were arsenic, iron, and manganese, which are ubiquitous in groundwater in and around the Site. Review of the inorganics results shows that these three metals (arsenic, iron, and manganese) were in exceedance of their Act 2 criteria in the deeper well EMW-50 and the remaining metals were non-detect. For the shallow well MW-91, seven metals (aluminum, antimony, arsenic, cadmium, iron, manganese, and silver) were in exceedance and six other metals had detectable concentrations. This shows, in general, that the shallow groundwater in this area has higher metal concentrations than the deeper groundwater. Of interest is that for iron and manganese, the deep groundwater

concentrations are greater than the shallow groundwater concentrations. This supports that iron and manganese are naturally elevated in the regional groundwater.

No VOCs or SVOCs were detected at EMW-50 above method detection limits (MDLs). In comparison, five PAHs were detected above their Act 2 criteria at monitoring well MW-91, which is a shallow monitoring well located 135 feet to the east of EMW-50. The bottom of the screened interval for MW-91 overlaps with the upper portion of the screened interval for EMW-50. Since EMW-50 did not contain any VOCs or SVOCs, and is screened to within 5 feet of the top of the water table, the entire EMW-50 screened interval has not been impacted by the SPL presence. Therefore, the parameters detected at MW-91 are likely from the uppermost 5 feet of the upper aquifer. Based on these data, it is concluded that the impact of the SPL floating on the water table is limited to the uppermost reaches of the upper aquifer. At this location, the depth of the upper aquifer groundwater impact is limited to the uppermost 5 feet.

Crude Tank Farm

The deep monitoring well MW-CR16 is located on the CTF (i.e., the Former Rendering Plant) and is screened from 15 to 25 ft bgs. The shallow monitoring well MW-CR15 is located 15 feet from MW-CR16. Both monitoring wells are located in an area that is unlikely to be impacted by releases from the storage tanks located on the CTF since there are no oil storage tanks or processing facilities located upgradient of these locations. The closest oil storage tanks are located approximately 450 feet south of MW-CR16, and the closest SPL plume is located approximately 500 feet north of MW-CR16. Both the closest oil storage tanks and SPL plume are located cross-gradient to MW-CR15 and MW-CR16. Considering no oil related compounds were detected in either well, it is not possible to compare the organic analytical results from the adjacent deep/shallow MW-CR16/MW-CR15 to evaluate whether an impact due to oil releases attributable to the Site is restricted to the shallow portion of the upper aquifer. However, the only four exceedances of VOCs present in groundwater on the CTF were detected in other monitoring wells installed in the shallow portion of the upper aquifer, which supports that the depth of the upper aquifer impact is shallow.

Review of the inorganics results shows that one metal (manganese) was in exceedance of its Act 2 criteria in the deeper well MW-CR-16 and only one other metal (zinc) had a detectable concentration. For the shallow well MW-CR-15, three metals (iron, manganese, and thallium) were in exceedance and arsenic had detectable concentrations. This shows, in general, that the shallow groundwater in this area has higher metals concentrations.

In contrast to the EMW-50/MW-91 area, the iron and manganese concentrations in the shallow groundwater are greater than in the deeper groundwater.

The above also supports that the depth of the upper aquifer impact is shallow.

Foster Brook Facility

The deep monitoring well BW-418 consists of multiple screened intervals located in the Light End Tank Farm of the Foster Brook Facility. The uppermost screened interval for BW-418 is from 51.0 to 76.0 ft bgs. No BTEX compounds were detected above their MDLs in any of the BW-418 screened intervals. The screened interval of the nearby shallow monitoring well MW-TF12 is from 3.0 to 23.0 ft bgs where benzene was detected above its Act 2 criteria and ethylbenzene and xylenes were detected at concentrations below their Act 2 criteria. Unfortunately, there are no monitoring wells located in close proximity to these two locations that monitor the 23.0 to 51.0-foot depth interval of the upper aquifer. Thus, it is not possible to definitively evaluate whether the groundwater from 23.0 to 51.0 ft bgs has been impacted by the Site.

The presence of these organic compounds in MW-TF12 supports that the shallow portion of the upper aquifer has been impacted but that the deeper portions have not. However, it is not possible to determine the exact depth to which the shallow groundwater impact occurs at this location.

Review of the inorganic results shows that for well nest BW-418, only total iron and magnesium results are available. Total iron exceeded its Act 2 criteria in all three intervals ranging from 6.6 to 13 mg/L, with the greatest concentration detected in the middle (i.e., the 96 to 121-foot bgs) screened interval.

For the shallow well MW-TF12, three metals (arsenic, iron, and manganese) exceeded their Act 2 criteria. The dissolved iron concentration in MW-TF12 (85 mg/L) was significantly greater than the total iron in the deeper wells. Typically, total metal concentrations are equal to or greater than dissolved concentrations in the same sample. The greater dissolved concentration supports that the shallow groundwater in this area has higher metal concentrations than the deeper groundwater.

The above support that the depth of the upper aquifer impact is shallow.

Summary

The groundwater analytical data for EMW-50 support that the groundwater within the upper aquifer as shallow as 13.1 ft bgs (5 feet below the water table) is not impacted by releases related to the Site. The analytical results for BW-418 also support that groundwater at depth is not impacted by Site releases. Unfortunately, the uppermost monitoring interval for BW-418 is from the 51.0 to 76.0 ft bgs interval compared to the impacted zone found at shallow well MW-TF12, which is screened from 3.0 to 23.0 ft bgs. Thus, the impacted thickness could be as deep as 51 feet, but there is no groundwater analytical data from the 23 to 51 foot interval in this area to make a more accurate determination.

The most reliable shallow/deep monitoring well pairing data is located on the Main Refinery (MW-91 and EMW-50), and this pairing supports that the depth of the groundwater impact is limited to the uppermost 5 feet of the upper aquifer. As a result, a depth of 10 feet within the upper aquifer groundwater has been used to estimate the groundwater discharge and chemical loading to Tunungwant Creek. Given that vertical groundwater flow is upward in the vicinity of Tunungwant Creek, and thus beneath the Site, the use of 10 feet for the depth of groundwater impact to the upper aquifer is expected to be representative of actual conditions and is likely somewhat conservative.

6.2.2 CALCULATION OF CHEMICAL LOADING AND IN-STREAM CONCENTRATIONS

The methodology used to calculate the chemical loading to Tunungwant Creek and the in-stream concentrations is outlined as follows:

i) groundwater flow zones were defined throughout the Site based on observed groundwater flow directions and the distribution of dissolved phase parameters detected in groundwater. The defined limits of each flow zone are presented on Figures 6.1 to 6.3. The dissolved phase concentrations of BTEX, PAHs, and chlorinated VOCs are presented on Figures 6.1 to 6.3 along with the December 17-19, 2003 groundwater elevation contours. The flow zone boundaries were selected to correspond to locations where changes occur in the groundwater flow directions, as demonstrated by the December 17-19, 2003 groundwater elevation contours, such that each flow zone represents an approximate uniform flow direction. The flow zone boundaries were also selected to fall between individual dissolved phase concentration plumes. Eight flows zones were defined on the Main Refinery (MR-1 to MR-8), two flow zones

were defined on the Crude Tank Farm (CTF-1 and CTF-2), and three flow zones were defined on the Foster Brook Facility (FB-1 to FB-3). One flow zone was defined on each of the Administration/Research and Development Area (ADM-1), National Transit Property (NT-1), and Packaging Plant (PP-1).

ii) for each flow zone, average chemical concentrations were calculated for each chemical detected in groundwater using the most recent groundwater quality data collected between 1999 and 2005 at monitoring wells located along the downgradient boundary of the flow zone (i.e., closest to Tunungwant Creek). The downgradient monitoring wells selected for each flow zone are listed in Table 6.4 and are highlighted on Figures 6.1 to 6.3. The average chemical concentrations were calculated by summing the most current concentrations detected in the samples collected from the downgradient monitoring wells and then dividing this sum by the number of wells (i.e., an arithmetic mean).

The groundwater quality data for the Site collected from 1999 to 2005 indicate relatively stable to decreasing trends in detected concentrations. This demonstrates that the groundwater impact is at worst at an approximate steady-state condition, but, considering the SPL removal and groundwater extraction activities occurring at the Site, the groundwater impact most likely is in a declining condition. As a result, the downgradient monitoring wells represent the potential concentrations discharging to Tunungwant Creek under steady-state (or declining) conditions, and reflect the degree of attenuation occurring between source areas and the downgradient monitoring wells. In addition to the SPL removal and groundwater extraction activities that are ongoing at the Site, it is important to note that natural attenuation processes are occurring in groundwater beneath the Site (e.g., chemical and biological degradation as well as the physical processes of advection and dispersion). Therefore, the chemical loading calculated using the 1999 to 2005 groundwater quality data at the downgradient monitoring wells is a conservative estimate of the actual chemical loading to Tunungwant Creek;

iii) the groundwater discharge rate to Tunungwant Creek through the impacted depth of the upper aquifer (i.e., the top 10 feet of the upper aquifer) was estimated for each flow zone using the calibrated groundwater flow model developed for the Site. The development of the groundwater flow model is presented in Appendix AK. The groundwater flow model was calibrated to the groundwater and surface water elevations measured at the Site in December 2003. The groundwater discharge rate to Tunungwant Creek through the impacted depth of the upper aquifer from each flow zone was estimated using particle tracking methods and the simulated groundwater discharge to surface water under December 2003 conditions. The details of using the

groundwater flow model to estimate the groundwater discharge rate are described in Appendix AK. Table 6.5 presents the simulated shallow groundwater discharge rate for each flow zone through the impacted depth of the upper aquifer (i.e., the top 10 feet of the upper aquifer). The total groundwater flow from the Site entering Tunungwant Creek is estimated to be 3.22 cfs for the December 2003 conditions that have been modeled. The flows from each area are as follows:

Main Refinery	0.74
Administration/R&D Area	0.21
Crude Tank Farm	0.44
Foster Brook	1.42
National Transit Property	0.21
Packaging Plant	0.20
	3.22 cfs

Also included in Table 6.5 are the 7Q10 groundwater discharge rates calculated for each flow zone. The 7Q10 groundwater discharge rates are calculated by apportioning the 7Q10 Site groundwater discharge rate of 1 cfs according to the simulated shallow groundwater discharge rates for each flow zone indicated in Table 6.5. The 7Q10 Site groundwater discharge rate to Tunungwant Creek is based on the flow measurements obtained in May 2005 as described in Section 4.1.5;

iv) for each flow zone, a chemical loading rate was calculated for all detected chemicals by multiplying the average of the chemical concentrations detected at the downgradient monitoring wells by the 7Q10 groundwater discharge rate. The calculation of the chemical loading from each flow zone is presented in Tables 6.6 to 6.21. Tables 6.6 to 6.21 were developed using the groundwater analytical data collected in 1999, 2000, 2001, 2003, 2004, and 2005 for the downgradient monitoring wells within each flow zone. The analytical data from 1999, 2000, 2001, 2003, 2004, and 2005 were selected to ensure that at least one monitoring event per downgradient monitoring well was available to be applied in the chemical loading calculation. Tables 6.6 to 6.21 present the chemicals detected in each flow zone, the maximum of the concentrations detected among the downgradient monitoring wells, the arithmetic mean of the concentrations detected among the downgradient monitoring wells, and the chemical loading based on the arithmetic mean concentrations. The arithmetic mean concentrations were determined by using one-half of the detection limit for non-detect results and by averaging duplicate analytical results before

calculating the arithmetic mean. In some cases, chemicals were detected in only isolated locations within each flow zone and calculating the arithmetic mean using one-half of the detection limit provided an arithmetic mean concentration that was greater than the maximum detected concentration. In these cases, the maximum detected concentration was used in the chemical loading calculation. Tables 6.6 to 6.21 also present the PADEP Chapter 16 Water Quality Criteria for Toxic Substances based on the protection of aquatic life and human health. The lower of these two criteria was selected as the screening criteria, which were compared to the estimated in-stream concentrations to evaluate whether a parameter detected in groundwater represents a potential concern to human health or aquatic life following discharge to surface water. The chemical loading was estimated in Tables 6.6 to 6.21 for all chemicals detected among the downgradient monitoring wells regardless of whether they are detected above or below the screening criteria;

v) for each detected chemical, the chemical loading from each flow zone is presented in Table 6.23 and summed to provide the total chemical loading estimated over the entire length of the Site. The in-stream concentrations were estimated from the total chemical loading introduced via groundwater discharge from the Site by dividing by the 7Q10 surface water flow rate for Tunungwant Creek at the USGS gauging station SG-USGS. Based on these conditions, the total chemical loading from groundwater discharge leads to estimated in-stream concentrations that are below the screening criteria for all detected chemicals, with the exception of the three SVOCs [benzo(a)pyrene, benzo(k)fluoranthene, and chrysene] and one VOC (benzene); and

vi) one other comparative evaluation was conducted as a sensitivity exercise to determine the potential impact of groundwater discharge from the Site to surface water. This comparative evaluation involved calculating in-stream surface water concentrations at the surface water quality sampling locations presented on Figures 3.1 through 3.3 under 7Q10 conditions based on surface water chemistry measured under non-7Q10 conditions. Surface water concentrations under 7Q10 conditions were calculated using the May 2005 surface water sampling analytical results based on the equation provided in CRA's May 10, 2005 correspondence to Mr. D. Hegburg of PADEP Re: "Calculation of 7Q10 Surface Water Concentrations When Sampling at a Different Stream Flow Rate". The calculated surface water concentrations under 7Q10 conditions based on the May 2005 surface water sampling analytical results are presented in Table 6.22. As presented in Table 6.22, the calculated surface water concentrations under 7Q10 conditions are above the screening criteria for 26 parameters. Of these 26 parameters, 12 parameters are shown to have exceedances only because the

method detection limits were not low enough to achieve the applicable criteria, even though the most sensitive (i.e., lowest detection limit) analytical method was used. Of the remaining 14 parameters with exceedances, four had detectable concentrations only in the Dresser Outfall sample (i.e., benzo(a)pyrene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. The remaining 10 parameters with detectable concentrations in exceedance of their criteria were:

i) one total metal (aluminum);

ii) three dissolved metals (iron, manganese, and mercury);

iii) four SVOCs (benzo(a)anthracene, benzo(b)fluoranthene, chrysene, and hexachlorobenzene); and

iv) two VOCs (methylene chloride and tetrachloroethene).

It is noted that when the measured May 2005 surface water concentrations were converted to concentrations that would be expected under 7Q10 conditions, the primary metals with exceedances resulted in the inclusion of dissolved manganese. For the SVOCs and VOCs, the same parameters had exceedances at the same locations for both the actual analytical results and the analytical results converted to 7Q10 conditions.

For total aluminum, only one upstream location had an exceedance with a concentration slightly greater than its criteria (i.e., 0.22 vs 0.2 mg/L).

For dissolved mercury, only two upstream locations had exceedances with concentrations slightly greater than its criteria. For dissolved iron only three locations had exceedances. For dissolved manganese, the number of locations with exceedances was 24. The maximum dissolved iron and manganese concentrations were 0.36 and 0.18 mg/L, respectively, compared to the groundwater criteria of 0.3 and 0.05 mg/L, respectively.

A summary of the four SVOCs with detected concentrations in exceedance of their criteria for the May 2005 sampling event is provided below.

	Benxo(a)anthracene	Benzo(b)Fluoranthene	Chrysene	Hexachlorobenzene
Criteria (mg/L)	0.0000044	0.0000044	0.0000044	0.00000075
Tunungwant Creek				
- Upstream	0.000011 to 0.000024	0.000020	0.000016 to 0.000017	0.000011
- Site Reaches	0.000010 to 0.000074	0.000020 to 0.000048	0.000016 to 0.000054	0.000011 to 0.000019
Kendall Creek				
- Upstream	0.000016	0.000020	0.000016	0.000011
- Downstream	0.000011	0.000020	0.000017	0.000011
Bolivar Run				
- Upstream	0.000029	0.000020	0.000016	0.000011
- Downstream	0.000023	0.000020	0.000017	0.000011
Foster Brook				
- Upstream	0.000010	0.000020	0.000016	0.000011
- Downstream	0.000011	0.000020	0.000017	0.000011
CTF Tributary				
- Downstream	0.000011	0.000020	0.000016	0.000011
Dresser Outfall	0.00015	0.00013	0.00016	0.000059

For all four SVOCs, the maximum upstream concentrations are less than the maximum Site reach concentrations. Many of the concentrations for these four SVOCs along the Site reaches are the same as the upstream concentrations and most remain below the applicable criteria. However, in a few select areas, the Site reach concentrations can be as high as three times the upstream concentration. Benzo(a)anthracene has detectable concentrations in 3 Site reach locations (out of 15), chrysene in 2 Site reach locations, and benzo(b)fluoranthene and hexachlorobenzene in 1 Site reach location, each. As indicated above, the concentrations in the Dresser Outfall for each of these four SVOCs were 2 to 3 times greater than those detected in Tunungwant Creek and would have contributed to the concentrations measured in the Site reaches.

Tetrachloroethene only had exceedances at three locations, two of which were along the east bank adjacent to and downstream of the chlorinated organics plume in the northern portion of the CTF and one in the mouth of Foster Brook. Both methylene chloride exceedances occurred in the most downstream location (i.e., SW-013) in the west bank and middle samples. Neither of these parameters are associated with releases from the ARG facility.

The maximum and minimum of the calculated surface water concentrations under 7Q10 conditions are summarized in Table 6.22 and are also reproduced in Table 6.23. In Table 6.23, 7Q10 surface water concentrations calculated based on

groundwater loading to Tunungwant Creek are also provided under 7Q10 groundwater discharge conditions.

For the metals and VOCs listed in Table 6.23, the calculated in-stream concentrations based on groundwater loading are generally within the range of the measured concentrations, with some parameters having calculated concentrations less than and some greater than the measured concentrations. For most of the SVOCs listed in Table 6.23, the calculated concentrations are less than the measured concentrations. This occurred because the calculated in-stream concentrations were calculated using groundwater concentrations which were low level or non-detect (in which case one half the detection level was used for calculation) and then were diluted by the Creek flow resulting in values that are less than the detection limits for the surface water samples. Thus, for those parameters which are indicated as having an exceedance only because of the surface water sample detection limits and which do not show an exceedance based on the groundwater loadings, it is possible that the parameter is not in exceedance of its criteria. Such parameters are indeno(1,2,3-cd)pyrene and 1,2,4-TMB.

6.2.3 SUMMARY

The chemical loadings for the Site are presented in Table 6.23 and show that the total estimated chemical loading contributed by groundwater to surface water under calculated 7Q10 conditions are as follows:

Chemical Type	*Chemical Loading (lbs/day)*
Total VOCs	1.77
Total SVOCs	0.09
TPH (extractable)	5.11

For Total VOCs, the chemical loading includes 0.44 lbs/day of chlorinated VOCs that are not related to the Site (see Table 6.23). Excluding chlorinated VOCs, the majority of the remaining Total VOC chemical loading of 1.33 lbs/day consists of 0.27 lbs/day benzene (42%), 0.16 lbs/day xylenes (26%), 0.12 lbs/day MEK (19%), and 0.09 lbs/day ethylbenzene (13%) (see Table 6.23). For Total SVOCs, the chemical loading is comprised of 0.05 lbs/day 2-methylnaphthalene (53%), 0.01 lbs/day phenanthracene (13%), and 0.01 lbs/day acenaphthalene (12%) (see Table 6.23).

There is also a considerable amount of dissolved inorganic compounds being discharged into the Creek from the groundwater beneath the Site; most of which is naturally occurring. The most prominent inorganics are as follows:

Sodium	734 lb/day
Calcium	223 lb/day
Iron	209 lb/day
Magnesium	53 lb/day
Manganese	26 lb/day

These five inorganic compounds account for more than 98% of the inorganic loading to the Creek from the groundwater.

Based upon the loading calculations provided in Table 6.23, it can be seen that the Foster Brook Facility provides the highest loading to Tunungwant Creek. The Foster Brook Facility contributes 53% of the VOCs, 56% of the SVOCs, and 62% of the dissolved metals as shown in the following:

Area	*Chemical Loading lb/day (%)*		
	VOCs	*SVOCs*	*Inorganics*
Main Refinery	0.34 (19)	0.03 (31)	237 (20)
Admin/R&D	0.16 (9)	ND (0)	75 (5)
Crude Tank Farm	0.05 (3)	0.003 (3)	70 (5)
Foster Brook Facility	0.95 (54)	0.05 (56)	790 (62)
National Transit Property	0.23 (13)	0.01 (10)	26 (2)
Packaging Plant	0.04 (2)	ND (0)	74 (6)
	1.77	**0.09**	**1,271**

It is to be noted that the entire loading from the Foster Brook Facility comes from the portion of the area that is south of Foster Brook. Flow zones FB-1 provides the highest chemical loading of VOCs and SVOCs, and is the second highest loading source of dissolved metals to Tunungwant Creek. This is as expected due to the amount of light end SPL on the groundwater table in this area and due to the fact that there is no active groundwater remedial measures in place in this area other than the manual SPL removal program.

The Main Refinery area is the next most significant source of chemicals entering Tunungwant Creek. Without the operation of the horizontal and vertical well systems in the Main Refinery, the chemical loading to Tunungwant Creek would be considerably

higher. However, the groundwater remediation measures currently in place in the Main Refinery area have been effective in drastically reducing this area's impact on the Creek.

With regard to the inorganic compounds, it is likely that the petroleum products in the groundwater are consuming a considerable portion of the available oxygen content in the groundwater. This results in the creation of anaerobic conditions which will promote dissolution of the metals from the soils into the groundwater flow beneath the Site. This, in turn, results in higher inorganic concentrations in the groundwater and higher inorganic loadings to the Creek. As time goes on and the available SPL is removed from the groundwater, there is an expectation that concentrations of the petroleum related compounds in the groundwater will reduce, oxygen content will rise, and therefore, dissolution of inorganics from the soils will be reduced. This will result in lower inorganic concentrations and loadings in the future as aerobic conditions become more prevalent again.

The actual chemical loading to Tunungwant Creek is expected to be considerably lower than that calculated under 7Q10 conditions. This is due to the following:

i) The downgradient monitoring wells used to characterize the groundwater quality applied in the chemical loading calculations are up to 100 feet from the point of groundwater discharge to the Creek (i.e., the Creek shoreline) and considerable additional attenuation will occur between these two locations. As a result, the calculated loadings overestimate the actual chemical loading entering the Creek;

ii) The chemical loadings are based on the assumption that the entire uppermost 10 feet of the upper aquifer has been impacted while the actual depth of groundwater impact is likely less than 10 feet due to the upward groundwater flow to Tunungwant Creek beneath the Site and the fact that the source of the groundwater impact (the SPL) is suspended on top of the water table; and

iii) Many of the chemical concentrations used in calculating the chemical loadings are from previous years data (as far back as 1999). Given the decreasing chemical concentration trends measured at many wells, current chemical concentrations are expected to be lower at many of these wells now and therefore, use of these historic data is expected to overestimate the current chemical concentrations and consequently, the chemical loadings as well.

The future chemical loading to Tunungwant Creek is also expected to be less than that calculated under the December 2003 conditions. This is due to the observed trends in the detected chemical concentrations that show that concentrations are either stable or

decreasing. The decreasing trend is believed to be associated with improved spill prevention plans that have been implemented at the Site and Crompton's program of aggressive removal of the historic SPL from the subsurface. With lower concentrations in the groundwater in the future, the chemical loadings will naturally also decrease accordingly.

Based upon the known conditions at the Site and the calculated chemical loadings, it can be seen that the existing groundwater/SPL extraction system (e.g., horizontal and vertical extraction wells) and programs (e.g., SPL manual recovery) are effectively protecting Tunungwant Creek and maintaining the surface water quality at levels that are compliant with Pennsylvania regulations.

The estimated in-stream concentrations based on groundwater loadings and the calculated surface water concentrations using the May 2005 surface water sample results under 7Q10 conditions show that in the majority of locations, the concentrations within the Site reaches were similar to the upstream concentrations. However, there are a few parameters with slight exceedances located sporadically within the Site reaches of Tunungwant Creek. The surface water results for the tributaries support that the Site is not adversely impacting the tributaries.

7.0 HUMAN HEALTH RISK ASSESSMENT SUMMARY FROM SEPARATE HRA REPORT

As part of the SCR, Chemtura was also to include a baseline human health risk assessment (HHRA) to evaluate potential human exposure at the Bradford refinery (Site) and for two adjacent off-Site areas. The HHRA is being submitted as a separate document. The HHRA was conducted in accordance with the Pennsylvania Department of Environmental Protection's (PADEP) 25 PA Code 250 (PADEP, 1997) and Pennsylvania's Land Recycling Program; Technical Guidance Manual (PADEP, 2001) and applicable updates. As allowed in the Technical Guidance Manual, supplemental methodology and information was obtained from the U.S. Environmental Protection Agency's (USEPA) Risk Assessment Guidance for Superfund (RAGS) (USEPA, 1989, 1991) and other Region-wide and Region-specific guidance.

The purpose of this section is to present the results of the HHRA for the constituents detected in soil (surface and subsurface), soil vapor, groundwater, SPL, surface water, and sediment at and downgradient of the Site. The primary objectives of the HHRA are to:

i) Compare data with medium specific concentrations (MSCs) established by PADEP under the Statewide Health Standard (25 PA Code 250 Subchapter C);

ii) Develop and evaluate attainment of Site-Specific Standards (SSSs) (25 PA Code 250 Subchapter D) for those constituents present at concentrations exceeding the Statewide Health Standard; and

iii) Prioritize which exposure units, media, and constituents at the Site may require further actions (i.e., remediation, management controls, etc.) if deemed necessary.

The HHRA conducted for the Site consists of the following components:

i) Site Characterization/Selection of Constituents of Potential Concern (COPCs);

ii) Exposure Assessment;

iii) Toxicity Assessment;

iv) Risk Characterization; and

v) Derivation of Site-Specific Cleanup Levels.

7.1 SUMMARY OF THE SITE CHARACTERIZATION/ SELECTION OF COPCS

For the purpose of the HHRA, the Site has been divided into six discrete exposure units (EUs). In addition, two adjacent off-Site EUs have been included in the HHRA, bringing the total number of EUs to eight, as follows:

Exposure Unit	*Location*
EU1 Main Refinery	• encompasses the Main Refinery and includes all Site property south of Kendall Avenue
EU2 Administration/ Research Area	• encompasses the area north of Kendall Avenue, east of Tunungwant Creek, and south of Kendall Creek
EU3 Crude Tank Farm	• encompasses the Crude Tank Farm area located north of Kendall Creek, east of Tunungwant Creek and south of the National Transit Property
EU4 Foster-Brook Facility South	• encompasses the area north of Bolivar Drive, east of State Route 219, and south of Foster Brook
EU5 Foster-Brook Facility North	• encompasses the area north of Foster Brook, east of State Route 219 and south of the northern Site property boundary
EU6 Packaging Plant	• encompasses the area surrounding the Packaging Plant, including the area north of Bolivar Run, west of Tunungwant Creek, east of State Route 219, and south of the Graham Packaging property
EU7 Tunungwant Creek	• encompasses the length of Tunungwant Creek traversing south to north through the Main Refinery area (EU1), along the western side of EU2, EU3, and EU4, and along the eastern side of EU6
EU8 Off-Site of National Transit Property	• encompasses the impacted property upgradient of the National Transit Property and the two adjacent residential properties located south of Bolivar Drive

Site analytical data were evaluated to determine the COPCs in each EU. COPCs are those constituents detected in soil (surface and subsurface), groundwater, SPL, surface water, and sediment samples at concentrations exceeding background levels or the Non-Residential MSCs for Regulated Substances in Pennsylvania's Land Recycling Program, Technical Guidance Manual (PADEP, 2001). The analytical results of previous studies, and the SSD sampling conducted by CRA were used as input into the HHRA.

Based on this screening process, the COPCs identified in each exposure unit by media are presented in Table 7.1.

7.2 SUMMARY OF THE EXPOSURE ASSESSMENT

The exposure assessment provides a systematic analysis of the potential mechanism by which a receptor may be exposed to COPCs at or originating from the Site. As the Site is and will remain industrialized, the potential human populations considered relevant to the HHRA include a general facility worker (indoor and outdoor), hypothetical on-Site trespasser, and a worker involved in general construction activities., For the off-Site properties adjacent to the ARG facility, future residents, trespassers, construction workers, recreation anglers, and recreational visitors to Tunungwant Creek were also evaluated in the HHRA. Based on these receptors and the results of the COPC selection, the media and potential human exposures identified for quantitative risk evaluation are as presented in Table 7.2.

SPL is also present within EU1, EU2, EU3, EU4, EU6, EU7, and EU8; however, for all EUs except EU7, it is present at depths which are not likely to be encountered during current or future subsurface activities. Nonetheless, excavation work in these EUs could lead to construction worker exposure to SPL, and this exposure will need to be addressed by the worker Health and Safety plan. Procedures to ensure that appropriate H&S measures are implemented for on-site areas are presented in Section 2.7 of Appendix AR and Appendices AO and AP. For the off-Site properties, the procedures are described in Section 2.7 of Appendix AR and Appendices AS and AT..

For EU7, the potential for a recreational user to be exposed to SPL on the EU1 concrete wall bench was evaluated. No unacceptable risk or hazard was calculated for this exposure pathway.

7.3 SUMMARY OF THE TOXICITY ASSESSMENT

The toxicity assessment weighs the available evidence regarding the potential for a particular COPC to cause adverse effects in exposed individuals and estimates the extent of exposure and possible severity of adverse effects. In selecting the toxicity factors used to estimate carcinogenic risk [cancer slope factors (CSFs)] and the potential for non-carcinogenic systemic effects [reference doses (RfDs)], preference was given to the most recently developed values. Toxicity values were primarily obtained from the 25 PA Code Chapter 250 Appendix A Table 5 of the Regulations with updates taken

from the Land Recycling Program Toxicity Database at the following website, *http://www.dep.state.pa.us/toxicity/ToxicityValueChanges/htm#CSFi7.20Change%20.*

7.4 SUMMARY OF THE RISK CHARACTERIZATION

The risk characterization integrates the exposure assessment and toxicity assessment to provide a complete evaluation of the potential human health risks associated with exposure to COPCs at or near the Site. Two levels of exposure were evaluated: i) the Central Tendency (CT), which utilizes the mean COPC concentrations and approximates the most probable exposure conditions; and ii) the Reasonable Maximum Exposure (RME), which utilizes the 95 percent upper confidence level of the COPC mean concentrations and approximates maximum exposure conditions. The estimated cumulative carcinogenic risks resulting from exposure to Site COPCs were compared to a target cumulative risk (TCR) of 10^{-4}. Estimated non-carcinogenic hazards were calculated and compared to a Hazard Index (HI) of 1. A summary of the Reasonable Maximum Exposure (RME) cumulative risk results is presented below:

Exposure Unit	*Construction Worker*		*Indoor Worker*		*Outdoor Worker*		*Trespasser*		*Recreational Visitor*		*Resident/Child/Adults*	
	CR	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*
EU1	1.1E-04	21,000	7.4E-05	6.9	2.2E-06	0.09	2.3E-07	0.023	NA	NA	NA	NA
EU1 Off-Site Hilton Street	–	0.46	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Penn Electric	–	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Mill Street	7.4E-06	6,600	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site B&P Railroad (MEK & Rose)	1.5E-05	7,500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Conrail	9.6E-07	6,600	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site B&P Railroad (Crude Unit)	5.2E-06	14,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Kendall Avenue	2.7E-04	17,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Werzalit	2.2E-06	17,000	2.1E-06	0.12	NA	NA	NA	NA	NA	NA	NA	NA
EU2	1.2E-05	21,000	2.7E-06	0.033	9.9E-07	0.016	1.2E-07	0.005	NA	NA	NA	NA
EU3	7.0E-04	22,000	7.8E-05	1.5	1.7E-05	0.24	2.1E-06	0.071	NA	NA	NA	NA
EU3/EU8 Off-Site B&P Railroad	2.3E-04	21,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU3 Off-Site Conrail	4.0E-04	38,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU4	9.7E-03	130,000	2.5E-03	150	1.4E-05	2.3	1.4E-06	0.24	NA	NA	NA	NA
EU4 Off-Site PennDOT	9.1E-04	14,000	NA	NA	NA	NA	5.1E-05	0.18	NA	NA	NA	NA

Exposure Unit	*Construction Worker*		*Indoor Worker*		*Outdoor Worker*		*Trespasser*		*Recreational Visitor*		*Resident/Child/Adults*	
	CR	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*
EU4 Off-Site Bolivar Drive	5.7E-07	1,100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU4 Off-Site B&P Railroad	3.5E-04	12,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU5	1.7E-06	10	7.6E-06	0.16	1.8E-05	0.39	2.2E-06	0.39	NA	NA	NA	NA
EU6	2.1E-06	1,000	1.9E-06	0.036	NA	NA	NA	NA	NA	NA	NA	NA
EU6 Off-Site Graham Packaging	1.3E-06	1,000	9.9E-07	0.006	NA	NA	NA	NA	NA	NA	NA	NA
EU7 (Child/Adult)	NA	NA	NA	NA	NA	NA	NA	NA	8.1E-05	0.71/0.12	NA	NA
EU8 Off-Site Residential	2.3E-06	18,000	3.5E-06	0.09	NA	NA	NA	NA	NA	NA	2.5E-05	2.2/0.68

Notes:

NA = Not Applicable

-- = not calculated

7.5 INTERPRETATION OF RISK RESULTS

The results of the HHRA show that the risks exceeding the cumulative risk of 10^{-4}, were identified for the indoor worker in EU4 (RME=2.5E-03), the on-Site construction worker in EU1 (RME = 1.1E-04), EU3 (RME -= 7.0E-04), EU4 (RME=9.7E-03), and the off-Site construction worker in EU1-Kendall Avenue (RME = 2.7E-04), EU3/EU8-B&P Railroad (RME = 2.3E-04), EU3-Conrail (RME = 4.0E-04), EU4-PennDOT (RME = 9.1E-04), and EU4-B&P Railroad (RME = 3.5E-04). EU Hazard Indices exceeding the target HI of 1 were identified for the indoor worker in EU1 (RME=6.9), EU3 (RME = 1.5), and EU4 (RME = 150), the on-Site construction worker in EU1 (RME=21,000), EU2 (RME=21,000), EU3 (RME=22,000), EU4 (RME=130,000), EU5 (RME=10), and EU6 (RME=1,000). For the off-Site construction worker HIs exceeding 1 were identified in EU1-Mill Street (RME=6,600), EU1-B&P Railroad (MEK/Rose) (RME=7,500), EU1-Conrail (RME=6,600), EU1-B&P Railroad (Crude Unit) (RME=14,000), EU1-Kendall Avenue (RME=17,000), EU1-Werzalit (RME = 17,000), EU3/EU8-B&P Railroad (RME = 21,000), EU3-Conrail (RME = 38,000), EU4-PennDOT (RME = 14,000), EU4-Bolivar Drive (RME = 1,100), EU4-B&P Railroad (RME = 12,000), EU6-Graham Packaging (RME = 1,000), and EU8-Residential (RME = 18,000). For the resident, the results show an HI exceeding 1 for a child in EU8-Residential (RME = 2.2).

It should be noted that these cancer risk and HI exceedances incorporate some highly conservative assumptions. It is improbable that the same person would experience all potential exposures associated with the Site, or that he/she would experience these exposures over the periods of years specified in the individual RME scenarios.

7.6 SUMMARY OF THE PRELIMINARY SITE-SPECIFIC CLEANUP LEVEL DEVELOPMENT

Site-specific standards (SSSs) were developed for each COPC exceeding Statewide Health Standards (SHS) in each media, as outlined in Appendix M. Briefly, the SSSs were developed by conducting the RA process in reverse. In other words, the HQ/HI formula and risk formula are solved for the exposure concentration by setting the HI or risk to a specified target level. SSSs were developed for a target HI of 1 and target risk of 1E-05. Section 6.0 contains a detailed description of the SSSs for all receptors and exposure pathways.

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU1	Indoor Worker (Current/ Future)	Soil Gas (Indoor Air Inhalation)	1,1,2,2-Tetrachloroethane	µg/m³	4.6E+03	1.4E+02	4.8E+03	6.1
			1,2-Dibromo-3-chloro-propane	µg/m³	4.0E+03	5.8E+01	2.7E+04	
			1,2-Dibromoethane	µg/m³	2.6E+03	3.7E+01	5.5E+03	
			Chloroform	µg/m³	2.5E+03	9.2E+01	3.4E+03	
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Aluminum	mg/kg	5.5E+03	1.9E+05	3.2E+04	6.12
			Chromium	mg/kg	7.3E+01	1.9E+05	1.5E+03	
			Copper	mg/kg	5.4E+03	1.9E+05	5.9E+03	
			Anthracene	mg/kg	1.9E+01	1.9E+05	1.4E+02	
			Benzo(a)pyrene	mg/kg	9.7E+00	1.9E+05	1.0E+02	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	1.8E+02	
			Benzo(k)fluoranthene	mg/kg	8.5E+00	1.9E+05	2.7E+02	
			Fluoranthene	mg/kg	8.5E-01	1.9E+05	3.7E+02	
			Benzene	mg/kg	1.9E-02	2.4E+02	1.1E+01	
			Ethylbenzene	mg/kg	9.2E-01	1.0E+04	6.1E+01	
			Naphthalene	mg/kg	1.7E-02	1.9E+05	9.0E+01	
			Xylene	mg/kg	6.3E-02	1.0E+04	1.8E+02	
		Groundwater (Ingestion Dermal Inhalation)	Antimony	mg/L	4.5E-02	6.0E-03	2.9E-01	6.13
			Benzene	mg/L	2.2E-01	5.0E-03	1.5E+00	
			Naphthalene	mg/L	8.2E-02	1.0E-01	2.7E-01	
			Manganese	mg/L	1.7E+00	3.0E-01	3.9E+01	
			Fluoranthene	mg/L	3.9E-01	2.6E-01	5.0E-01	
			Arsenic	mg/L	6.9E-02	5.0E-02	1.6E-01	
			Iron	mg/L	1.4E+02	3.0E-01	2.0E+02	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
			Thallium	mg/L	1.1E-02	2.0E-03	2.0E-02	
			Benzo(a)anthracene	mg/L	2.5E-03	3.6E-03	1.6E-01	
			Benzo(a)pyrene	mg/L	1.7E-04	2.0E-04	2.8E-02	
			Benzo(b)fluoranthene	mg/L	1.7E-03	1.2E-03	1.6E-02	
			Benzo(k)fluoranthene	mg/L	1.9E-02	5.5E-04	3.1E-02	
			Dibenz(a,h)anthracene	mg/L	7.9E-05	3.6E-04	3.0E-03	
			1,2,4-Trimethylbenzene	mg/L	8.2E-02	3.5E-02	1.5E+00	
			1,3,5-Trimethylbenzene	mg/L	8.6E-02	3.5E-02	4.8E-01	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU1 Off-Site Mill Street	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzo(a)pyrene	mg/kg	6.1E+00	1.9E+05	6.3E+00	6.12
EU1 Off-Site B&P Railroad (MEK Unit)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	1.6E+02	1.9E+05	4.5E+03	6.12
			Chromium	mg/kg	7.3E+01	1.9E+05	1.5E+03	
			Vanadium	mg/kg	2.0E+01	1.9E+05	2.3E+01	
			Benzo(a)pyrene	mg/kg	3.1E+00	1.9E+05	6.3E+00	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	3.9E+01	6.13
EU1 Off-Site Conrail	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Naphthalene	mg/L	2.5E-01	1.0E-01	2.7E-01	6.13
EU1 Off-Site B&P Railroad (Crude Unit)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Naphthalene	mg/kg	3.2E-02	1.9E+05	1.6E+01	6.12
			Aluminum	mg/kg	3.7E+03	1.9E+05	2.3E+04	
			Manganese	mg/kg	5.4E+01	1.9E+05	2.3E+02	
EU1 Off-Site Kendall Avenue	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzene	mg/kg	5.6E-02	2.4E+02	1.1E+01	6.12
			Naphthalene	mg/kg	1.6E-01	1.9E+05	1.3E+01	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	2.3E+01	6.13
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	3.7E-01	
			Arsenic	mg/L	1.4E-01	5.0E-02	1.5E-01	
EU2	Indoor Worker (Current/ Future)	Groundwater (Indoor Air Inhalation)	Vinyl Chloride	mg/L	1.2E-01	3.0E+00	1.5E-01	6.2
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	1.6E+02	1.9E+05	1.1E+03	6.12
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	4.4E+00	3.0E-01	3.2E+01	6.13
EU3	Indoor Worker (Current/ Future)	Groundwater (Indoor Air Inhalation)	Vinyl Chloride	mg/L	1.0E-01	3.0E+00	2.4E-01	6.2
		Soil (Indoor Air Inhalation)	Benzene	mg/kg	8.2E-02	6.3E-01	5.5E+00	6.3

Exposure Unit	Receptor	Medium (Route)	Chemical of Potential Concern	Units	Cumulative SSS	SHS MSCs	Maximum Detected Concentration	HHRA Table Reference
EU3 (cont'd)	Indoor Worker (Current/ Future) (cont'd)	Surface Soil (Ingestion Inhalation)	Arsenic	mg/kg	5.9E+01	5.3E+01	9.2E+01	6.4
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	9.2E+01	6.6
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	8.4E+01	1.9E+05	9.4E+01	6.120
			Benzene	mg/kg	1.9E-02	2.4E+02	5.5E+00	
			Benzo(a)pyrene	mg/kg	4.2E+00	1.9E+05	7.1E+00	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	2.2E-01	5.0E-03	6.0E-01	6.13
			cis-1,2-Dichloroethene	mg/L	4.7E-01	7.0E-02	1.3E+00	
			Tetrachloroethene	mg/L	2.5E-01	5.0E-03	4.5E-01	
			Manganese	mg/L	2.9E+00	3.0E-01	1.9E+01	
			Vinyl Chloride	mg/L	1.5E-01	2.0E-03	2.4E-01	
			Arsenic	mg/L	1.4E-01	5.0E-02	1.1E+00	
EU3 Off-Site B&P Railroad	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	1,2,4-Trimethylbenzene	mg/kg	1.0E-02	3.6E+02	5.0E+01	6.12
			1,2-Dibromo-3-chloropropane	mg/kg	2.8E-04	2.0E-02	1.1E+00	
			1,3,5-Trimethylbenzene	mg/kg	4.5E-03	3.6E+02	1.8E+01	
			Benzo(a)pyrene	mg/kg	1.5E+00	4.6E+00	5.8E+00	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.2E+00	3.0E-01	3.8E+00	6.13
			1,2,4-Trimethylbenzene	mg/L	1.0E-01	3.5E-02	9.6E-01	
			1,3,5-Trimethylbenzene	mg/L	1.0E-01	3.5E-02	4.8E-01	
			Benzo(a)anthracene	mg/L	2.9E-04	3.6E-03	3.4E-01	
			Benzo(a)pyrene	mg/L	2.0E-03	2.0E-04	3.0E-01	
			Benzo(b)fluoranthene	mg/L	2.0E-02	1.2E-03	3.6E-01	
			Dibenz(a,h)anthracene	mg/L	2.2E-02	3.6E-04	3.7E-02	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU3 Off-Site Conrail	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	3.3E-01	5.0E-03	6.0E-01	6.13
			Tetrachloroethene	mg/L	3.0E-01	5.0E-03	3.3E-01	
EU4	Indoor Worker (Current/ Future)	Soil Gas (Indoor Air Inhalation)	1,1,2,2-Tetrachloroethane	µg/m³	2.5E+02	1.4E+02	8.0E+04	6.1
			1,1,2-Trichloroethane	µg/m³	1.2E+04	5.1E+02	6.5E+04	
			1,2-Dibromo-3-chloropropane	µg/m³	2.6E+02	5.8E+01	4.6E+05	
			1,2-Dibromoethane	µg/m³	1.7E+02	3.7E+01	9.0E+04	
			1,2-Dichloroethane	µg/m³	4.4E+02	3.1E+02	4.8E+04	
			1,2-Dichloropropane	µg/m³	1.3E+03	7.9E+02	5.5E+04	
			1,3-Dichlorobenzene	µg/m³	2.8E+04	1.1E+03	7.0E+04	
			1,4-Dichlorobenzene	µg/m³	2.4E+03	1.3E+03	7.0E+04	
			Benzene	µg/m³	1.7E+03	1.1E+03	1.8E+06	
			Bromodichloromethane	µg/m³	7.6E+02	2.2E+02	8.0E+04	
			Bromomethane	µg/m³	6.9E+03	1.4E+03	4.6E+04	
			Carbon tetrachloride	µg/m³	9.2E+02	5.5E+02	7.5E+04	
			Chloroform	µg/m³	1.3E+02	9.2E+01	5.5E+04	
			Chloromethane	µg/m³	4.0E+04	4.5E+03	9.5E+04	
			cis-1,3-Dichloropropene	µg/m³	3.9E+03	2.0E+03	5.5E+04	
			Dibromochloromethane	µg/m³	1.5E+03	3.0E+02	1.0E+05	
			Ethylbenzene	µg/m³	5.9E+04	7.3E+03	2.2E+05	
			m&p-Xylene	µg/m³	7.1E+05	3.0E+04	9.2E+05	
			Trans-1,3-Dichloropropene	µg/m³	3.9E+03	2.0E+03	5.5E+04	
			Vinyl Chloride	µg/m³	1.3E+03	9.5E+02	3.0E+04	
			1,2,4-Trimethylbenzene	µg/m³	2.4E+04	1.7E+03	7.9+04	
		Surface Soil (Ingestion Inhalation)	Antimony	mg/kg	2.0E+02	1.1E+03	5.6E+02	6.4
		Soil (Inhalation)	Benzene	mg/kg	5.9E+01	2.4E+02	1.5E+02	6.5
			Naphthalene	mg/kg	3.9E+02	1.9E+05	7.6E+02	
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	3.5E+01	6.6
			Antimony	mg/kg	2.0E+02	1.1E+03	5.6E+02	
		Soil (Inhalation)	Benzene	mg/kg	2.2E+01	2.4E+02	1.5E+02	6.7
			Naphthalene	mg/kg	1.5E+02	1.9E+05	7.6E+02	
			Xylene	mg/kg	5.2E+02	1.0E+04	1.0E+03	
			1,2,4-Trimethylbenzene	mg/kg	6.7E+01	3.6E+02	1.5E+02	
			1,3,5-Trimethylbenzene	mg/kg	5.8E+01	3.6E+02	1.4E+02	

Exposure Unit	Receptor	Medium (Route)	Chemical of Potential Concern	Units	Cumulative SSS	SHS MSCs	Maximum Detected Concentration	HHRA Table Reference
EU4 (cont'd)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Antimony	mg/kg	2.4E+01	1.9E+05	5.6E+02	6.12
			Benzene	mg/kg	1.9E-02	2.4E+02	1.5E+02	
			Naphthalene	mg/kg	5.8E-02	1.9E+05	7.6E+02	
			Xylene	mg/kg	4.4E-01	1.0E+04	1.0E+03	
			Aluminum	mg/kg	2.8E+03	1.9E+05	6.2E+04	
			Mercury	mg/kg	1.7E+01	1.9E+05	3.3E+01	
			Fluoranthene	mg/kg	6.4E-01	1.9E+05	3.9E+02	
			Pyrene	mg/kg	3.9E+01	1.9E+05	3.5E+02	
			Ethylbenzene	mg/kg	9.3E-01	1.0E+04	1.6E+02	
			Toluene	mg/kg	3.0E+00	1.0E+04	4.1E+02	
			Arsenic	mg/kg	8.4E+01	1.9E+05	2.3E+02	
			Chromium	mg/kg	7.3E+01	1.9E+05	8.8E+01	
			Anthracene	mg/kg	1.9E+01	1.9E+05	7.2E+01	
			Benzo(a) pyrene	mg/kg	1.3E+01	1.9E+05	5.2E+01	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	9.0E+01	
			Benzo(k)fluoranthene	mg/kg	8.5E+00	1.9E+05	1.1E+02	
			1,1-Dichloroethane	mg/kg	6.5E-01	1.2E+03	7.6E+00	
			1,2,4-Trimethylbenzene	mg/kg	3.6E-02	3.6E+02	1.5E+02	
			1,3,5-Trimethylbenzene	mg/kg	1.0E-02	3.6E+02	1.4E+02	
			Chloromethane	mg/kg	1.7E-01	1.0E+03	1.4E+00	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	2.2E-01	5.0E-03	2.2E+01	6.13
			Naphthalene	mg/L	1.2E-01	1.0E-01	3.3E-01	
			Xylene	mg/L	2.8E+00	1.0E+01	1.2E+01	
			Manganese	mg/L	4.4E+00	3.0E-01	2.8E+01	
			Toluene	mg/L	4.1E+00	1.0E+00	2.1E+01	
			Arsenic	mg/L	1.4E-01	5.0E-02	2.6E-01	
			Iron	mg/L	1.4E+02	3.0E-01	2.0E+02	
			Benzo(a) pyrene	mg/L	2.0E-03	2.0E-04	3.3E-03	
			Dibenz(a,h)anthracene	mg/L	9.4E-04	3.6E-04	7.2E-03	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU4 Off-Site PennDOT	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzene	mg/kg	2.8E-02	2.4E+02	1.6E+01	6.12
			Naphthalene	mg/kg	8.6E-02	1.9E+05	1.1E+02	
			Xylene	mg/kg	7.0E-01	1.0E+04	5.3E+02	
			Ethylbenzene	mg/kg	1.3E+00	1.0E+04	1.1E+02	
			Lead (1)	mg/kg	1.2E+02	1.9E+05	1.4E+02	
			Anthracene	mg/kg	1.9E+01	1.9E+05	3.6E+01	
			Benzo(a) pyrene	mg/kg	8.4E+00	1.9E+05	2.3E+01	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	3.0E+01	
			1,1,1-Trichloroethane	mg/kg	4.0E+00	1.0E+04	3.5E+01	
			1,1-Dichloroethane	mg/kg	6.5E-01	1.2E+03	3.0E+01	
			1,2,4-Trimethylbenzene	mg/kg	6.7E-02	3.6E+02	2.0E+02	
			1,2-Dichloroethane	mg/kg	1.0E-01	7.3E+01	4.8E+00	
			1,3,5-Trimethylbenzene	mg/kg	2.1E-02	3.6E+02	9.2E+01	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	3.3E-01	5.0E-03	2.8E+00	6.13
			Naphthalene	mg/L	1.2E-01	1.0E-01	4.3E-01	
			Xylene	mg/L	2.8E+00	1.0E+01	1.5E+01	
			Manganese	mg/L	4.4E+00	3.0E-01	2.0E+01	
			Iron	mg/L	1.4E+02	3.0E-01	1.9E+02	
EU4 Off-Site Bolivar Drive	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	1,2,4-Trimethylbenzene	mg/kg	4.8E-02	3.6E+02	5.0E+01	6.12
			1,3,5-Trimethylbenzene	mg/kg	1.5E-02	3.6E+02	1.8E+01	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	4.7E+00	6.13
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	9.1E-01	
			1,3,5-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	2.4E-01	
EU4 Off-Site B&P Railroad	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Mercury	mg/kg	3.0E-01	1.9E+05	3.3E+01	6.12
			Lead	mg/kg	8.7E+01	1.9E+05	9.0E+01	
		Groundwater (Ingestion Dermal Inhalation)	Benzo(a)anthracene	mg/L	2.9E-02	3.6E-03	9.9E-02	6.13
			Benzo(a)pyrene	mg/L	2.0E-03	2.0E-04	8.7E-02	
			Benzo(b)fluoranthene	mg/L	2.0E-02	1.2E-03	1.1E-01	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU5	Indoor Worker (Current/ Future)	Surface Soil (Ingestion Inhalation)	Arsenic	mg/kg	5.3E+01	5.3E+01	8.4E+01	6.4
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	8.4E+01	6.6
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	8.1E+01	1.9E+05	2.3E+03	6.12
			Thallium	mg/kg	2.0E+01	1.9E+05	2.1E+01	
			Arsenic	mg/kg	4.0E+01	1.9E+05	8.4E+01	
			Barium	mg/kg	6.0E+02	1.9E+05	1.1E+03	
			Iron	mg/kg	8.4E+04	1.9E+05	1.5E+05	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	4.4E+00	3.0E-01	2.7E+01	6.13
EU6	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Aluminum	mg/kg	1.1E+04	1.9E+05	2.2E+04	6.12
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	8.7E+00	3.0E-01	3.0E+01	6.13
EU6 Off-Site Graham Packaging	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	8.7E+00	3.0E-01	2.2E+01	6.13
EU7	Recreational Visitor (Current/ Future)	Surface Water (Fish Ingestion)	Hexachlorobenzene	mg/L	9.6E-06	7.5E-07	2.3E-05	6.15
			Benzo(a)anthracene	mg/L	2.4E-05	4.4E-06	7.3E-05	
			Benzo(b)fluoranthene	mg/L	2.3E-05	4.4E-06	4.8E-05	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU8 Residential (R&S)	Resident (Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	7.2E+00	1.2E+01	2.2E+01	6.10
		Soil (Inhalation)	1,2,4-Trimethylbenzene	mg/kg	8.3E+00	1.1E+02	5.6E+01	6.11
			1,3,5-Trimethylbenzene	mg/kg	7.2E+00	1.1E+02	3.9E+01	
			1,2-Dibromo-3-chloropropane	mg/kg	1.0E+00	3.8E+00	1.1E+00	
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Xylene	mg/kg	1.9E-01	1.0E+04	5.9E+01	6.12
			1,2,4-Trimethylbenzene	mg/kg	1.6E-02	3.6E+02	5.6E+01	
			1,3,5-Trimethylbenzene	mg/kg	1.2E-02	3.6E+02	3.9E+01	
			Ethylbenzene	mg/kg	1.9E+00	1.0E+04	8.3E+00	
			1,2-Dibromo-3-chloropropane	mg/kg	7.9E-04	1.2E+01	1.1E+00	
		Groundwater (Ingestion Dermal Inhalation)	Naphthalene	mg/L	8.2E-02	1.0E-01	1.0E+00	6.13
			Xylene	mg/L	1.9E+00	1.0E+01	1.5E+01	
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	1.6E-02	5.9E+00	
			1,3,5-Trimethylbenzene	mg/L	1.4E-01	1.6E-02	1.9E+00	

Note:

(1) Lead SSS calculated using the Adult Lead Model and compared to the medium arithmetic mean rather than maximum detected concentration.

8.0 ECOLOGICAL RISK ASSESSMENT SUMMARY FROM SEPARATE HABITAT AND ERA REPORTS

A screening-level ecological risk assessment (SERA) was also conducted for the Site. The SERA is being submitted as three separate documents:

i) Screening Level Ecological Risk Assessment

ii) Addendum to Screening Level Ecological Risk Assessment; and

iii) Ecological Risk Assessment-Step 3.

The SERA was conducted in accordance with the guidelines as set forth in the Pennsylvania Land Recycling and Environmental Remediation Standards Program (under the authority of Acts 2 and 25 PA Code Chapter 250)) and the United States Environmental Protection Agency's (USEPA) *Ecological Risk Assessment Guidance for Superfund, Process for Designing and Conducting Ecological Risk Assessment* (USEPA, 1997). The option selected for this SERA is the Site-specific initial screen, which essentially follows Steps 1 and 2 of the USEPA's eight-step process and Step 3, but with several modifications for the Pennsylvania Act 2 program.

In accordance with the Act 2 guidance, the Site-specific initial screen (Steps 1 and 2) includes a screening-level problem formulation, a detailed description of the environmental setting, identification of known or suspected contaminants, a discussion of contaminant fate and transport, identification of potentially complete exposure pathways, selection of assessment and measurement endpoints, an effects evaluation, exposure estimate, and risk characterization. Step 3, which is referred to as the problem formulation step, refines the list of chemical constituents identified as Chemicals of Potential Ecological Concern (COPECs). An analysis of uncertainties in the SERA is also provided.

8.1 SUPPORTING STUDIES

A wetlands delineation, habitat characterization study, and aquatic biological study were also conducted in support of this SERA. These three studies are included as Appendices A, B, and C of the SERA, respectively.

8.1.1 WETLANDS DELINEATION

Most of the wetlands on the Site are associated with Tunungwant Creek and its three tributaries that traverse the Site – Foster Brook, Kendall Creek, and Bolivar Run. The types of wetlands and aquatic habitats encountered on the Site include riverine open water upper perennial, riverine open water intermittent, palustrine emergent wetland, palustrine scrub-shrub wetland, palustrine forested wetland, and palustrine open water. All of the wetlands are classified as "other" wetlands on the basis of criteria identified in Pennsylvania Chapter 105.17. There are no "Exceptional Value" wetlands on the Site.

8.1.2 HABITAT CHARACTERIZATION STUDY

The habitat characterization study identified ten general types of terrestrial habitats and cover types. The majority of the Site is developed land. Three of the ten habitats and cover types fall into this developed category: industrial, residential, and commercial. Three of the habitat and cover types are dominated by herbaceous vegetation: mowed lawn, field, and old field. Two types of scrub-shrub uplands are present: early successional and late successional. The remaining two types of terrestrial habitats and cover types are early successional deciduous forest and mature secondary growth deciduous forest. The habitat characterization study identifies ecological receptors associated with each of the habitats and cover types.

The habitat characterization study also identified species of concern and habitats of concern potentially on or within 2,500 feet of the Site. Based on correspondence with the State and Federal resource agencies, along with observations made during onsite investigations, American brook lamprey (*Lampetra appendix*) and Ohio lamprey (*Ichthyomyzon bdellium*) are identified as species of concern. The American Brook lamprey is a Pennsylvania-listed endangered species; the Ohio lamprey is a Pennsylvania-listed threatened species. In the vicinity of the Site, there are no suitable habitat areas for these two species. Marginal habitat for both of these species may be present in some upstream areas of the Tunungwant Creek watershed although any such areas are beyond the Site boundaries. State resource agencies also identified American bittern (*Botaurus lentiginosus*), listed as Pennsylvania endangered, and the osprey (*Pandion haliaetus*), listed as Pennsylvania threatened, as potentially occurring within the vicinity of the Site. However, no suitable habitat for either species is present on or in the vicinity of the Site. Although not identified as "Exceptional Value", all wetlands on the Site are identified as habitats of concern because they provide identified function and value.

8.1.3 BENTHIC MACROINVERTEBRATE STUDY

A benthic macroinvertebrate study was performed to assess the aquatic biology features of Tunungwant Creek and its tributaries. The study indicated that some of the impairment in the aquatic community below the Site could not be attributed solely to the refinery. The impairment of the macroinvertebrate community is believed to be due to multiple causes, including habitat modifications (historic and continuing flood control activities) and nonpoint sources that are contributing to the nutrient loadings. A toxic response was not indicated by the data. Furthermore, petroleum was not observed in the water column or the substrate of the stream. Habitat modifications and continuing habitat disturbances were concluded to be major factors limiting the distribution of *species of concern* and the quality of the stream as a *habitat of concern*. The habitat quality was not sufficient to fulfill the *species of concern* life history requirements. Therefore, *habitats of concern* and *species of concern* have not been significantly impacted by the refinery operations.

8.2 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

The SERA evaluated risk to ecological receptors posed by chemical constituents in the various areas of the Site. The constituents carried forward to Step 3 of the USEPA's 8-Step process are presented in Table 8.1. Reasons for their inclusion in the list are described below.

For Steps 1, 2 and 3, the chemical constituents in soil, sediment, and surface water were evaluated for the following areas:

For soil:

- Main Refinery;
- Crude Tank Farm;
- Exposure Unit 4 of the Foster Brook Facility;
- Exposure Unit 5 of the Foster Brook Facility; and
- Tunungwant Creek-Foster Brook Corridor.

For sediment:

- Tunungwant Creek; and
- Foster Brook.

For surface water:

- Tunungwant Creek;
- Foster Brook;
- Kendall Creek;
- Bolivar Run; and
- Crude Tank Farm Tributary.

For the surface water of Tunungwant Creek, Kendall Creek, Bolivar Run, the Crude Tank Farm tributary, and Foster Brook (Exposure Unit-7), Continuous Concentrations Criteria (CCC) for the protection of fish and aquatic life as published in *Chapter 16. Water Quality Toxics Management Strategy – Statements of Policy* (or other appropriate reference documents) were used as ecological screening values (ESVs) for surface water. A total of 17 surface water chemical constituents were evaluated in Step 3 of the ERA process. Based on the available data, aluminum is the only constituent detected in the surface water of Tunungwant Creek that exceeded the ESV. The mean concentration of aluminum exceeded its ESV. Selenium and silver are the only constituents detected in Foster Brook that exceeded their ESVs. The mean concentrations of both exceeded their respective ESVs. Twelve organic constituents, including six polycyclic aromatic hydrocarbons (PAHs), and one metal were not detected in surface water, but were carried forward as a precautionary measure because their limits of detection (LOD) exceeded their ESVs. Also, one organic constituent (cis-1,2-dichloroethene) was carried forward because an ESV is not available.

For sediment, Probable Effects Concentrations (PEC) identified by MacDonald et al. (2000) were used as ESVs. If a PEC was not available, a Threshold Effects Concentration (TEC), also from MacDonald et al. (2000) or other appropriate reference documents were used. A total of 100 sediment chemical constituents were carried forward to Step 3. These included 1,2,4-TMB, acetone, acrylonitrile, benzene, ethylbenzene, toluene, xylene, antimony, beryllium, iron, and manganese which were detected in the sediments of Tunungwant Creek and exceeded their ESVs. An ESV for 1,3,5-TMB, sec-butylbenzene, tert-butylbenzene, trichlorofluoromethane, and vanadium are not available in the sources consulted. Consequently, these constituents and 83 other constituents for which the LODs exceeded their ESV were carried forward as a precautionary measure. For Foster Brook, acetone, vinyl acetate, beryllium, and iron are the four constituents detected in the sediments that exceeded their ESV. An ESV is not available for trichlorofluoromethane, barium, vanadium, or selenium and therefore they were carried forward as a precautionary measure. Fifteen constituents, including chlorinated organic

constituents, were also carried forward because, although not detected in sediments, these compounds have LODs that exceeded their screening values.

For surface soils, separate analyses were conducted for the Main Refinery (Exposure Unit-1), Crude Tank Farm (Exposure Unit-3), Foster Brook Facility South – Exposure Unit 4, Foster Brook Facility North - Exposure Unit 5, and the Tunungwant Creek - Foster Brook Corridor (Exposure Unit-7). Ecological soil screening levels (ECO-SSL), if available, were used as ESVs for soil. When ECO-SSLs were available for more than one taxonomic group, the lowest ECO-SSL was selected as the ESV. If an ECO-SSL was not available for a constituent, other appropriate reference documents were used.

For the surface soils in the Main Refinery, benzene, fluoranthene, phenanthrene, chromium, iron, lead, mercury, and vanadium are the detected constituents that exceeded their ESV and were carried forward to Step 3 for further evaluation. In addition, 32 other constituents had LODs greater than their ESV and were carried forward to Step 3.

For the Crude Tank Farm, benzene, hexachlorobutadiene, naphthalene, phenanthrene, pyrene, chromium, iron, lead, mercury, selenium, vanadium and zinc were carried forward because their mean concentrations exceeded their ESVs. Twenty-seven other constituents had LODs greater than their ESV and five constituents had no ESV available. These 32 constituents were also carried forward.

Organic constituents and metals detected in the surface soil of the Foster Brook Facility South (Exposure Unit 4) were carried forward to Step 3. The mean concentrations of 1,1,1-trichloroethane, 1,1-dichloroethane, 1,2-dibromomethane, 1,2-dichloromethane, bis(2-ethylhexyl)phthalate, benzene, ethylbenzene, xylene, 2-methylnaphthalene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, fluoranthene, naphthalene, phenanthrene, pyrene, antimony, chromium, copper, iron, lead, mercury, selenium, vanadium, and zinc exceeded their ESVs. Constituents that were detected but do not have ESVs and were therefore carried forward include 1,2,4-trichlorobenzene, 1,3,5-trimethylbenzene, 2-phenylbutane, cymene, isopropylbenzene, and n-propylbenzene. Forty other constituents had LODs greater than their ESV and were also carried forward to Step 3.

Constituents detected in the Foster Brook Facility North (Exposure Unit-5) that were carried forward because their mean concentrations exceeded their ESVs included bis(2-ethylhexyl)phthalate, benzo(a)pyrene, chrysene, fluoranthene, naphthalene, phenanthrene, pyrene, chromium, copper, iron, lead, mercury, selenium, thallium, vanadium, and zinc. Benzoic acid and dibenzofuran were also detected and were

carried forward because ESVs are not available. In addition, 22 constituents had LODs greater than their ESV and were also carried forward to Step 3.

For the Tunungwant Creek - Foster Brook corridor, anthracene, benzo(a)pyrene, fluoranthene, naphthalene, phenanthrene, pyrene, chromium, iron, mercury, and vanadium were carried forward to Step 3 Because their mean concentrations exceeded their respective ESVs. Thirty-four constituents had LODs greater than their ESV and were also carried forward to Step 3.

In summary, a total of 168 chemical constituents in soil were carried forward to Step 3.

8.3 STEP 3 ECOLOGICAL RISK ASSESSMENT

In Steps 1 and 2, the most conservative ecological benchmark concentrations were identified as the Ecological Screening Values (ESV) against which to assess each chemical constituent in each media (soil, sediment, and surface water). In the first phase of Step 3, ecological benchmark concentrations that are more appropriate for site-specific conditions (refinement benchmarks) are identified. Factors such as site-specific background concentrations (for metals) and surrogate chemical concentrations (for chemicals that do not have ESV or other ecological benchmark concentrations) are also identified. Then the maximum and mean concentrations of the COPECs at the Site are compared to the refinement benchmark concentrations. For those constituents retained in the first phase of Step 3 as COPECs that exceed the refinement benchmark concentrations, simple food chain models were then used to evaluate potential risk for various trophic guilds.

The evaluation performed in the first refinement phase of Step 3 identified five chemical constituents that were retained as COPECs in soil:

- 1,2,4-trimethylbenzene;
- 1,3,5-trimethylbenzene;
- bis(2-ethylhexyl)phthalate;
- 2-methylnaphthalene; and
- copper.

There were no chemical constituents that were identified as COPECs for either the sediment or for the surface water media.

These five chemical constituents were then further evaluated in the second phase of Step 3 using simple food chain models and wildlife indicator species to evaluate risk to various trophic guilds of ecological receptors. Short-tailed shrew and American woodcock were used to evaluate risk to mammalian insectivores and avian insectivores, respectively. The deer mouse was used to evaluate risk to mammalian herbivores. The red fox and red-tailed hawk were used to evaluate risk to mammalian carnivores and avian carnivores, respectively. Each analysis evaluated a range of exposure scenarios (maximum, mean, and 95 percent upper confidence level concentrations) to determine whether these five chemical constituents would result in an observable adverse effect in these wildlife indicator species.

Results of the food chain analyses show that the potential for risk is within acceptable limits for the wildlife indicator species exposed to the COPECs in the soil in the Foster Brook Facility and Tunungwant Creek-Foster Brook Corridor. Scenarios based on the mean and 95 percent upper confidence level concentration and Lowest Observable Adverse Effects Level generally produced a Hazard Quotient less than one indicating that the risk levels are within acceptable limits. Because conservative assumptions were used for area use (i.e., 100 percent area use) and exposure (e.g., 100 percent bioavailability), Hazard Quotients slightly greater than one were interpreted to be within the limits of acceptable potential for risk. When more realistic assumptions of area use are considered, the Hazard Quotients for all scenarios are generally less than one. Use of more realistic bioavailability assumptions would further reduce the Hazard Quotients.

Because no constituents were identified as COPECs for either surface water or sediment, food chain analyses were not used to evaluate the potential for risk to semi-aquatic wildlife that forage on fish or other aquatic organisms. This has been identified and included as a source of uncertainty in the Step 3 evaluation of risk.

One additional issue that was evaluated during the ecological risk assessment involved the observations of iron staining in the sediment of Tunungwant Creek. PADEP was concerned that the iron staining could be a source of concern for potential risk to ecological receptors in the water column and sediment of Tunungwant Creek. The results of the assessment performed show that the iron staining may cause an adverse impact on the aesthetics of Tunungwant Creek. However, the potential for risk to ecological receptors due to iron in surface water and sediment was found to be within acceptable limits. Furthermore, the macroinvertebrate survey conducted as part of the SERA did not identify any impacts to the benthic community that could be attributed to iron or any other COPEC.

8.4 SUMMARY

Completion of Steps 1 and 2 of the SERA triggered the first Scientific Management Decision Point (SMDP) in the ecological risk assessment process. The SMDP provides the risk assessor and agencies an opportunity to review the results of the screening level assessment and to chart a path forward for continuing with the risk assessment process. To assist in preparation for the first SMDP, the SERA concludes with a section outlining recommendations for additional evaluation of the 168 constituents that were carried forward to Step 3.

Based on the results of the refinement process and food chain analyses, it can be concluded that the potential for risk to ecological receptors is within acceptable limits in all surface water, sediment, and soil media in all assessment areas at the ARG facility. Consequently, there is neither need nor justification for a baseline risk assessment and the ecological risk assessment process can be exited at Step 3.

Given the absence of any identified unacceptable risk in any of the media, the ecological risk assessment for the ARG Facility is complete.

9.0 PREVIOUS REMEDIAL ACTIVITIES

There have been a number of remedial efforts undertaken over the years at the Site. Many of them would have been associated with the containment and capture of spills and leaks. Up until the 1980's, documentation for these sorts of efforts would have been very limited. However, in recent years, efforts made to contain and collect releases were documented and forwarded to PADEP as required. A summary of the most recent release events and associated recovery measures implemented is presented in Section 2.8 of this SCR.

In addition, there have been a number of remedial efforts undertaken to minimize the impacts of historic releases. A large percentage of these efforts are focussed on the groundwater and SPL floating atop the groundwater, although other remedial efforts such as source control actions (container/drum removals) have also occurred. Each of the major remedial efforts of the past 20 years is presented in the following chronological account.

9.1 1984 – SPL RECOVERY WELLS

Beginning in 1984, New England Pollution Control Company, Inc. (NEPCCO), a consultant working for Witco, installed a series of eight groundwater extraction wells that were designed to stop oil discharges to Tunungwant Creek by capturing floating SPL from the water table surface before it entered the Creek. These eight recovery wells were given the designation RW-1 through RW-8. Seven of these wells (RW1 and RW3 through RW8) were installed adjacent to the sheet piling which acts as a retaining wall along Tunungwant Creek in the main refinery area as shown on Figure 9.1. RW-2 was located in the Barrel House Area. Based on a review of the available information, the NEPCCO and current well designations are believed to be:

NEPCCO Designation	*Current Designation*
RW-1	RW-1
RW-2	RW-11
RW-3	RW-2
RW-4	RW-3
RW-5	RW-16
RW-6	RW-4
RW-7	RW-6
RW-8	RW-5

Except for RW-1, which was constructed using a 10-inch diameter well screen and riser, the RW series recovery wells were constructed using 12-inch diameter carbon steel casings and screened to 35 feet bgs. Recovery well RW-2 was later replaced with a 24-inch diameter stainless steel telescoping screen to a depth of 30 feet bgs.

The wells were situated in the shallow, lower permeable portion of the aquifer. The shallower points of the aquifer is less permeable due to the fining upward sequence of glacial sediments in the valley bottom beneath the Main Refinery area. As such, groundwater recovery rates from these pumping wells were relatively low, averaging approximately seven gpm. The wells were equipped with a dual-phase petro-purge/hydro-purge recovery system. This system consisted of:

i) an oil/water interface probe that sensed the floating oil/groundwater interface, and controlled the groundwater recovery pump;

ii) a submersible groundwater depression pump with associated valving, discharge, hose, and appurtenances;

iii) a groundwater pump controller;

iv) an oil layer sensing probe; and

v) a petro-purge product recovery pump (that only removes the floating oil layer).

The groundwater pump was located near the bottom of the well and was used to create a depression in the groundwater table. The captured oil was skimmed off the top of the water column by the petro-purge pump and recycled back into the refinery process. The system was able to recover some of the oil product from the surface of the groundwater and operated relatively efficiently for the first few years. However, problems with well screen fouling and the small area of influence created by the wells were seen as drawbacks.

Over the years of operation, 20 vertical recovery wells were installed at the Main Refinery. Many of them were included in the groundwater and SPL recovery program and their successes varied from well to well. A few of these wells remained in operation through to June 1997 while many operated for only short periods of time.

9.2 1995 – PUMPING CENTERS

In 1995, following years of additional Site studies, pilot testing, and aquifer testing, it was determined that the use of one or more large pumping centers to depress the

groundwater table was a more practical approach to capturing the floating layer of oil. These collection points would generate large groundwater capture areas beneath the SPL impacted areas. In doing so, they would reverse the natural direction of groundwater flow away from the Creek and aggressively remove SPL from the groundwater table surface. This concept was developed, designed, and implemented by R.E. Wright Associates, also a consultant to Witco.

The implementation of this pumping center scheme focussed on the installation of caisson angle well systems (CAWS). Two CAWS were installed in the Main Refinery area at the locations shown on Figure 9.1. The first CAWS was installed in 1995 as a pilot test and was pumped at a rate of up to 45 gpm. CAWS-1 consists of a central large diameter caisson (6 feet in diameter) that was installed vertically to a depth of about 16 feet. From this central caisson, four 4-inch diameter stainless steel well points extend out horizontally (10 degree downward angle) in all directions from an elevation just below the groundwater table. A typical CAWS vertical cross-section is depicted in Figure 9.2. The length of the recovery arms of CAWS-1 were approximately 40 feet. Each of these collector arms was equipped with a high-pressure multistage stainless steel centrifugal pump as was the central caisson. These pumps were operated by a multi-jet venturi system that coordinated the pumping efforts to depress the groundwater table throughout the area. The central caisson was also equipped with a self-priming oil recovery pump which recovered the SPL that was captured as a result of the depressed groundwater table and fed it back to the refinery operations.

CAWS-1 operated in conjunction with the RW series wells. Between April and October 1995, when CAWS-1 was initially operated, a total of 24,700 gallons of SPL was recovered out of a total of 8,800,000 gallons of water pumped. In the first month of operation, CAWS-1 recovered approximately 7,000 gallons of SPL. By the end of first year of operation, it was recovering on the order of 1,000 gallons of SPL per month. According to R.E. Wright (March 1998), the SPL recovery rate averaged 50 gpd over the first 3 years of operation.

Following the success of this first CAWS unit, R.E. Wright Associates performed some additional evaluations and modeling of the groundwater flow regime and, in 1996, recommended the installation of a second CAWS unit and one additional vertical well (HG-401, nka RW-7). The second CAWS (CAWS-2) was constructed in the Main Refinery in 1997 and became operational in June 1997. CAWS-2 was 10 feet in diameter, 20 feet deep, and had four sub-horizontal well points (each 145 feet long) and one vertical well point (80 feet deep) (see Figure 9.2 for areal extent). It was believed that the longer the arms, the greater the area of influence would become and the more effective

the SPL recovery would become. This CAWS unit was located approximately 15 feet from the north end of Building 43 (see Figure 9.1).

The start up of the CAWS-2 unit was accompanied by the start up of a newly completed groundwater treatment system which is also located in the Main Refinery area. The location of the groundwater treatment system is shown on Figure 9.1. The system consisted of an oil/water separator, pH adjustment, dissolved iron control, and carbon adsorption unit that was designed to treat 400 gpm. The carbon adsorption unit was never used. The treated effluent from this system was discharged directly to Tunungwant Creek under National Pollutant Discharge Elimination System (NPDES) Permit No. PA0222151.

The oil/water separator (OWS) from this original treatment system remains in service today. Since July 2000, the remainder of the treatment system has not been used. In its place, the effluent from the OWS was discharged into ARG's wastewater treatment system from July 2000 to April 2005 to complete the treatment process prior to discharge from the Site. The treated groundwater discharge was combined with ARG's wastewater discharge which is regulated under ARG's NPDES discharge permit to Tunungwant Creek (NPDES Permit No. PA0002674). Since April 2005 the effluent from the OWS has been piped to the newly constructed groundwater treatment plant, as described in Section 9.10. The treated effluent from the groundwater treatment plant is discharged directly to Tunungwant Creek under NDPES Permit No. PA0222151.

The vertical extraction well HG-401 (nka RW-7) is located along Kendall Avenue near the southeast corner of Building 37 as shown on Figure 9.1. This well is an 8-inch diameter well that was installed to a depth of 75 feet bgs. It was anticipated that this well would be able to deliver up to 120 gpm but was expected to operate in the 60 to 72 gpm range.

From 1997 through early 2000, the two CAWS units were operated in conjunction with 5 vertical recovery wells as the groundwater remedial system. The vertical wells included in the operating remedy were:

R.E. Wright Identifier	*Current Identifier*
HG-328	RW-10
HG-330	RW-9
HG-401	RW-7
HG-408	RW-8
RW-8	RW-5

These wells pumped at a combined rate of 350 gpm to keep the floating SPL out of the Creek and to maximize SPL collection.

It is believed that operation of CAWS-1 ceased in early 1998.

As previously mentioned, the number of vertical recovery wells included in the actual groundwater/SPL recovery program varied over the course of the years of operation, consistent with their identified effectiveness.

9.3 1996 – REFUSE AREA CONTAINER REMOVAL

In 1996, a voluntary removal action and Site characterization was performed by Witco in a former refuse area, located in the north end of the Foster Brook Facility. The location is shown on Figure 9.4. The Foster Brook refuse area was the former site of miscellaneous demolition debris and container disposal activities from the refinery up until the early 1970s.

The removal of exposed and buried containers and their contents was planned following an agreement with PADEP. This removal activity encountered and characterized approximately 3,200 containers for off-Site disposal. Also, approximately 400 cubic yards of total petroleum hydrocarbon (TPH)-affected soil was excavated and taken to an off-Site landfill for disposal as non-hazardous waste. Containers and their contents were inventoried, screened, sampled, and analyzed to determine the appropriate disposal alternatives. The types of materials found in the containers included water treatment resin, tar, soil, oil, and other petroleum-related solids and semisolids. Less than 20 of the containers were determined to contain hazardous material. These containers' contents exhibited hazardous characteristics for chromium and barium. All of the other containers and their contents were non-hazardous and were disposed in the County Landfill in Clarion, Pennsylvania.

Following container removal and backfilling activities, Witco prepared a subsurface characterization plan for the entire refuse Site. This plan included sampling and analysis of Site soil and shallow groundwater. Direct-push (Geoprobe®), hand-auger sampling, and both on- and off-Site analytical methods were employed to collect representative samples of soil and groundwater in the former refuse disposal area. This sampling was conducted in September 1997 and resulted in the collection of 62 soil samples and 10 groundwater samples from 32 boring locations across the area. The potential chemicals of concern, based on conservative, non-residential exposure criteria,

included PCE, arsenic, lead, and nickel in the soil; and TCE, beryllium, cadmium, lead, and nickel in the shallow groundwater.

Comparing the maximum detected concentrations with the most restrictive available Act 2 standard, only 2 soil samples of the 62 collected exhibited constituents above the statewide standards. One sample (Location 6, nka RAS-6) contained elevated concentrations of PCE and the other sample (Location 19, nka RAS-19) contained elevated concentrations of arsenic, lead, and thallium. Although benzo(a)pyrene was detected in one sample above the direct-contact surface criteria, this sample was collected from a depth greater than two feet below ground surface (bgs) and, therefore, does not pose a dermal contact or incidental ingestion risk. The maximum detected concentrations of the three elevated metals were very close to the statewide standard. Thus, the remaining soils on Site following removal of the drums and impacted soil pose minimal risk or concern.

Comparing the maximum detected concentrations with the Act 2 statewide standard, only two groundwater samples exceeded the criteria. Concentrations just above the statewide standard for the metals beryllium, cadmium, lead, and nickel were found at piezometer location No. 2 (nka RAW-02). TCE was found at groundwater sampling location No. 7 (nka RAW-07) at a concentration of 16 μg/L compared to the maximum contaminant level of 5 μg/L.

Based on the maximum detected groundwater concentrations, only cadmium, chromium, copper, and zinc could potentially impact both acute and chronic aquatic surface water criteria. No VOCs were found in the groundwater samples that exceeded the surface water quality criteria except for the TCE concentration identified in the groundwater which is greater than the surface water criteria (2.7 μg/L). Because the resulting concentration of these constituents in groundwater would be significantly diluted by Foster Brook, or Tunungwant Creek, and significantly retarded along the groundwater flow path to get to the creeks, it is unlikely that surface water impacts would occur from any of the chemicals detected in the refuse area groundwater.

9.4 1998 – FOSTER BROOK FACILITY GROUNDWATER REMEDIATION

In 1998, an SPL recovery well (RW-147) was installed in the Foster Brook Facility. This recovery well was intended to capture the SPL plume identified to be present in the vicinity of the former burn pit area as shown on Figure 9.4. The well was never operated.

9.5 2000 – HORIZONTAL WELL SPL RECOVERY SYSTEM

The CAWS units combined with the operation of the five vertical groundwater extraction wells operated as the groundwater remedial system until September 2000. While the CAWS/vertical well system did recover a substantial volume of SPL and prevented its discharge into the Creek, the system did result in the need to treat a considerable volume of groundwater. Coupling this factor with the diminishing volume of SPL being recovered and the fact that SPL discharges and sheens were still occasionally occurring along Tunungwant Creek in the Main Refinery area, it was decided that another groundwater remedial technology may be more effective.

In 2000, ESI designed and installed a horizontal well system for the recovery of SPL/protection of Tunungwant Creek. The horizontal well system consisted of a series of twelve overlapping horizontal wells that were installed along Tunungwant Creek in close proximity to the flood control walls and sheet pile walls that line the Main Refinery area. These walls were installed in the 1950s by the Corps to protect the adjacent areas from flood waters.

Each horizontal well originates in an entry pit (approximately 4' X 6' X 2' deep) that was later converted into a 2' X 2' X 2' vault. A drill rig capable of horizontal drilling was used to install a 4" diameter well screen following the drilling of an initial pilot hole which was drilled to ease the installation of the well screen. Each horizontal well extended between 200 and 400 feet in length depending upon access for origination and termination points for the wells. The first four horizontal wells were completed using Schedule 40 PVC well materials. Due to installation difficulties encountered with the first installations, the remaining horizontal wells were constructed using stainless steel well screens. A total of 12 horizontal wells were installed although only 10 are in use at the present time. Horizontal wells HW-1 through HW-4 became operational on September 29, 2000 and the vertical recovery wells pumping at that time (i.e., RW-1, RW-2, RW-3, RW-4, RW-14, and RW-15) were subsequently shut-down. HW-5 commenced operation in March 2002, followed by HW-6 (October 2002), HW-7 (November 2002), HW-8 (November 2002), HW-9 (December 2002), and HW-10 (April 2003). The remaining 2 horizontal wells HW-11 and HW-12) were installed as a precautionary measure in the event that they were ever needed to control SPL plumes in these areas of the Main Refinery. The locations of the horizontal wells are presented on Figure 9.1.

Each horizontal well was equipped with a pneumatically operated withdrawal system that draws groundwater and SPL via a suction line from within the horizontal well. Initially, the suction points were installed approximately 50 feet from the point of origination of the well. Over time, the suction points have been moved to locations more consistent with the lowest points along the horizontal wells to create as effective a drawdown on the groundwater table as possible. The vertical alignment of the horizontal wells varies over the length of the wells as was necessary to circumvent various below grade structures (e.g., foundations, etc.) and other utilities. The initial intent of the wells was to be positioned at an elevation that would be about 2 feet below the lowest typical groundwater elevation and yet above the elevation of the base of the flood control walls along the Creek. Being in this range allowed for the minimum recovery of groundwater while optimizing the collection of SPL before it could discharge to the Creek via the flood control wall weep holes. Weep holes were constructed along the base of the flood control wall to relieve the hydraulic pressure that could otherwise build up behind the wall and potentially result in structural failure of the wall. Thus the vertical elevation of the horizontal wells was critical to being able to intercept SPL floating atop the groundwater table before it could reach the Creek via the weep holes.

The pumps for the 10 horizontal wells are powered by a 50 horsepower compressor. Because the wells are pneumatically operated, they are able to pump the horizontal wells to a dry condition without having a detrimental impact on the pump components.

Since the wells are situated in the lower permeable upper soil/fill unit, and the wells are located in close proximity to the top of the naturally occurring surface of the groundwater table, there is limited recharge into the horizontal wells. Operating experience since the system has gone on line in 2000 has shown that each well is typically capable of providing on the order of 2 to 5 gpm on a continuous basis. This is consistent with the hydraulic conditions within which the wells are set.

Each well is connected to an insulated, steam heated forcemain that transfers the collected groundwater and SPL to the previously constructed groundwater treatment system.

For the operating period between May 2003 and the end of March 2004 (the time period when all 10 wells were operating), a total of approximately 14,876,420 gallons of groundwater were collected and treated. Of this volume, approximately 8,000 gallons was SPL. This translates into a recovery rate of approximately 0.054 gallons of SPL per 100 gallons of groundwater. For the next three 12-month periods (April 2004 to March 2005; April 2005 to March 2006; and April 2006 to March 2007), 18,998,960;

15,044,000; and 15,183,000 gallons of groundwater were collected and treated. Of this volume, 5,600; 4,700; and 3,500 gallons was SPL, which translates to a recovery rate of approximately 0.029; 0.031; and 0.023 gallons of SPL per 100 gallons of groundwater. This reduction in recovery rate supports that the volume of recoverable SPL is being reduced.

9.6 2002 - INTERIM SPL INTERCEPTOR TRENCHES

In 2002, ESI installed three interim SPL interceptor trenches along the banks of Tunungwant Creek, immediately north of the Kendall Avenue bridge. Two trenches are located on the east bank and one is located on the west bank as shown on Figure 9.1. The trenches were initially constructed as excavations, approximately 3 to 4 feet deep and ranging from 18 to 46 feet long. The trenches were installed to supplement SPL recovery from the area adjacent to the bridge abutments.

The interim trenches were intended to create a porosity break in relation to the surrounding saturated soils, effectively creating a hydraulic barrier to inhibit the mobility of SPL. The higher porosity of the stone backfill used in the trench construction was expected to provide space where SPL could accumulate and regularly be removed on a manual basis. However, it is believed that the void space created by the stone has since infilled and greatly reduced the initial porosity.

The streamside wall of each trench was lined with a heavy-gauge polyethylene sheet that extended a few feet above grade. Three perforated PVC sumps were placed vertically into each excavation and the trenches were then backfilled with washed gravel. The extended polyethylene sheet was then folded over the gravel and covered with additional gravel and cobbles.

Where present, the weep holes from the foundation of the Kendall Avenue bridge abutments were directly connected to the sumps using PVC pipe to further enhance SPL recovery from behind the abutments.

The vertical perforated sumps were to act as access points from which the accumulated SPL could be recovered. Inspections of these sumps in 2003 have shown that the sumps have also infilled with fine-grained soils. To date, no SPL has been known to have been recovered from the trenches.

9.7 2002 - MANUAL SPL RECOVERY

As requested by PADEP in 2002, Crompton authorized ESI and then CRA (in 2003), to supplement the horizontal well recovery of SPL with manual recovery efforts for all areas on the Site where the SPL was present. As a result, over the course of the past three years, a manual SPL recovery program has been developed. The program was developed from an initial survey of all available groundwater monitoring wells to identify every location where SPL was present. Based upon this initial survey, every groundwater monitoring well that has or had SPL present at one time or another has been included into the manual SPL recovery program. Those wells that have minimal or no SPL present any more, are checked less frequently than those that have recoverable SPL.

Each well with recoverable SPL is visited by a technician on a prescribed frequency (which can be weekly, monthly, quarterly, or semi annually). The technician inserts a bailer into the well and removes whatever volume of SPL that is recoverable at that time. During the initial visits, volumes of up to tens of gallons of SPL were recovered. However, over the past 21 months, recoverable volumes have diminished significantly as shown by the following SPL recovery rates, except for the October to December 2004 period:

Manual SPL Recovery

Quarter	*SPL Recovered (gallons)*
July - Sept 2002	3,100
Oct - Dec 2002	6,080
Jan - March 2003	3,100
April - June 2003	800
July - Sept 2003	330
Oct - Dec 2003	500
Jan – March 2004	580
April - June 2004	418
July - Sept 2004	800
Oct - Dec 2004	2,275
Jan - Mar 2005	360
Apr – Jun 2005	610
Jul – Sept 2005	1,328
Oct – Dec 2005	1619
Jan – Mar 2006	634
Apr – Jun 2006	1,123
Jul – Sept 2006	805
Oct – Dec 2006	1,200
Jan – Mar 2007	1,550

For the October to December 2004 period, the increase in recovered volume is primarily due to an intensified effort in the use of mobile Oil/Water Separator units to enhance SPL recovery.

In addition, CRA removed approximately 4,400 gallons of SPL attributable to the diesel spill reported by ARG in May 2004.

As shown in Tables 9.1, 9.2, and 9.3, there are up to 125 wells included in the SPL recovery. The frequency of SPL monitoring/recovery and the number of wells included for each frequency as of July 2005 were:

Frequency	*No. of Wells*
Weekly	44
Monthly	38
Semi-Annual	43
Total	**125**

For the time period ending December 2004, the amount of SPL recovered had:

i) decreased in 75 of the wells;

ii) increased in 29 of the wells (which is mostly due to increased frequency and/or improved methods of recovery); and

iii) was 0 in the remaining wells.

This demonstrates that the program has been very successful in reducing the volume of mobile SPL that remains in the groundwater today. Over the course of the manual removal program to March 31, 2007, a total of 27,200 gallons of SPL, not including the 4,400 gallons from the May 2004 diesel spill, has been recovered and recycled.

On its own initiative, Chemtura has taken the manual SPL recovery program one step further. Chemtura has identified through the ongoing monitoring program that a few of the wells continue to be more prolific with regard to SPL recovery than the other wells. For these wells, a more aggressive SPL recovery program has been developed. This program involves the set up of an active pumping system that recovers SPL from these wells on a continuous basis. The pumping systems include both oil skimming pumps, which only operate when oil is present floating on the groundwater table surface, and peristaltic pumping systems. The peristaltic pumps operate on a continuous low flow basis and recover both groundwater and SPL within the defined capture zone of the pump. The SPL recovery from these wells is monitored, and occasionally, the pumps are moved to other prospective wells to maximize their use. To date, this enhanced program has also been successful and over the course of the 8 months leading up to December 31, 2003 has resulted in the recovery of an additional 1,000 gallons of SPL as follows:

Quarter	*SPL Recovered (gallons)*
July - Sept	570
Oct - Dec	440

With the approval of PADEP, the enhanced program was discontinued for the winter months because of freezing problems of the pumps due to the cold weather. The program was restarted in the spring of each following year.

A summary of the efforts of the manual and enhanced SPL recovery programs for the time period from February 2003 through March 2005 is presented in Tables 9.1, 9.2, and

9.3. The tables list all of the wells in the SPL manual/enhanced programs (125 wells and the volume of SPL collected from each well. Furthermore, Table 9.3 lists the frequency of removal activity as of July 2005.

9.8 SPL SEEPS

There are currently a number of remedial actions being performed to prevent SPL seeps into Tunungwant Creek. These are:

i) SPL impacted groundwater is being removed by the horizontal collector wells and vertical recovery wells located behind the flood control walls;

ii) manual SPL removal from monitoring wells in which SPL has been identified to be present;

iii) automated SPL removal from select wells, from which typically larger volumes of SPL are recoverable;

iv) monitoring and addressing SPL seeps, if any (using absorbent pads, booms, etc.) along the shoreline to prevent entry into Tunungwant Creek; and

v) monitoring, reporting, and addressing sheens on Tunungwant Creek in accordance with the Consent Order and Agreement (COA).

The actions required by the COA to visually inspect the area of Tunungwant Creek shown on Figure 4.16 and the actions to be implemented for observed sheens are described in Section 4.4.

The sheens observed since monitoring and reporting of sheens has been required by the COA are presented in Table 4.6. A total of 28 sheens have been observed. Of these, 11 were non-reportable. Of the 17 reportable sheens, 8 were determined to have been sourced from properties other than the ARG Refinery.

9.9 RELEASE CLEANUPS

As previously mentioned, documentation regarding historic spills and cleanup efforts for the facility are very limited. However, in more recent times, such documentation is now prepared and submitted to PADEP on an as required basis. Typical examples demonstrating that the proper process is being followed is presented in the following series of Site Characterization Reports that were prepared by MACTEC Engineering and Consulting, Inc. on behalf of ARG. MACTEC submitted reports for each of the following tank releases or suspected tank releases as listed in Section 3.1:

Location/ Tank #	*Material Released*	*Date of Release*	*Volume of Reported Release (gallons)*	*Actions Taken*
22	Diesel Fuel	April 11/01	84	- tank removed from service - pooled diesel fuel recovered - stained soil removed - tank bottom replaced
173	Crude Oil	October 24/00	Suspected	- tank bottom repaired
248	Naphtha	May 4/01	Suspected	- tank closed in place - SPL recovery efforts from groundwater
264	Extracted Lube Oil	April 25/00	Suspected	- Replaced tank bottom
270	Bright Stock Extract Oil	April 15/00	Suspected	- Replaced tank bottom
603	Unleaded Gasoline	May 11/98	Suspected	- Replaced tank bottom
721	Crude Oil	November 4/99	42,000	- Contained and recovered from within earthen dike
Transfer Pump Area	Crude Oil	January 14, 2004 and March 31, 2004	1,000 and 5,000	- Recovered pooled oil and excavated soil
618	No. 2 Fuel Oil	April 30, 2004	Unknown	- Contained and recovered oil from within earthen dike
CTF Pipeline	Diesel	May 2004	Unknown (>4,200 gallons)	- Placed booms in intermittent Creek - SPL recovered from groundwater

For each of these releases and suspected tank releases, a follow-up investigation was performed, remedial measures were taken, and in many cases, are still ongoing today through the various SPL recovery programs. Future releases will be actively addressed by ARG as quickly as possible.

9.10 2004/05 TREATMENT SYSTEM UPGRADE

A new groundwater treatment facility, located in the northern portion of the R&D Area (see Figure 9.2), was constructed in the fall of 2004 and spring of 2005. The facility began full time operation in April 2005. The facility is housed in a 38 foot by 68 foot prefab single storey building. The system was installed for the removal of oils and iron from groundwater to meet NPDES Permit No. PA0222151 requirements. Groundwater first enters the existing oil/water separator located in the Crude Unit of the Main Refinery for the removal of free oils before being transferred to the new treatment building via an aboveground force main (1300' in length). In the new treatment building the water enters an aerated pH adjustment tank and then gravity flows to a Dissolved Air Flotation (DAF) clarifier. The precipitation of iron and separation of oil from the groundwater is improved by the addition of a coagulant. The sludge that forms is skimmed off and collected in a sludge holding tank for eventual off-Site disposal. The DAF effluent flows to surface water outfall 001. To date, the system has operated successfully and is fully capable of meeting the PADEP permit discharge limits.

Operation of the horizontal well and treatment systems will continue for the foreseeable future.

9.11 SOIL GAS VENTING SYSTEM - FOSTER BROOK FACILITY ATTENDANT'S STATION

In order to intercept any soil gas build up beneath this occasionally occupied space, Crompton performed an IRM to provide a preferred outlet for any air/soil gas trapped underneath the building. The IRM included the installation of 4 -inch diameter perforations in the 2-foot high concrete foundation walls supporting this building. Six perforations were installed through the walls at the locations shown on Figure 9.5 and vent plates were installed over these perforations. The vents allow a direct air exchange between outdoor air and the air space directly beneath the floor slab of the building. It is noted that the 2-foot space between the ground surface and the building floor is an open air space (this space was not filled with soil). Thus the air space beneath the

building will now be the same as the ambient outdoor air. Thus, this potential exposure pathway has been eliminated.

10.0 CONCLUSIONS

Based upon the assessments and evaluations of the data performed, the following conclusions have been formulated. The conclusions are presented in order of the SCR Sections.

10.1 ENVIRONMENTAL SETTING

i) The current use of the Site is industrial and is expected to remain industrial in the future. Current land uses adjacent to the Site are:

   a) vegetated undeveloped to the north; and

   b) industrial/commercial/residential to the east, south, and west.

ii) The Site is located in the Tunungwant Creek Valley. Tunungwant Creek flows northward and is located east of the south portion of the Site, bisects the middle portion, and is west of the Foster Brook Facility.

iii) Four tributaries (Kendall Creek, Bolivar Run, an unnamed tributary in the CTF, and Foster Brook) flow into Tunungwant Creek in the vicinity of the Site.

iv) No groundwater wells are used as a community water supply source within PADEP's reporting zone identified as within 3,640 feet of the Site boundaries.

v) No Zone-2 wellhead protection areas exist within 1,000 feet of the Site.

vi) Three man-made reservoirs, located on the West Branch of Tunungwant Creek and tributaries thereto, provide potable water to the City of Bradford and Foster Township. A City ordinance controls the use of groundwater for potable supply in the vicinity of the Site.

10.2 HYDROGEOLOGIC SETTING

i) The hydrogeologic unit impacted by activities related to the Site is the Upper Aquifer, an unconfined aquifer generally on the order of 70 feet thick. This is underlain by the upper clay aquitard.

ii) Upward vertical gradients are present through the upper clay aquitard to the Upper Aquifer, thus preventing any possible impact upon the groundwater below the upper clay aquitard. Furthermore, the upward gradient tends to keep impacted groundwater near the water table surface.

iii) Groundwater flow in the Upper Aquifer discharges to Tunungwant Creek and its tributaries.

iv) The soil within the Upper Aquifer becomes coarser with depth resulting in higher hydraulic conductivities with depth.

v) Pumping in the area of an SPL plume causes a depression in the groundwater table which, in the area of an SPL plume, results in SPL flowing to the well and the accumulation of greater thicknesses of SPL within the depression. The greater SPL thickness results in more effective SPL removal.

vi) The overlapping influences of pumping all of the horizontal wells provides significantly more drawdown than the pumping of an individual well. This results in more effective prevention of SPL and associated impacted groundwater migration to Tunungwant Creek.

vii) The combination of:

a) upward gradient in the Upper Aquifer; and

b) floating SPL,

results in only the upper 10-foot thickness of groundwater in the Upper Aquifer being impacted by constituents attributable to the Site.

10.3 CHEMICAL CHARACTERIZATION SUMMARY

For the discussions provided in the subsequent sections, the following descriptions are used:

i) low level exceedances are ≤5 times the SHS MSC;

ii) moderate exceedances are >5 to ≤50 times the SHS MSC; and

iii) significant exceedances are >50 times the SHS MSC.

Groundwater locations which had exceedances of different levels on different dates were assigned the higher level in the following discussion.

10.3.1 ENTIRE SITE

i) Significant iron and manganese exceedances occur throughout the groundwater underlying and upgradient of the Site. These conditions are believed to be typical for the area although the Site has caused some increase of the iron and manganese concentrations beneath the Site. There are no applicable SHS MSCs for iron or manganese in soil. In general, the concentrations of iron and

manganese in the groundwater are holding constant or slowly decreasing with time. These two parameters are not further discussed in the following sections.

10.3.2 MAIN REFINERY (EXPOSURE UNIT 1)

Media	*Number of Locations with Exceedances* (1) *Groundwater*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	21 to 87	10 to 12	84 to 98	93 to 112
Non-Chlorinated VOCs	7/10/4	1/0/0	9/1/0	11/3/0
Chlorinated VOCs	3/0/0	0/0/0	0/0/0	0/0/0
PAHs	7/4/4	0/0/0	5/0/0	6/1/0(3)
Arsenic	37/0/0(2)	0/0/0	0/0/0	13/0/0
Other Metals	3/4/2(2)	2/0/0(4)	3/0/0	27/3/0

(1) 12/7/2 = number of locations with low level/moderate/significant exceedances.
(2) Dissolved Metals
(3) Excluding naphthalene which is included in Non-Chlorinated VOCs.
(4) Background concentration for lead greater than on-Site exceedance.

Number of SPL Plumes : 16 (SPL-1 through SPL-15 and SPL-29)
Volume of SPL based on Corrected Thickness : 55,200 gallons

The above shows that much of the groundwater and saturated soil underlying the Main Refinery has been impacted by arsenic, non-chlorinated VOCs, and PAHs. The areas of greatest impact are those beneath or downgradient of SPL plumes. In general, the groundwater PAH concentrations are decreasing with time while the non-chlorinated VOCs are holding constant or decreasing with time.

10.3.3 ADMINISTRATION AND RESEARCH AREA (EXPOSURE UNIT 2)

Media	*Number of Locations with Exceedances* [1] *Groundwater*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	8 to 9	3	6	4 to 6
Non-Chlorinated VOCs	1/0/0	0/0/0	0/0/0	0/0/0
Chlorinated VOCs	1/3/2[2][5]	0/0/0	0/0/0	0/0/0
PAHs	0/0/0	0/0/0	0/0/0	0/0/0
Arsenic	4/0/0[4]	0/0/0	0/0/0	0/0/0
Other Metals	1/0/0[3][4]	0/0/0	0/0/0	1/0/0

(1) 1/3/2 = number of locations with low level/moderate/significant exceedances.
(2) Not sourced by activities attributable to the Site.
(3) Background concentration for aluminum greater than on-Site exceedance.
(4) Dissolved Metals.
(5) Background concentrations for Cis-1,2-DCE and VCM greater than on-Site exceedances.

Number of SPL Areas : 1, a continuation of SPL-14 from EU1
Volume of SPL : Included in EU1

The above shows that the Administration and Research area has been minimally impacted by Site-related activities except for the area adjacent to Kendall Avenue which correlates with the SPL in this area. The groundwater chlorinated VOC concentrations appear to be decreasing with time.

10.3.4 CRUDE TANK FARM (EXPOSURE UNIT 3)

Media	*Number Of Locations With Exceedances (1)* *Groundwater*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	13 to 36	17 to 20	33 to 34	11
Non-Chlorinated VOCs	2/0/1	0/1/0	2/0/0	1/0/0
Chlorinated VOCs	0/5/6 [2][3]	0/0/0	0/0/0	0/0/0
PAHs	0/0/0	0/0/0	0/0/0	0/0/0
Arsenic	3/0/0 [4]	3/0/0	1/0/0	2/0/0
Other Metals	1/0/0 [4]	2/0/0	1/0/0	2/0/0

(1) 0/5/6 = number of locations with low level/moderate/significant exceedances.

(2) Not sources by activities attributable to the Site.
(3) Background concentration(s) greater than on-Site exceedances.
(4) Dissolved Metals.

Number of SPL Areas : 3 (SPL-16 to SPL-18)

Volume of SPL based on Corrected Thickness : 8,500 gallons

[not including portion of SPL-18 off-site (540 gallons) and beneath National Transit Property) (420 gallons)]

The above shows that the Crude Tank Farm has been minimally impacted by Site related activities except for the three areas where SPL is present. No trend with time could be discerned for the non-chlorinated and chlorinated VOC groundwater concentrations.

10.3.5 FOSTER BROOK FACILITY SOUTH (EXPOSURE UNIT 4)

Number Of Locations With Exceedances (1)

Media	*Groundwater* *On-Site*	*Groundwater* *Downgradient*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	63 to 78	4 to 11	34 to 38	67 to 115	22 to 52
Non-Chlorinated VOCs	8/7/27	1/2/2	3/4/0	4/11/20	6/5/9
Chlorinated VOCs	1/6/0	0/0/0	2/1/0	2/0/0	0/1/0
PAHs	2/3/0 (3)	0/0/0	1/0/0	3/0/0(3)	1/1/0(3)
Arsenic	32/1/0(2)	2/0/0 (2)	0/0/0	1/0/0	3/0/0
Other Metals	11/1/0 (2)	1/0/0 (2)	9/3/0	7/0/0	0/1/0

(1) 8/7/27 = number of locations with low level/moderate/significant exceedances.
(2) Dissolved Metals.
(3) Excluding naphthalene which is included in non-chlorinated VOCs.

Number of SPL Areas : 7 (SPL-22 to SPL-28)

Volume of SPL based on Corrected Thickness : 19,200 gallons

The above shows that much of the groundwater, unsaturated subsurface soil, and saturated soil underlying the Foster Brook Facility South has been significantly impacted by non-chlorinated VOCs. The groundwater also has low-level impacts due to PAHs and metals, primarily arsenic. The areas of greatest impact are the Light End Tank Farm, Garage/Shed Area, and the Former Burn Pit Area. These three areas correlate with areas where SPL is present. On-Site groundwater concentrations for the PAHs and non-chlorinated VOCs appear to be constant or decreasing with time.

Also, two off-Site areas have been impacted. The first is the groundwater downgradient of the Light End Tank Farm which has been moderately to significantly impacted with benzene. The second is the Former Burn Pit Area soil and groundwater west of the Site boundary. These off-Site soils have been significantly impacted principally with

naphthalene, 1,2,4-TMB, 1,3,5-TMB, and benzene whereas the off-Site groundwater has been significantly impacted with benzene.

10.3.6 FOSTER BROOK FACILITY NORTH (EXPOSURE UNIT 5)

Media	*Number Of Locations With Exceedances (1)*			
	Groundwater	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	3 to 9	28	19 to 25	9 to 11
Non-Chlorinated VOCs	0/0/0	0/0/0	0/0/0	0/0/0
Chlorinated VOCs	2/1/0	0/0/0	0/0/0	0/0/0
PAHs	0/0/0	0/0/0	0/0/0	0/0/0
Arsenic	0/0/0 (2)	2/0/0	1/0/0	6/0/0
Other Metals	4/0/1 (2)	2/0/0	1/0/0	3/1/0

(1) 2/0/1 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals

Number of SPL Areas : None

The above shows that the Foster Brook Facility North has been minimally impacted by Site related activities.

10.3.7 PACKAGING PLANT (EXPOSURE UNIT 6)

Media	*Number Of Locations With Exceedances (1)*			
	Groundwater	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Location	9	NS	3	NS
Non-Chlorinated VOCs	0/0/0		0/0/0	
Chlorinated VOCs	0/7/0		0/0/0	
PAHs	0/0/0		0/0/0	
Arsenic	0/0/0 (2)		0/0/0	
Other Metals	0/0/0 (2)		0/0/0	

(1) 0/7/0 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals

NS Not Sampled

Number of SPL Areas : 2 (SPL-20 and SPL-21)

Volume of SPL based on Corrected Thickness : 1,300 gallons

The above shows that the groundwater underlying the Packaging Plant has been moderately impacted by chlorinated VOCs. The area of impact correlates with the

location of the two SPL plumes. No trend with time could be discerned for the chlorinated VOC groundwater concentrations.

10.3.8 TUNUNGWANT CREEK (EXPOSURE UNIT 7)

Number Of Locations With Exceedances (1)		
Media	*Surface Water*	*Sediment*
Number of Sample Locations	46	30 to 38
Non-Chlorinated VOCs	0/0/0	0/0/0
Chlorinated VOCs	5/0/0	0/0/0
PAHs	0/8/0	0/0/0
Arsenic	0/0/0 (2)	24/1/0
Other Metals	7/0/0 (2)	3/0/0

(1) 7/0/0 = number of locations with low level/moderate/significant exceedances, not including August 2006 results.

(2) Dissolved Metals

The above shows that Tunungwant Creek has been minimally impacted by Site-related activities. This is supported by the results of the macroinvertebrate study which showed that while a slight to moderate impairment is evident, no toxic impact attributable to Site related chemicals was apparent. The major factors causing the impairment are habitat modifications and continuing physical disturbances that have been performed in conjunction with flood control efforts.

10.3.9 NATIONAL TRANSIT PROPERTY (EXPOSURE UNIT 8)

	Number Of Locations With Exceedances (1)			
Media	*Groundwater*	*Surface Soil*	*Unsaturated Soil*	*Saturated Soil*
Number of Sample Locations	3 to 53	42 to 52	44 to 47	16 to 35
Non-Chlorinated VOCs	5/28/6	4/1/0	3/0/0	6/0/0
Chlorinated VOCs	2/1/0	0/0/0	0/0/0	0/0/0
PAHs	3/0/0	0/0/0	0/0/0	0/0/0
Arsenic	0/0/0 (2)	0/0/0	0/0/0	0/0/0
Other Metals	1/0/0 (2)	0/0/0	0/0/0	0/0/0

(1) 6/2/0 = number of locations with low level/moderate/significant exceedances.

(2) Dissolved Metals

Number of SPL Areas : 2 (part of SPL-18 and SPL-19)

Volume of SPL based on Corrected Thickness : 450 gallons (on-site)

: 540 gallons (off-site)

The above shows that the groundwater and saturated soil underlying the National Transit Property has been significantly and moderately impacted, respectively, by non-chlorinated VOCs. The areas of highest impact correlate with the areas where SPL is present in the eastern one-third of the Property.

10.4 PIPELINE INVESTIGATIONS

i) The abandoned underground pipelines, including the Duke Center crude oil pipeline have been properly abandoned and were structurally in good condition.

ii) The pipelines contained clear water. No indication of product was observed in the water samples.

iii) No indication of leakage from the pipelines was observed at the investigation locations.

10.5 SEPARATE PHASE LIQUID

i) Thirty SPL plumes with a total volume of approximately 85,200 gallons (corrected thickness) currently exist.

ii) The number of plumes and volume (corrected thickness) for each Exposure Unit are:

Exposure Unit	*SPL Plumes*	*Volume (Gallons)*
EU1	SPL-1 through SPL-15 and SPL-29	55,200
EU2	continuation of SPL-14	included in EU1
EU3	SPL-16 through SPL-18	8,500
EU4	SPL-22 through SPL-28 and SPL-30	19,200
EU5	None	0
EU6	SPL-20 and SPL-21	1,300
EU8 on-site	SPL-18 and SPL-19	450
EU8 off-site	SPL-18 and SPL-31	540

SPL Plume	*Location*	*Description*	*Specific Gravity*	*Dynamic Viscosity (centipoise)*
SPL-1	MEK Unit	Solvent Distillate	0.84 to 0.86	10.2
SPL-2	MEK Unit	--	0.82	--
SPL-3	MEK Unit	MN (Medium Neutral)	--	--
SPL-4	MEK Unit	--	--	--
SPL-5	ROSE Unit	HN (Heavy Neutral) with MN	0.82 to 0.87	21.6
SPL-6	ROSE Unit	HN	0.79	--
SPL-7	ROSE Unit	HN and MN	0.85 to 0.89	89.0
SPL-8	ROSE Unit	--	--	--
SPL-9	Dubbs Unit	--	--	--
SPL-10	Crude Unit Upper Yard	Solvent Distillate with LLN and HN	0.84 to 0.87	4.44
SPL-11	Crude Unit	Solvent Distillate with MN and HN	0.86	12.4
SPL-12	MR Barrel House	MN and HN	0.86	10.3
SPL-13	MR Barrel House	HN, MN and Solvent Distillates	0.83 to 0.88	46.3
SPL-14	MR Barrel House/Adm	HN and Solvent Distillates	0.84	
SPL-15	Erie Wye Unit	Unknown with Solvent Distillate	0.80 to 0.83	2.29
SPL-16	CTF	--	0.82	3.49
SPL-17	CTF	--	0.87	17.5
SPL-18	Independent Production Area South	2001 - Severely Weathered Crude 2003 – Light End Hydrocarbons	0.79 to 0.82	2.23
SPL-19	NT Property	--	--	--
SPL-20	Packaging Plant	--	0.88	91.1
SPL-21	Packaging Plant	--	--	--
SPL-22	Bulk Haul/	Gasoline or Diesel based (MW-TF10)	0.84 to 0.87	10.5
	Light End Tank Farm	Gasoline based (MW-TF28)	0.74 to 0.75	0.96
SPL-23	FB Barrel House	--	0.89	35.1
SPL-24	Light End Tank Farm	--	--	--
SPL-25	Former Impoundment Area	--	--	--
SPL-26	Garage/Shed Area	Gasoline Based	0.74 to 1.00	3.25
SPL-27	Bauxite Fill Area	Gasoline Based	0.85 to 1.00	11.3
SPL-28	Former Burn Pit Area	--	0.92	1,140
SPL-29	Platformer Unit	--	--	--
SPL-30	EU4 Railway Unloading	Crude Oil	----	----

In addition, 2 off-site SPL plumes upgradient of the Site have been identified. One is a newly identified SPL plume located on the Buffalo and Pittsburgh Railway south of

Bolivar Drive (i.e., SPL-31) and the other is on the Custer City Oil property north of Bolivar Drive (i.e., SPL-CC01).

10.6 CLOSURE EVALUATION - FOSTER BROOK FACILITY

Five areas in the Foster Brook Facility were evaluated to determine if they were properly closed in compliance with Pennsylvania laws and regulations and, if not, what additional measures are needed to achieve proper closure.

10.6.1 BAUXITE FILL AREA

The evaluations showed that:

i) the bauxite fill is uncovered and friable and thus subject to erosion;

ii) benzene, ethylbenzene, and naphthalene exceeded SHS MSCs in the unsaturated soil; and

iii) benzene, arsenic, iron, and manganese exceeded SHS MSCs in groundwater.

Therefore, the area will be closed under a combined SHS MSC and SSS.

The above show that an impact to groundwater have occurred. To properly close the Bauxite Fill Area, the following actions are proposed:

i) regrading to achieve compliance, to the extent practical, with the slope requirements;

ii) placement of a 6-inch thick crushed limestone cover to prevent contact and to reduce infiltration; and

iii) implement deed restrictions to restrict land and groundwater use and develop operating procedures to ensure appropriate H&S measures are implemented for subsurface activities.

10.6.2 FLY ASH AREA

The evaluation showed that:

i) no parameters exceeded SHS MSCs in soil;

ii) no groundwater analytical results are available. However, considering no exceedances of SHS MSCs occurred in the soil, it is unlikely that the groundwater has Site-related exceedances;

iii) the fly ash is covered with a 4 to 6-inch thick layer of clay/slag material with a slope of 1% or less. The cover appears to be controlling infiltration;

iv) the cover is only partially vegetated and thus some areas are subject to erosion.

Because there are no exceedances of SHS MSCs, this area will be closed under the SHS MSCs.

The above shows that an impact to groundwater is unlikely to be occurring. The existing cover is preventing contact and reducing infiltration. However, to assist in controlling future erosion, it is proposed to:

i) perform minor isolated regrading to enhance precipitation runoff to Foster Brook;

ii) supplement the existing cover with 6 to 8 inches of topsoil (where needed) which will better support vegetation; and

iii) revegetate the Fly Ash Area with grasses and herbaceous seed mix to enhance the ecological value of the area.

10.6.3 FORMER BURN PIT AREA

The evaluations showed that:

i) the area is completely vegetated with only a few small isolated bare spots;

ii) the ground surface is currently sloped at approximately 2% toward Foster Brook and the drainage swale of State Route 219;

iii) PAHs, BTEX, chlorinated VOCs, lead, and selenium were detected in soil at concentrations in exceedance of SHS MSCs;

iv) PAHS, benzene, ethylbenzene, chlorinated VOCs, arsenic, and manganese were detected in groundwater at concentrations in exceedance of SHS MSCs; and

v) most areas are covered with a 2 to 4 foot thick layer of clayey silt.

Because there are exceedances of SHS MSCs, this area will be closed under a combined SHS MSC and SSS.

The above shows a significant impact to groundwater has occurred. To properly close the Former Burn Pit Area, the following actions are proposed:

i) moderate regrading of the existing 2 to 4-foot thick clayey silt cover to enhance precipitation runoff toward Foster Brook and the State Route 219 drainage swale;

ii) placement of an additional 6-inch thick cover of topsoil;

iii) revegetate with grasses and herbaceous seed mix to enhance the ecological value of the area; and

iv) implement deed restrictions to restrict land and groundwater use and develop operating procedures to ensure appropriate H&S measures are implemented for subsurface activities.

10.6.4 CONSTRUCTION DEBRIS AREA

The evaluations showed that:

i) the area is partially vegetated (70% coverage);

ii) the fill, where present, is generally exposed at ground surface;

iii) chlorinated VOCs, metals, and benzene were detected in the soil at concentrations in exceedance of SHS MSCs; and

iv) chlorinated VOCs, iron, manganese, nickel, and beryllium were detected in groundwater at concentrations in exceedance of SHS MSCs.

Because there are exceedances of SHS MSCs, this area will be closed under a combined SHS MSC and SSS.

The above shows an impact to groundwater and the potential for erosion and contact with the fill. To properly close the Construction Debris Area, the following actions are proposed:

i) regrading of uneven and open, non-vegetated areas to promote surface water drainage;

ii) cover all exposed wastes and regraded areas with 12 inches of topsoil;

iii) revegetate with grasses and herbaceous seed mix to enhance the ecological value of the area; and

iv) implement deed restrictions to restrict land and groundwater use and develop operating procedures to ensure appropriate H&S measures are implemented for subsurface activities.

10.6.5 REFUSE/CONTAINER REMOVAL AREA

The evaluations showed that:

i) the previously completed container removal program has effectively remediated this area;

ii) the container removal area is partially vegetated (70% coverage);

iii) the rest of the area is completely vegetated;

iv) fill is exposed only in a small number of test pits and along a steep drop-off;

v) two locations had arsenic and one location had acetone, lead, and thallium concentrations in soil very slightly in exceedance of SHS MSCs. TPH concentrations ranged from non-detect to a maximum of 37,000 mg/kg except for 3 locations which ranged from 75,000 to 200,000 mg/kg. There is currently no SHS MSC for TPH. Individual compounds included in TPH, which are deemed to be of significant concern (e.g., BTEX), have SHS MSCs. No such compounds exceeded their SHS MSC;

vi) two locations had both arsenic and cobalt concentrations in soil very slightly in exceedance of SHS MSCs; and

vii) one location had beryllium and two locations had nickel in groundwater very slightly in exceedance of SHS MSCs.

Because there are exceedances of SHS MSCs, this area will be closed under a combined SHS MSC and SSS.

Given the low level exceedances and infrequent presence, the metals and acetone are not of environmental concern. Furthermore, because no compounds included in the TPH

exceeded their SHS MSC, it is believed that the TPHs are not a significant environmental concern.

Considering that all drummed waste and a considerable amount of other waste and contaminated soil has already been removed from this area and there are few and minimal exceedances of SHS MSCs, the following measures are proposed for the proper closure of this area:

i) minor regrading to improve surface water drainage;

ii) cover all exposed wastes and regraded areas with 12 inches of topsoil;

iii) revegetate the newly covered and regraded areas with grasses and herbaceous seed mix to enhance the ecological value of the area; and

iv) implement deed restrictions to restrict land and groundwater use and develop operating procedures to ensure appropriate H&S measures are implemented for subsurface activities.

10.7 FATE AND TRANSPORT EVALUATION

An evaluation was conducted of the potential fate and transport of chemicals detected in groundwater beneath the Site. The organic chemicals detected in groundwater beneath the Site are primarily related to the SPL present on top of the water table in various areas of the Site. Given that the Site is adjacent to Tunungwant Creek, the most significant migration pathway for chemicals present in groundwater is groundwater discharge to surface water. A fate and transport evaluation was conducted using the current chemical concentrations that have been detected in groundwater. The analytical results from a surface water sampling program completed in May 2005 has also been used to determine the Site's impact on adjacent surface water bodies. The majority of the chemical concentrations in groundwater are either constant or decreasing with time. Furthermore, with the SPL recovery program that is being implemented, it is expected that the groundwater concentrations will continue to decrease with time as the major chemical source (the SPL) is being removed. Thus, this evaluation is a conservative estimate of any future chemical loading to surface water.

10.7.1 POTENTIAL MIGRATION OF SPL TO GROUNDWATER

The evaluation was based on the assumption that the chemical concentrations in the groundwater directly underneath the SPL are representative of the leaching potential of the SPL.

Comparison of the SPL data with the groundwater data indicates the following:

i) the number of detected chemicals and the number of exceedances in groundwater reflect the chemical concentrations detected in SPL.

ii) in general, the concentrations in groundwater were lower than expected considering that these monitoring wells are located directly beneath an SPL plume.

Possible reasons for the lower than calculated concentrations in the groundwater are:

i) the phenomenon of relative solubility where the solubility of a chemical in a mixture with other chemicals is reduced proportional to its mole fraction;

ii) infiltrating water does not pass through the SPL but rather over and around it;

iii) the infiltrating water which has contacted the SPL will be diluted by the base flow of the groundwater;

iv) desorption of the chemicals in the groundwater onto the soil particles at some downgradient location;

v) chemical and biological degradation;

vi) losses due to volatilization as the impacted groundwater moves beyond the SPL area;

vii) dispersion caused by groundwater migration; and

viii) much of the SPL is likely highly weathered and has lost some of its leaching potential.

10.7.2 POTENTIAL MIGRATION OF GROUNDWATER COPECs TO SURFACE WATER

The assessment involved estimating potential in-stream concentrations for the Site-related parameters detected in groundwater at the Site, and comparing the estimated in-stream concentrations to the lower of the applicable PADEP surface water criteria protective of both human health and aquatic life.

Only groundwater flowing through the shallow portion (upper 10 feet or less) of the upper aquifer is impacted by Site-related chemicals and contributes chemical loading to surface water.

Given that vertical groundwater flow is upward in the vicinity of Tunungwant Creek, and thus beneath the Site, the use of 10 feet for the depth of groundwater impact to the upper aquifer is expected to be representative of actual conditions and is likely somewhat conservative.

The groundwater discharge rate to Tunungwant Creek through the impacted depth of the upper aquifer (i.e., the top 10 feet of the upper aquifer) was estimated for each flow zone using the calibrated groundwater flow model developed for the Site.

The total groundwater flow from the upper 10 feet for the entire Site entering Tunungwant Creek is estimated to be 3.22 cfs for the December 2003 conditions. The flows from each area are as follows:

Main Refinery	0.74
Administration/R&D Area	0.21
Crude Tank Farm	0.44
Foster Brook	1.42
National Transit Property	0.21
Packaging Plant	0.20
	3.22 cfs

For each flow zone, average chemical concentrations were calculated for each chemical detected in groundwater using the most recent groundwater quality data collected between 1999 and 2005 at monitoring wells located along the downgradient boundary of the flow zone (i.e., closest to Tunungwant Creek).

The downgradient monitoring wells represent the potential concentrations discharging to Tunungwant Creek under steady-state (or declining) conditions. Thus, the chemical loading calculated using the 1999 to 2005 groundwater quality data at the downgradient monitoring wells is a conservative estimate of the current actual chemical loading to Tunungwant Creek.

For each detected chemical, the total chemical loading from groundwater discharge results in estimated in-stream concentrations that are below the screening criteria for all

detected chemicals. As a result, the calculated chemical loadings from the groundwater to the surface water are not a concern to human health or the ecological aquatic environment.

The estimated chemical loadings for the Site show that the total estimated chemical loading contributed by groundwater to surface water under 7Q10 calculated conditions are as follows:

Chemical Type	*Chemical Loading (lbs/day)*
Total VOCs	1.77
Total SVOCs	0.09
TPH (extractable)	5.11

For Total VOCs, the chemical loading includes 0.44 lbs/day of chlorinated VOCs that are not related to the Site. Excluding chlorinated VOCs, the majority of the remaining Total VOC chemical loading of 1.33 lbs/day consists of 0.27 lbs/day benzene (42%), 0.16 lbs/day xylenes (26%), 0.12 lbs/day MEK (19%), and 0.09 lbs/day ethylbenzene (13%). For Total SVOCs, the chemical loading is comprised of 0.05 lbs/day 2-methylnaphthalene (53%), 0.01 lbs/day phenanthracene (13%), and 0.01 lbs/day acenaphthalene (12%).

There is also a considerable amount of dissolved inorganic compounds being discharged into the Creek from the groundwater beneath the Site; most of which is naturally occurring. The most prominent inorganics are as follows:

Sodium	734 lb/day
Calcium	223 lb/day
Iron	209 lb/day
Magnesium	53 lb/day
Manganese	26 lb/day

These five inorganic compounds account for more than 98% of the inorganic loading to the Creek from the groundwater.

Based upon the loading calculations, the Foster Brook Facility provides the highest loading to Tunungwant Creek. The Foster Brook Facility contributes 53% of the VOCs, 56% of the SVOCs, and 62% of the dissolved metals. It is to be noted that the entire

loading from the Foster Brook Facility comes from the portion of the area that is south of Foster Brook.

The Main Refinery area is the next most significant source of chemicals entering Tunungwant Creek. Without the operation of the horizontal and vertical well systems in the Main Refinery, the chemical loading to Tunungwant Creek would be considerably higher. However, the groundwater remediation measures currently in place in the Main Refinery area have been effective in drastically reducing this area's impact on the Creek and maintaining surface water quality at levels that are generally compliant with Pennsylvania regulations.

With regard to the inorganic compounds, as time goes on and the available SPL is removed from the groundwater, there is an expectation that concentrations of the petroleum related compounds in the groundwater will reduce, oxygen content will rise, and therefore, dissolution of inorganics from the soils will be reduced. This will result in lower inorganic concentrations and loadings in the future as aerobic conditions become more prevalent again.

The actual chemical loading to Tunungwant Creek is expected to be considerably lower than that calculated under the 7Q10 conditions. This is due to the following:

i) The downgradient monitoring wells used to characterize the groundwater quality applied in the chemical loading calculations are up to 100 feet from the point of groundwater discharge to the Creek (i.e., the Creek shoreline) and considerable additional attenuation will occur between these two locations;

ii) The chemical loadings are based on the assumption that the entire uppermost 10 feet of the upper aquifer has been impacted while the actual depth of groundwater impact is likely less than 10 feet due to the upward groundwater flow to Tunungwant Creek beneath the Site and the fact that the source of the groundwater impact (the SPL) is suspended on top of the water table; and

iii) Many of the chemical concentrations used in calculating the chemical loadings are from previous years' data (as far back as 1999). The decreasing trend is believed to be associated with improved spill prevention plans that have been implemented and the aggressive removal of the historic SPL from the subsurface. Given the decreasing chemical concentration trends measured at many wells, current chemical concentrations are expected to be lower at many of these wells now and therefore, use of these historic data is expected to overestimate the current chemical concentrations and consequently, the chemical loadings as well.

The estimated in-stream concentrations based on groundwater loadings and the calculated surface water concentrations using the surface water sample results under 7Q10 conditions show that in the majority of locations in the Site reach, the concentrations were similar to the upstream concentrations. However, there are a few parameters with slight exceedances located sporadically within the Site reaches of Tunungwant Creek. The surface water results for the tributaries support that the Site is not adversely impacting the tributaries.

10.7.3 POTENTIAL MIGRATION OF SPL TO SURFACE WATER

Presently, interim remedial measures (i.e., horizontal wells, vertical recovery wells, manual SPL recovery, and SPL absorption with adsorptive pads at the weep holes) are in place in EU1 to prevent the discharge of SPL to Tunungwant Creek.

Also during the ecological investigations of Tunungwant Creek, no SPL was observed within the sediments, which indicates that the SPL is not discharging to the surface water.

The SPL plumes in EU3, EU4, EU6, and EU8 are very localized and are a considerable distance from the creek. Given that these SPL plumes are a result of historical spills, the SPL plumes appear to be relatively immobile and the source removal of these SPL plumes will reduce and prevent potential migration of these plumes to the creek.

10.8 HUMAN HEALTH RISK ASSESSMENT

The risk characterization integrates the exposure assessment and toxicity assessment to provide a complete evaluation of the potential human health risks associated with exposure to COPCs at or near the Site. Two levels of exposure were evaluated:

i) the Central Tendency (CT), which utilizes the mean COPC concentrations and approximates the most probable exposure conditions; and

ii) the Reasonable Maximum Exposure (RME), which utilizes the 95 percent upper confidence level of the COPC mean concentrations and approximates maximum exposure conditions.

The estimated cumulative carcinogenic risks resulting from exposure to Site COPCs were compared to a target cumulative risk (TCR) of 10^{-4}. Estimated non-carcinogenic

hazards were calculated and compared to a Hazard Index (HI) of 1. A summary of the Reasonable Maximum Exposure (RME) cumulative risk results is presented below:

Exposure Unit	*Construction Worker*		*Indoor Worker*		*Outdoor Worker*		*Trespasser*		*Recreational Visitor*		*Resident/Child/ Adults*	
	CR	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*	*CR*	*HI*
EU1	1.1E-04	21,000	7.4E-05	6.9	2.2E-06	0.09	2.3E-07	0.023	NA	NA	NA	NA
EU1 Off-Site Hilton Street	--	0.46	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Penn Electric	--	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Mill Street	7.4E-06	6,600	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site B&P Railroad (MEK & Rose)	1.5E-05	7,500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Conrail	9.6E-07	6,600	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site B&P Railroad (Crude Unit)	5.2E-06	14,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Kendall Avenue	2.7E-04	17,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU1 Off-Site Werzalit	2.2E-06	17,000	2.1E-06	0.12	NA	NA	NA	NA	NA	NA	NA	NA
EU2	1.2E-05	21,000	2.7E-06	0.033	9.9E-07	0.016	1.2E-07	0.005	NA	NA	NA	NA
EU3	7.0E-04	22,000	7.8E-05	1.5	1.7E-05	0.24	2.1E-06	0.071	NA	NA	NA	NA
EU3/EU8 Off-Site B&P Railroad	2.3E-04	21,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU3 Off-Site Conrail	4.0E-04	38,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU4	9.7E-03	130,000	2.5E-03	150	1.4E-05	2.3	1.4E-06	0.24	NA	NA	NA	NA
EU4 Off-Site PennDOT	9.1E-04	14,000	NA	NA	NA	NA	5.1E-05	0.18	NA	NA	NA	NA
EU4 Off-Site Bolivar Drive	5.7E-07	1,100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU4 Off-Site B&P Railroad	3.5E-04	12,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EU5	1.7E-06	10	7.6E-06	0.16	1.8E-05	0.39	2.2E-06	0.39	NA	NA	NA	NA
EU6	2.1E-06	1,000	1.9E-06	0.036	NA	NA	NA	NA	NA	NA	NA	NA
EU6 Off-Site Graham Packaging	1.3E-06	1,000	9.9E-07	0.006	NA	NA	NA	NA	NA	NA	NA	NA
EU7 (Child/Adult)	NA	NA	NA	NA	NA	NA	NA	NA	8.1E-05	0.71/0.12	NA	NA
EU8 Off-Site Residential	2.3E-06	18,000	3.5E-06	0.09	NA	NA	NA	NA	NA	NA	2.5E-05	2.2/0.68

Notes:

NA = Not Applicable

-- = not calculated

The results of the HHRA show that the risks exceeding the cumulative risk of 10^{-4}, were identified for the indoor worker in EU4 (RME=2.5E-03), the on-Site construction worker

in EU1 (RME = 1.1E-04), EU3 (RME -= 7.0E-04), EU4 (RME=9.7E-03), and the off-Site construction worker in EU1-Kendall Avenue (RME = 2.7E-04), EU3/EU8-B&P Railroad (RME = 2.3E-04), EU3-Conrail (RME = 4.0E-04), EU4-PennDOT (RME = 9.1E-04), and EU4-B&P Railroad (RME = 3.5E-04). EU Hazard Indices exceeding the target HI of 1 were identified for the indoor worker in EU1 (RME=6.9), EU3 (RME = 1.5), and EU4 (RME = 150), the on-Site construction worker in EU1 (RME=21,000), EU2 (RME=21,000), EU3 (RME=22,000), EU4 (RME=130,000), EU5 (RME=10), and EU6 (RME=1,000). For the off-Site construction worker HIs exceeding 1 were identified in EU1-Mill Street (RME=6,600), EU1-B&P Railroad (MEK/Rose) (RME=7,500), EU1-Conrail (RME=6,600), EU1-B&P Railroad (Crude Unit) (RME=14,000), EU1-Kendall Avenue (RME=17,000), EU1-Werzalit (RME = 17,000), EU3/EU8-B&P Railroad (RME = 21,000), EU3-Conrail (RME = 38,000), EU4-PennDOT (RME = 14,000), EU4-Bolivar Drive (RME = 1,100), EU4-B&P Railroad (RME = 12,000), EU6-Graham Packaging (RME = 1,000), and EU8-Residential (RME = 18,000). For the resident, the results show an HI exceeding 1 for a child in EU8-Residential (RME = 2.2).

It should be noted that these cancer risk and HI exceedances incorporate some highly conservative assumptions. It is improbable that the same person would experience all potential exposures associated with the Site, or that he/she would experience these exposures over the periods of years specified in the individual RME scenarios.

Site-specific standards (SSSs) were developed for each COPC exceeding Statewide Health Standards (SHS) in each media, as outlined in Appendix M. Briefly, the SSSs were developed by conducting the RA process in reverse. In other words, the HQ/HI formula and risk formula are solved for the exposure concentration by setting the HI or risk to a specified target level. SSSs were developed for a target HI of 1 and target risk of 1E-05. Section 6.0 contains a detailed description of the SSSs for all receptors and exposure pathways.

Exposure Unit	Receptor	Medium (Route)	Chemical of Potential Concern	Units	Cumulative SSS	SHS MSCs	Maximum Detected Concentration	HHRA Table Reference
EU1	Indoor Worker (Current/ Future)	Soil Gas (Indoor Air Inhalation)	1,1,2,2-Tetrachloroethane	µg/m³	4.6E+03	1.4E+02	4.8E+03	6.1
			1,2-Dibromo-3-chloro-propane	µg/m³	4.0E+03	5.8E+01	2.7E+04	
			1,2-Dibromoethane	µg/m³	2.6E+03	3.7E+01	5.5E+03	
			Chloroform	µg/m³	2.5E+03	9.2E+01	3.4E+03	
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Aluminum	mg/kg	5.5E+03	1.9E+05	3.2E+04	6.12
			Chromium	mg/kg	7.3E+01	1.9E+05	1.5E+03	
			Copper	mg/kg	5.4E+03	1.9E+05	5.9E+03	
			Anthracene	mg/kg	1.9E+01	1.9E+05	1.4E+02	
			Benzo(a)pyrene	mg/kg	9.7E+00	1.9E+05	1.0E+02	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	1.8E+02	
			Benzo(k)fluoranthene	mg/kg	8.5E+00	1.9E+05	2.7E+02	
			Fluoranthene	mg/kg	8.5E-01	1.9E+05	3.7E+02	
			Benzene	mg/kg	1.9E-02	2.4E+02	1.1E+01	
			Ethylbenzene	mg/kg	9.2E-01	1.0E+04	6.1E+01	
			Naphthalene	mg/kg	1.7E-02	1.9E+05	9.0E+01	
			Xylene	mg/kg	6.3E-02	1.0E+04	1.8E+02	
		Groundwater (Ingestion Dermal Inhalation)	Antimony	mg/L	4.5E-02	6.0E-03	2.9E-01	6.13
			Benzene	mg/L	2.2E-01	5.0E-03	1.5E+00	
			Naphthalene	mg/L	8.2E-02	1.0E-01	2.7E-01	
			Manganese	mg/L	1.7E+00	3.0E-01	3.9E+01	
			Fluoranthene	mg/L	3.9E-01	2.6E-01	5.0E-01	
			Arsenic	mg/L	6.9E-02	5.0E-02	1.6E-01	
			Iron	mg/L	1.4E+02	3.0E-01	2.0E+02	
			Thallium	mg/L	1.1E-02	2.0E-03	2.0E-02	
			Benzo(a)anthracene	mg/L	2.5E-03	3.6E-03	1.6E-01	
			Benzo(a)pyrene	mg/L	1.7E-04	2.0E-04	2.8E-02	
			Benzo(b)fluoranthene	mg/L	1.7E-03	1.2E-03	1.6E-02	
			Benzo(k)fluoranthene	mg/L	1.9E-02	5.5E-04	3.1E-02	
			Dibenz(a,h)anthracene	mg/L	7.9E-05	3.6E-04	3.0E-03	
			1,2,4-Trimethylbenzene	mg/L	8.2E-02	3.5E-02	1.5E+00	
			1,3,5-Trimethylbenzene	mg/L	8.6E-02	3.5E-02	4.8E-01	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU1 Off-Site Mill Street	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzo(a)pyrene	mg/kg	6.1E+00	1.9E+05	6.3E+00	6.12
EU1 Off-Site B&P Railroad (MEK Unit)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	1.6E+02	1.9E+05	4.5E+03	6.12
			Chromium	mg/kg	7.3E+01	1.9E+05	1.5E+03	
			Vanadium	mg/kg	2.0E+01	1.9E+05	2.3E+01	
			Benzo(a)pyrene	mg/kg	3.1E+00	1.9E+05	6.3E+00	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	3.9E+01	6.13
EU1 Off-Site Conrail	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Naphthalene	mg/L	2.5E-01	1.0E-01	2.7E-01	6.13
EU1 Off-Site B&P Railroad (Crude Unit)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Naphthalene	mg/kg	3.2E-02	1.9E+05	1.6E+01	6.12
			Aluminum	mg/kg	3.7E+03	1.9E+05	2.3E+04	
			Manganese	mg/kg	5.4E+01	1.9E+05	2.3E+02	
EU1 Off-Site Kendall Avenue	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzene	mg/kg	5.6E-02	2.4E+02	1.1E+01	6.12
			Naphthalene	mg/kg	1.6E-01	1.9E+05	1.3E+01	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	2.3E+01	6.13
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	3.7E-01	
			Arsenic	mg/L	1.4E-01	5.0E-02	1.5E-01	
EU2	Indoor Worker (Current/ Future)	Groundwater (Indoor Air Inhalation)	Vinyl Chloride	mg/L	1.2E-01	3.0E+00	1.5E-01	6.2
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	1.6E+02	1.9E+05	1.1E+03	6.12
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	4.4E+00	3.0E-01	3.2E+01	6.13
EU3	Indoor Worker (Current/ Future)	Groundwater (Indoor Air Inhalation)	Vinyl Chloride	mg/L	1.0E-01	3.0E+00	2.4E-01	6.2
		Soil (Indoor Air Inhalation)	Benzene	mg/kg	8.2E-02	6.3E-01	5.5E+00	6.3

Exposure Unit	Receptor	Medium (Route)	Chemical of Potential Concern	Units	Cumulative SSS	SHS MSCs	Maximum Detected Concentration	HHRA Table Reference
EU3 (cont'd)	Indoor Worker (Current/ Future) (cont'd)	Surface Soil (Ingestion Inhalation)	Arsenic	mg/kg	5.9E+01	5.3E+01	9.2E+01	6.4
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	9.2E+01	6.6
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	8.4E+01	1.9E+05	9.4E+01	6.120
			Benzene	mg/kg	1.9E-02	2.4E+02	5.5E+00	
			Benzo(a)pyrene	mg/kg	4.2E+00	1.9E+05	7.1E+00	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	2.2E-01	5.0E-03	6.0E-01	6.13
			cis-1,2-Dichloroethene	mg/L	4.7E-01	7.0E-02	1.3E+00	
			Tetrachloroethene	mg/L	2.5E-01	5.0E-03	4.5E-01	
			Manganese	mg/L	2.9E+00	3.0E-01	1.9E+01	
			Vinyl Chloride	mg/L	1.5E-01	2.0E-03	2.4E-01	
			Arsenic	mg/L	1.4E-01	5.0E-02	1.1E+00	
EU3 Off-Site B&P Railroad	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	1,2,4-Trimethylbenzene	mg/kg	1.0E-02	3.6E+02	5.0E+01	6.12
			1,2-Dibromo-3-chloropropane	mg/kg	2.8E-04	2.0E-02	1.1E+00	
			1,3,5-Trimethylbenzene	mg/kg	4.5E-03	3.6E+02	1.8E+01	
			Benzo(a)pyrene	mg/kg	1.5E+00	4.6E+00	5.8E+00	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.2E+00	3.0E-01	3.8E+00	6.13
			1,2,4-Trimethylbenzene	mg/L	1.0E-01	3.5E-02	9.6E-01	
			1,3,5-Trimethylbenzene	mg/L	1.0E-01	3.5E-02	4.8E-01	
			Benzo(a)anthracene	mg/L	2.9E-04	3.6E-03	3.4E-01	
			Benzo(a)pyrene	mg/L	2.0E-03	2.0E-04	3.0E-01	
			Benzo(b)fluoranthene	mg/L	2.0E-02	1.2E-03	3.6E-01	
			Dibenz(a,h)anthracene	mg/L	2.2E-02	3.6E-04	3.7E-02	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU3 Off-Site Conrail	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	3.3E-01	5.0E-03	6.0E-01	6.13
			Tetrachloroethene	mg/L	3.0E-01	5.0E-03	3.3E-01	
EU4	Indoor Worker (Current/ Future)	Soil Gas (Indoor Air Inhalation)	1,1,2,2-Tetrachloroethane	µg/m³	2.5E+02	1.4E+02	8.0E+04	6.1
			1,1,2-Trichloroethane	µg/m³	1.2E+04	5.1E+02	6.5E+04	
			1,2-Dibromo-3-chloropropane	µg/m³	2.6E+02	5.8E+01	4.6E+05	
			1,2-Dibromoethane	µg/m³	1.7E+02	3.7E+01	9.0E+04	
			1,2-Dichloroethane	µg/m³	4.4E+02	3.1E+02	4.8E+04	
			1,2-Dichloropropane	µg/m³	1.3E+03	7.9E+02	5.5E+04	
			1,3-Dichlorobenzene	µg/m³	2.8E+04	1.1E+03	7.0E+04	
			1,4-Dichlorobenzene	µg/m³	2.4E+03	1.3E+03	7.0E+04	
			Benzene	µg/m³	1.7E+03	1.1E+03	1.8E+06	
			Bromodichloromethane	µg/m³	7.6E+02	2.2E+02	8.0E+04	
			Bromomethane	µg/m³	6.9E+03	1.4E+03	4.6E+04	
			Carbon tetrachloride	µg/m³	9.2E+02	5.5E+02	7.5E+04	
			Chloroform	µg/m³	1.3E+02	9.2E+01	5.5E+04	
			Chloromethane	µg/m³	4.0E+04	4.5E+03	9.5E+04	
			cis-1,3-Dichloropropene	µg/m³	3.9E+03	2.0E+03	5.5E+04	
			Dibromochloromethane	µg/m³	1.5E+03	3.0E+02	1.0E+05	
			Ethylbenzene	µg/m³	5.9E+04	7.3E+03	2.2E+05	
			m&p-Xylene	µg/m³	7.1E+05	3.0E+04	9.2E+05	
			Trans-1,3-Dichloropropene	µg/m³	3.9E+03	2.0E+03	5.5E+04	
			Vinyl Chloride	µg/m³	1.3E+03	9.5E+02	3.0E+04	
			1,2,4-Trimethylbenzene	µg/m³	2.4E+04	1.7E+03	7.9+04	
		Surface Soil (Ingestion Inhalation)	Antimony	mg/kg	2.0E+02	1.1E+03	5.6E+02	6.4
		Soil (Inhalation)	Benzene	mg/kg	5.9E+01	2.4E+02	1.5E+02	6.5
			Naphthalene	mg/kg	3.9E+02	1.9E+05	7.6E+02	
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	3.5E+01	6.6
			Antimony	mg/kg	2.0E+02	1.1E+03	5.6E+02	
		Soil (Inhalation)	Benzene	mg/kg	2.2E+01	2.4E+02	1.5E+02	6.7
			Naphthalene	mg/kg	1.5E+02	1.9E+05	7.6E+02	
			Xylene	mg/kg	5.2E+02	1.0E+04	1.0E+03	
			1,2,4-Trimethylbenzene	mg/kg	6.7E+01	3.6E+02	1.5E+02	
			1,3,5-Trimethylbenzene	mg/kg	5.8E+01	3.6E+02	1.4E+02	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU4 (cont'd)	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Antimony	mg/kg	2.4E+01	1.9E+05	5.6E+02	6.12
			Benzene	mg/kg	1.9E-02	2.4E+02	1.5E+02	
			Naphthalene	mg/kg	5.8E-02	1.9E+05	7.6E+02	
			Xylene	mg/kg	4.4E-01	1.0E+04	1.0E+03	
			Aluminum	mg/kg	2.8E+03	1.9E+05	6.2E+04	
			Mercury	mg/kg	1.7E+01	1.9E+05	3.3E+01	
			Fluoranthene	mg/kg	6.4E-01	1.9E+05	3.9E+02	
			Pyrene	mg/kg	3.9E+01	1.9E+05	3.5E+02	
			Ethylbenzene	mg/kg	9.3E-01	1.0E+04	1.6E+02	
			Toluene	mg/kg	3.0E+00	1.0E+04	4.1E+02	
			Arsenic	mg/kg	8.4E+01	1.9E+05	2.3E+02	
			Chromium	mg/kg	7.3E+01	1.9E+05	8.8E+01	
			Anthracene	mg/kg	1.9E+01	1.9E+05	7.2E+01	
			Benzo(a) pyrene	mg/kg	1.3E+01	1.9E+05	5.2E+01	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	9.0E+01	
			Benzo(k)fluoranthene	mg/kg	8.5E+00	1.9E+05	1.1E+02	
			1,1-Dichloroethane	mg/kg	6.5E-01	1.2E+03	7.6E+00	
			1,2,4-Trimethylbenzene	mg/kg	3.6E-02	3.6E+02	1.5E+02	
			1,3,5-Trimethylbenzene	mg/kg	1.0E-02	3.6E+02	1.4E+02	
			Chloromethane	mg/kg	1.7E-01	1.0E+03	1.4E+00	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	2.2E-01	5.0E-03	2.2E+01	6.13
			Naphthalene	mg/L	1.2E-01	1.0E-01	3.3E-01	
			Xylene	mg/L	2.8E+00	1.0E+01	1.2E+01	
			Manganese	mg/L	4.4E+00	3.0E-01	2.8E+01	
			Toluene	mg/L	4.1E+00	1.0E+00	2.1E+01	
			Arsenic	mg/L	1.4E-01	5.0E-02	2.6E-01	
			Iron	mg/L	1.4E+02	3.0E-01	2.0E+02	
			Benzo(a) pyrene	mg/L	2.0E-03	2.0E-04	3.3E-03	
			Dibenz(a,h)anthracene	mg/L	9.4E-04	3.6E-04	7.2E-03	

Exposure Unit	Receptor	Medium (Route)	Chemical of Potential Concern	Units	Cumulative SSS	SHS MSCs	Maximum Detected Concentration	HHRA Table Reference
EU4 Off-Site PennDOT	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Benzene	mg/kg	2.8E-02	2.4E+02	1.6E+01	6.12
			Naphthalene	mg/kg	8.6E-02	1.9E+05	1.1E+02	
			Xylene	mg/kg	7.0E-01	1.0E+04	5.3E+02	
			Ethylbenzene	mg/kg	1.3E+00	1.0E+04	1.1E+02	
			Lead (1)	mg/kg	1.2E+02	1.9E+05	1.4E+02	
			Anthracene	mg/kg	1.9E+01	1.9E+05	3.6E+01	
			Benzo(a) pyrene	mg/kg	8.4E+00	1.9E+05	2.3E+01	
			Benzo(b)fluoranthene	mg/kg	3.1E-02	1.9E+05	3.0E+01	
			1,1,1-Trichloroethane	mg/kg	4.0E+00	1.0E+04	3.5E+01	
			1,1-Dichloroethane	mg/kg	6.5E-01	1.2E+03	3.0E+01	
			1,2,4-Trimethylbenzene	mg/kg	6.7E-02	3.6E+02	2.0E+02	
			1,2-Dichloroethane	mg/kg	1.0E-01	7.3E+01	4.8E+00	
			1,3,5-Trimethylbenzene	mg/kg	2.1E-02	3.6E+02	9.2E+01	
		Groundwater (Ingestion Dermal Inhalation)	Benzene	mg/L	3.3E-01	5.0E-03	2.8E+00	6.13
			Naphthalene	mg/L	1.2E-01	1.0E-01	4.3E-01	
			Xylene	mg/L	2.8E+00	1.0E+01	1.5E+01	
			Manganese	mg/L	4.4E+00	3.0E-01	2.0E+01	
			Iron	mg/L	1.4E+02	3.0E-01	1.9E+02	
EU4 Off-Site Bolivar Drive	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	1,2,4-Trimethylbenzene	mg/kg	4.8E-02	3.6E+02	5.0E+01	6.12
			1,3,5-Trimethylbenzene	mg/kg	1.5E-02	3.6E+02	1.8E+01	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	2.9E+00	3.0E-01	4.7E+00	6.13
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	9.1E-01	
			1,3,5-Trimethylbenzene	mg/L	1.4E-01	3.5E-02	2.4E-01	
EU4 Off-Site B&P Railroad	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Mercury	mg/kg	3.0E-01	1.9E+05	3.3E+01	6.12
			Lead	mg/kg	8.7E+01	1.9E+05	9.0E+01	
		Groundwater (Ingestion Dermal Inhalation)	Benzo(a)anthracene	mg/L	2.9E-02	3.6E-03	9.9E-02	6.13
			Benzo(a)pyrene	mg/L	2.0E-03	2.0E-04	8.7E-02	
			Benzo(b)fluoranthene	mg/L	2.0E-02	1.2E-03	1.1E-01	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU5	Indoor Worker (Current/ Future)	Surface Soil (Ingestion Inhalation)	Arsenic	mg/kg	5.3E+01	5.3E+01	8.4E+01	6.4
	Outdoor Worker (Current/ Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	2.2E+01	5.3E+01	8.4E+01	6.6
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Manganese	mg/kg	8.1E+01	1.9E+05	2.3E+03	6.12
			Thallium	mg/kg	2.0E+01	1.9E+05	2.1E+01	
			Arsenic	mg/kg	4.0E+01	1.9E+05	8.4E+01	
			Barium	mg/kg	6.0E+02	1.9E+05	1.1E+03	
			Iron	mg/kg	8.4E+04	1.9E+05	1.5E+05	
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	4.4E+00	3.0E-01	2.7E+01	6.13
EU6	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Aluminum	mg/kg	1.1E+04	1.9E+05	2.2E+04	6.12
		Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	8.7E+00	3.0E-01	3.0E+01	6.13
EU6 Off-Site Graham Packaging	Construction Worker (Current/ Future)	Groundwater (Ingestion Dermal Inhalation)	Manganese	mg/L	8.7E+00	3.0E-01	2.2E+01	6.13
EU7	Recreational Visitor (Current/ Future)	Surface Water (Fish Ingestion)	Hexachlorobenzene	mg/L	9.6E-06	7.5E-07	2.3E-05	6.15
			Benzo(a)anthracene	mg/L	2.4E-05	4.4E-06	7.3E-05	
			Benzo(b)fluoranthene	mg/L	2.3E-05	4.4E-06	4.8E-05	

Exposure Unit	*Receptor*	*Medium (Route)*	*Chemical of Potential Concern*	*Units*	*Cumulative SSS*	*SHS MSCs*	*Maximum Detected Concentration*	*HHRA Table Reference*
EU8 Residential (R&S)	Resident (Future)	Surface Soil (Ingestion Dermal Inhalation)	Arsenic	mg/kg	7.2E+00	1.2E+01	2.2E+01	6.10
		Soil (Inhalation)	1,2,4-Trimethylbenzene	mg/kg	8.3E+00	1.1E+02	5.6E+01	6.11
			1,3,5-Trimethylbenzene	mg/kg	7.2E+00	1.1E+02	3.9E+01	
			1,2-Dibromo-3-chloropropane	mg/kg	1.0E+00	3.8E+00	1.1E+00	
	Construction Worker (Current/ Future)	Soil (Ingestion Dermal Inhalation)	Xylene	mg/kg	1.9E-01	1.0E+04	5.9E+01	6.12
			1,2,4-Trimethylbenzene	mg/kg	1.6E-02	3.6E+02	5.6E+01	
			1,3,5-Trimethylbenzene	mg/kg	1.2E-02	3.6E+02	3.9E+01	
			Ethylbenzene	mg/kg	1.9E+00	1.0E+04	8.3E+00	
			1,2-Dibromo-3-chloropropane	mg/kg	7.9E-04	1.2E+01	1.1E+00	
		Groundwater (Ingestion Dermal Inhalation)	Naphthalene	mg/L	8.2E-02	1.0E-01	1.0E+00	6.13
			Xylene	mg/L	1.9E+00	1.0E+01	1.5E+01	
			1,2,4-Trimethylbenzene	mg/L	1.4E-01	1.6E-02	5.9E+00	
			1,3,5-Trimethylbenzene	mg/L	1.4E-01	1.6E-02	1.9E+00	

Note:

(1) Lead SSS calculated using the Adult Lead Model and compared to the medium arithmetic mean rather than maximum detected concentration.

10.9 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

The Screening Level Ecological Risk Assessment that was performed for the Site included the following three components in support of the Assessment:

i) A Wetlands Delineation;

ii) A Habitat Characterization Study; and

iii) A Benthic Macroinvertebrate Study.

The conclusions formulated for each of these components of the Ecological Risk Assessment are as follows:

Wetlands Delineation

i) There are no "Exceptional Value" wetlands on the Site.

ii) All of the wetlands present on the Site are classified as "Other" wetlands on the basis of criteria identified in Pennsylvania Chapter 105.17.

iii) The types of wetlands and aquatic habitats encountered on the Site include:

- Riverine open water upper perennial;
- Riverine open water intermittent;
- Palustrine emergent wetland;
- Palustrine scrub-shrub wetland;
- Palustrine forested wetland; and
- Palustrine open water

Habitat Characterization Study

i) There are 10 general types of terrestrial habitats and cover types on the Site and surrounding area including:

- Developed
  - Industrial
  - Residential
  - Commercial
- Herbaceous Vegetation
  - Mowed lawn
  - Field
  - Old field
- Scrub-Shrub Uplands
  - Early successional
  - Late successional
- Early Successional Deciduous Forest
- Mature Secondary Growth Deciduous Forest

ii) The identified Species of Concern for the Site are the American brook lamprey and the Ohio lamprey although there is no suitable habitat at the Site to support these two species.

iii) Two other Species of Concern potentially inhabiting the area are the American bittern and the osprey. However, there is no suitable habitat for either species present on or in the vicinity of the Site.

iv) All of the wetlands on the Site are identified as Habitats of Concern because they provide identified function and value. However, none are identified as "Exceptional Value".

Benthic Macroinvertebrate Study

i) Although some impairment of the aquatic community adjacent to the Site was noted (compared to the upstream control area), not all of the impairment is related to the refinery.

ii) No toxic response was indicated by the data.

iii) Petroleum was not noted to be present in the water column or the sediment of the Tunungwant Creek or its Tributaries.

iv) Habitat modifications and continuing habitat disturbances are concluded to be major factors limiting the distribution of Species of Concern and the quality of the stream as a Habitat of Concern.

v) Habitats of Concern and Species of Concern have not been significantly impacted by refinery operations.

vi) Kendall Creek and Bolivar Run were determined to be non-impaired.

vii) Foster Brook was determined to be moderately impaired but this is based upon a lack of suitable habitat; not as a result of impact from the Site.

viii) The benthic invertebrate community has improved or recovered since the PADEP survey conducted in 2000.

Screening Level Ecological Assessment (Steps 1 and 2)

The SERA evaluated risk to ecological receptors posed by chemical constituents in the various areas of the Site. Some of the risk to ecological receptors posed by chemical constituents at the Site were in excess of the various ecological screening values for surface water, sediment, and surface soils. Consequently, it was necessary to continue to Step 3 of the USEPA's 8-Step ecological evaluation process. Many of the constituents carried forward to Step 3 did not exceed the ecological screening values, but simply had elevated detection levels (even though they were not detected). These constituents were carried forward to Step-3 as a precautionary measure. In Step-3, more Site specific characteristics were taken into consideration in the evaluation process. The constituents carried forward to Step 3 of the USEPA's 8-Step process are described below.

Surface Water

For the surface water of Tunungwant Creek, Kendall Creek, Bolivar Run, the Crude Tank Farm tributary, and Foster Brook (Exposure Unit-7), Continuous Concentrations

Criteria (CCC) for the protection of fish and aquatic life as published in *Chapter 16. Water Quality Toxics Management Strategy – Statements of Policy* (or other appropriate reference documents) were used as ecological screening values (ESVs) for surface water. Based on the available data:

i) aluminum and cis-1,2-dichloroethene are the only constituents detected in the surface water of Tunungwant Creek that were carried forward to Step 3;

ii) selenium and silver are the only constituents detected in Foster Brook that were carried forward; and

iii) twelve organic constituents including six polycyclic aromatic hydrocarbons (PAHs), and one metal were not detected in surface water, but were carried forward as a precautionary measure because their limits of detection exceeded their ESVs.

In summary, a total of 17 surface water chemical constituents were carried forward to Step 3.

Sediment

For sediment, Probable Effects Concentrations (PEC) identified by MacDonald et al. (2000) were used as ESVs. If a PEC was not available, a Threshold Effects Concentration (TEC), also from MacDonald et al. (2000) or other appropriate reference documents were used. Based on the available data:

i) for Tunungwant Creek, 1,2,4-TMB, acetone, acrylonitrile, benzene, ethylbenzene, toluene, xylenes, antimony, beryllium, iron, and manganese are the constituents detected in the sediments in exceedance of their ESV that were carried forward to Step 3;

ii) for Foster Brook, acetone, trichlorofluoromethane, vinyl acetate, barium, beryllium, iron, selenium, and vanadium are the eight constituents detected in the sediments in exceedance of their ESV that were carried forward; and

iii) fifteen constituents, including chlorinated organics constituents, were also carried forward because, although not detected in sediments, these compounds have limits of detection that exceeded their screening values.

In summary, a total of 100 sediment chemical constituents will be carried forward to Step 3.

Surface Soil

For surface soils, separate analyses were conducted for the Main Refinery (Exposure Unit 1), Crude Tank Farm (Exposure Unit 3), Foster Brook Facility South (Exposure Unit 4), Foster Brook Facility North (Exposure Unit 5), and the Tunungwant Creek - Foster Brook Corridor (Exposure Unit 7). Ecological soil screening levels (ECO-SSL), and other pertinent criteria, were used as ESVs for soil. The parameters that exceeded their ESV and were carried forward to Step 3 for further evaluation are:

i)	Main Refinery:	benzene	iron
		fluoranthene	lead
		phenanthrene	mercury
		chromium	vanadium
ii)	Crude Tank Farm:	benzene	naphthalene
		hexachlorobutadiene	pyrene
		phenanthrene	iron
		chromium	mercury
		lead	vanadium
		selenium	zinc
iii)	Foster Brook Facility South:	1,1,1-trichloroethane	1,1-dichloroethane
		1,2-dibromomethane	1,2-dichloromethane
		1,2,4-trichlorobenzene	1,3,5-trimethylbenzene
		2-phenylbutane	cymene
		isopropylbenzene	n-propylbenzene
		bis(2-ethylhexyl)phthalate	benzene
		ethylbenzene	xylene
		2-methylnaphthalene	anthracene
		benzo(a)anthracene	benzo(a)pyrene
		benzo(k)fluoranthene	fluoranthene
		chrysene	phenanthrene
		naphthalene	antimony
		pyrene	copper
		chromium	lead
		iron	selenium
		mercury	zinc
		vanadium	

iv)	Foster Brook Facility North:	benzoic acid	dibenzofuran
		bis(2-ethylhexyl)phthalate	benzo(a)pyrene
		chrysene	fluoranthene
		naphthalene	phenanthrene
		pyrene	chromium
		iron	copper
		vanadium	lead
		mercury	selenium
		thallium	zinc
v)	Tunungwant Creek - Foster Brook corridor:	anthracene	benzo(a)pyrene
		fluoranthene	naphthalene
		phenanthrene	pyrene
		chromium	iron
		mercury	vanadium

In summary, a total of 168 soil chemical constituents were carried forward to Step 3.

Completion of Steps 1 and 2 of the SERA triggered the first Scientific Management Decision Point (SMDP) in the ecological risk assessment process. The SMDP provides the risk assessor and agencies an opportunity to review the results of the screening level assessment and to chart a path forward for continuing with the risk assessment process.

Screening Level Ecological Assessment (Step 3)

The evaluation performed in the first refinement phase of Step 3 identified five chemical constituents that were retained as COPECs in soil:

- 1,2,4-trimethylbenzene;
- 1,3,5-trimethylbenzene;
- bis(2-ethylhexyl)phthalate;
- 2-methylnaphthalene; and
- copper.

There were no chemical constituents that were identified as COPECs for either the sediment or for the surface water media.

These five chemical constituents were then further evaluated in the second phase of Step 3 using simple food chain models and wildlife indicator species to evaluate risk to various trophic guilds of ecological receptors.

Results of the food chain analyses show that the potential for risk is within acceptable limits for the wildlife indicator species exposed to the COPECs in the soil in the Foster Brook Facility and Tunungwant Creek-Foster Brook Corridor. Because conservative assumptions were used for area use (i.e., 100 percent area use) and exposure (e.g., 100 percent bioavailability), Hazard Quotients slightly greater than one were interpreted to be within the limits of acceptable potential for risk. When more realistic assumptions of area use are considered, the Hazard Quotients for all scenarios are generally less than one. Use of more realistic bioavailability assumptions would further reduce the Hazard Quotients.

Because no constituents were identified as COPECs for either surface water or sediment, food chain analyses were not used to evaluate the potential for risk to semi-aquatic wildlife that forage on fish or other aquatic organisms. This has been identified and included as a source of uncertainty in the Step 3 evaluation of risk.

Based on the results of the refinement process and food chain analyses, it can be concluded that the potential for risk to ecological receptors is within acceptable limits in all surface water, sediment, and soil media in all assessment areas at the ARG facility. Consequently, there is neither need nor justification for a baseline risk assessment and the ecological risk assessment process can be exited at Step 3.

The results of the assessment performed show that the iron staining may cause an adverse impact on the aesthetics of Tunungwant Creek. However, the potential for risk to ecological receptors due to iron in surface water and sediment was found to be within acceptable limits. Furthermore, the macroinvertebrate survey conducted as part of Steps 1 and 2 did not identify any impacts to the benthic community that could be attributed to iron or any other COPEC.

Given the absence of any identified unacceptable risk in any of the media, the ecological risk assessment for the ARG Facility is complete.

10.10 IMPLEMENTED REMEDIAL ACTIONS

i) The completed container removal program in the Refuse/Container Removal Area has effectively remediated this area.

ii) The pumping of the horizontal wells, supplemented by select vertical wells is effectively preventing the discharge of SPL and significantly reducing the flux of Site-impacted groundwater to Tunungwant Creek. This conclusion is based on the fact that between May 2003 and March 2005, approximately 33,875,000 gallons of groundwater and 13,600 gallons of SPL was collected from these pumping systems. This conclusion is further supported by the minimal observed occurrences of seeps to the Creek via the flood control wall weep holes over the past year compared to previous years.

iii) Construction of the new groundwater treatment facility which is successfully operating and is fully capable of meeting the PADEP permit discharge limits.

iv) A program of manual SPL recovery has been implemented at the Site and has significantly reduced the thickness and volume of SPL underlying the Site. Approximately 27,200 gallons of SPL have been recovered from the manual SPL Recovery Program to March 31, 2007.

v) Implementation of an IRM beneath the Foster Brook Facility attendant's station to ensure that the air space beneath the building will be the same as the ambient outdoor air and eliminate the soil gas to indoor air pathway.

11.0 PLANNED REMEDIAL ACTIONS

11.1 SITE

The remedial actions planned to be implemented for the Site include the following:

i) continued operation of the horizontal and vertical collection wells;

ii) continued operation of the groundwater treatment system;

iii) continued implementation of the manual SPL recovery program;

iv) inspection and reporting of the Creek bank conditions, including mapping of the iron stained areas on an annual basis;

v) implementation of corrective actions to address any observed SPL or sheens noted during the Creek bank inspection; and

vi) closure and inspection/monitoring of the five specific areas in the Foster Brook Facility.

In addition, a macroinvertebrate study and surface water sampling will be performed every two years which started in 2006, until such study/sampling are no longer required as specified in the conditions provided in Section 3.c of the COA. It is noted that the surface water sampling is to be performed when flow conditions equal to or less than 7Q10 exist (or when conditions acceptable to PADEP exist).

A listing of the technologies selected for the recommended remedial option for each SPL area is provided in Table 11.1. The recommended technologies for SPL-1, SPL-4, SPL-9, SPL-20, SPL-21, SPL-27, and SPL-30 are:

i) manual SPL/groundwater recovery;

ii) natural attenuation; and

iii) institutional controls.

The recommended technologies for SPL-2/3 and SPL-18 are:

i) manual SPL/recovery;

ii) manual SPL/groundwater recovery;

iii) natural attenuation; and

iv) institutional controls.

The recommended remedial technologies for SPL-16 are:

i) excavation;
ii) natural attenuation; and
iii) institutional controls.

The recommended technologies for SPL-23 are:

i) manual SPL recovery;
ii) in-situ remediation;
iii) natural attenuation; and
iv) institutional controls.

The recommended technologies for SPL-17, SPL-25, SPL-28, and SPL-29 are:

i) natural attenuation; and
ii) institutional controls.

The recommended technologies for SPL-10 are:

i) manual SPL/recovery;
ii) vertical SPL extraction wells;
iii) horizontal collection wells;
iv) natural attenuation; and
v) institutional controls.

The recommended technologies for SPL-5, SPL-6, SPL-7, SPL-8, SPL-11, SPL-12/13, SPL-14, and SPL-15 are:

i) manual SPL recovery;
ii) horizontal collection wells;
iii) natural attenuation; and
iv) institutional controls.

The recommended technologies for SPL-22, SPL-24, and SPL-26 are:

i) manual SPL recovery;

ii) AS/SVE;

iii) natural attenuation; and

iv) institutional controls.

An expanded description of these planned remedial actions is provided in Appendix AR. Draft language for the deed restrictions and operating procedures are provided in Appendices AO and AP, respectively.

11.2 OFF-SITE AREAS

This section summarizes the planned remedial actions for the off-site properties adjacent to and/or downgradient of the Site.

A listing of the technologies recommended for each off-Site area is presented in Table 11.1. In summary, natural attenuation and institutional controls were recommended for all off-Site properties, except for two areas; the portion of the B&P Railroad south of Kendall Avenue where manual SPL/groundwater recovery and the portion of the B&P Railroad adjacent to EU3/EU8 where manual SPL recovery were also recommended.

Furthermore, the recommended technologies for SPL-31 also include manual SPL recovery and dual phase extraction.

With regard to the construction worker, procedures will be put in place to ensure that appropriate health and safety measures are implemented when subsurface work is being performed.

For the off-site private properties, deed restrictions will be put in place to preclude the use of groundwater, other than that needed for monitoring and remedial purposes. The interim health and safety measures to be implemented during the negotiation period of the deed restrictions are:

i) assist off-site property owners during pre-bid meetings and provide a template of a HASP to address Health and Safety issues for subsurface work;

ii) perform periodic inspections (i.e., semi-annually) of the off-site properties to visually identify activities which may result in unacceptable exposure and follow-up with the property owner if such are identified;

iii) submittal of annual letter requesting property owner to identify any upcoming work in the next year that could result in potential exposure;

iv) include reminder in annual letter that Chemtura/ARG are available to assist the owners to ensure that appropriate health and safety measures are taken for any upcoming subsurface work. Potential measures which may be taken are described in Appendix AT of the SCR;

v) continue working with owners to have appropriate postings/notices in place in case any subsurface work is required; and

vi) assist property owners with handling of water and soil adversely impacted with SPL/chemicals attributable to the Site.

For the properties that are under the control of public entities (e.g., City of Bradford) or utility companies (e.g., railroads), deed restrictions will not be implemented. Rather, procedures will be in place to ensure that ARG/Chemtura are notified of any subsurface activities that are planned and that an appropriate health and safety plan is available and implemented for the activity.

Draft language for the procedures to put the deed restriction in place and to ensure appropriate H&S measures are implemented are provided in Appendices AS and AT, respectively.

12.0 PUBLIC INVOLVEMENT

In accordance with §250.6, notification regarding the Notice of Intent to Remediate (NIR) was provided to the City of Bradford and Foster Township. Both the City and Township requested to be involved in the development of the remediation and reuse plans for the Site, as demonstrated by the returned notification signed by representatives of the City and Township. Copies of the signed notifications are provided in Appendix AL.

The public involvement plan for the City of Bradford and Foster Township with regard to documents is that they be provided a copy of such documents. Compliance with this plan is shown by the inclusion of both parties in the cc list in the appropriate cover letters.

In accordance with §250.5, the public notice regarding the NIR was published in The Bradford Era on May 10, 2004. A copy of the notarized notice is provided in Appendix AL.

No comments on the draft SCR, HHRA, or SERA submitted in July 2005 have been received from the public by PADEP, Chemtura, ARG, or CRA.

Public notice regarding the submission of the SCR, HHRA, and SERA in July 2007 was published in the Bradford ERA on July 9, 2007. A copy of the notarized notice will be provided.

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