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Supply and Services
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Phase 1 Site Assessment

Muggah Creek Watershed,
Sydney, Nova Scotia

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Prepared by:

CBCL Limited

50 Dorchester Street, PO Box 567
Sydney, Nova Scotia



CBCL LIMITED

Consulting Engineers

Conestoga-Rovers
& Associates

651 Colby Drive
Waterloo, Ontario N2V 1C2



Contents

Executive Summary

1	Study Purpose and Methodology	1
1.1	History of Development.....	1
1.2	Environmental Consequences.....	1
1.3	The Process of Remediation	3
1.4	The Joint Action Group Mandate and Direction.....	4
1.5	Objective and Scope	6
1.5.1	Muggah Creek Watershed	7
1.5.2	Investigation Area.....	8
1.5.3	Site Area	8
1.6	Information Sources.....	8
1.6.1	Base Map	10
1.6.2	Report Organization.....	10
2	Information Assessment	12
2.1	Environmental Setting	12
2.1.1	Topography.....	12
2.1.2	Bedrock and Overburden.....	12
2.1.2.1	Muggah Creek Watershed	14
2.1.3	Hydrology	16
2.1.3.1	Coke Ovens Brook Watershed	17
2.1.3.1.1	Whitney Pier Brook	17
2.1.3.1.2	Radar Brook.....	17
2.1.3.1.3	Frederick Street Brook.....	17
2.1.3.1.4	DOMTAR Brook	18
2.1.3.1.5	Incinerator Marsh.....	18
2.1.3.1.6	Cossitt Lake	18
2.1.3.1.7	Cagney Brook	18
2.1.3.1.8	Coke Ovens Brook.....	19
2.1.3.2	Wash Brook Watershed.....	19
2.1.3.2.1	Mud Lake.....	20
2.1.3.2.2	Gilhomes Lake	20
2.1.3.2.3	Wash Brook	20
2.1.3.3	Muggah Creek (Tar Ponds)	20
2.1.4	Hydrogeology	20
2.1.4.1	Muggah Creek Watershed	21
2.1.5	Climatology	24
2.1.6	Air Quality	27
2.1.7	Terrestrial Habitats	29
2.1.8	Aquatic Habitats	29

2.1.9	Sensitive Areas	30
2.2	Land Use	30
2.2.1	History of Industrial Land Use	31
2.2.2	Ownership.....	34
2.3	Site Area Facilities and Operations.....	36
2.3.1	Above Ground Facilities	36
2.3.1.1	Coke Ovens Site	36
2.3.1.1.1	Coal Stocking Area (22)	36
2.3.1.1.2	Coal Crushing and Blending.....	36
2.3.1.1.3	Coke Batteries.....	37
2.3.1.1.4	By-Products.....	37
2.3.1.1.5	DOMTAR Plant.....	38
2.3.1.1.6	Benzol Plant and Storage Tanks	38
2.3.1.1.7	Miscellaneous Structures	39
2.3.2	Below Ground Structures.....	39
2.3.3	Storage	40
2.3.3.1	Coke Storage Area.....	40
2.3.3.2	Mullins Bank	40
2.3.3.3	Coal Storage Runway	40
2.3.4	Services.....	40
2.3.5	Wells.....	40
2.3.6	Waste Disposal and Known Spill Sites – Site Area.....	44
2.3.6.1	Coke Ovens Site	44
2.3.6.1.1	Surface Water.....	47
2.3.6.2	DOMTAR.....	49
2.3.7	Waste Disposal and Known Spill Sites – Investigation Area	50
2.3.7.1	SYSCO	50
2.3.7.1.1	Surface Water.....	50
2.3.7.1.2	Infilling	51
2.3.7.2	Muggah Creek Tar Ponds.....	52
2.3.7.3	Railyards.....	54
2.3.7.4	Marsh Dump and Municipal Landfill.....	56
2.3.7.5	Additional Disposal Sites	58
2.3.8	Physical Hazards.....	58
2.3.9	Security	63
2.4	Remedial Investigations and Activities	63
2.4.1	Remedial Investigations.....	63
2.4.1.1	Background Studies.....	64
2.4.1.2	Sydney Tar Ponds Investigations	66
2.4.1.3	Muggah Creek Containment Project	67
2.4.1.4	JAG Investigations	68
2.4.1.5	Investigation Area Environmental Studies.....	71
2.4.2	Physical Remediation Activities	72

	2.4.2.1	Tar Ponds.....	72
	2.4.2.2	Coke Ovens and DOMTAR	75
	2.4.2.3	SYSCO	77
	2.4.2.4	Coke Ovens Demolition Work	77
	2.4.2.5	Muggah Creek Collector Sewer	78
3		Nature and Extent of Contaminants	79
3.1		Nature of Contaminants	79
3.1.1		Chemical Family Profiles	79
3.1.1.1		Polycyclic Aromatic Hydrocarbons (PAHs)	80
	3.1.1.1.1	Chemical Identity.....	80
	3.1.1.1.2	Ambient Concentrations	80
	3.1.1.1.3	Environment Fate.....	81
	3.1.1.1.4	Toxicity.....	81
3.1.1.2		Volatile Organic Compounds	82
	3.1.1.2.1	Chemical Identity.....	82
	3.1.1.2.2	Ambient Concentrations	83
	3.1.1.2.3	Environment Fate.....	83
	3.1.1.2.4	Toxicity	84
3.1.1.3		Heterocyclic Compounds	84
	3.1.1.3.1	Chemical Identity.....	84
	3.1.1.3.2	Ambient Concentrations	84
	3.1.1.3.3	Environment Fate.....	85
	3.1.1.3.4	Toxicity	85
3.1.1.4		Polychlorinated Biphenyls (PCBs).....	85
	3.1.1.4.1	Ambient Concentrations	85
	3.1.1.4.2	Environment Fate.....	86
	3.1.1.4.3	Toxicity	86
3.1.1.5		Metals	87
	3.1.1.5.1	Chemical Identity.....	87
	3.1.1.5.2	Ambient Concentration.....	87
	3.1.1.5.3	Environment Fate.....	88
	3.1.1.5.4	Toxicity	88
3.1.1.6		Radionuclides	89
3.2		Sources and Contaminated Areas	89
3.3		Pathways of Contaminated Migration	93
3.4		Particulate Deposition.....	101
3.4.1		Particulate Emissions Estimates	102
3.4.2		Dispersion Model Inputs.....	103
	3.4.2.1	Meteorological Data	103
	3.4.2.2	Complex Terrain Data and Receptor Grid.....	103
	3.4.2.3	Emission Source Parameters for SYSCO Steel and Coke Facility.....	104
	3.4.2.4	Emission Source Parameters Coke Facility	

	PAH Emissions.....	105
3.4.3	Dispersion Modelling Results.....	106
3.4.3.1	Contaminant Concentrations in Particulate	107
3.4.4	Summary	108
3.5	Potential Exposure Locations	110
3.6	Inputs and Outputs	110
3.7	Summary – Conceptual model of Contamination and Exposure	115
3.7.1	Widely Dispersed Sources – Solid and Liquid Coking Wastes	115
3.7.2	Acid Generating Source Materials.....	117
3.7.3	Contaminated Source Materials at Previous Coking and Distillation Sites.....	118
3.7.4	Coal Tar in Coke Ovens Brook.....	118
3.7.5	Tar Ponds Sediments	119
3.7.6	Atmospheric Transport – Dry and Wet Fallout; Dust from Contaminant Source Materials	119
4	Recommended Interim Measures	121
4.1	Interim Measures	121
4.2	Exposed Coal Tar – Coke Oven Site	121
4.3	Former DOMTAR Storage Tank	122
4.4	Removal of Above Ground Structures and General Site Cleanup.....	122
4.5	Surface Water Drainage.....	123
4.6	Infilling of the Muggah Creek Tar Ponds	123
4.7	Dust Control Measures	123
4.8	Site Area Security	124
4.9	Separation Zones.....	125
4.10	Site Health and Safety Plan.....	127
4.11	Existing Monitoring Wells.....	128
4.12	Municipal Ash Incinerator Disposal (MAID) Site.....	128
5	Framework for Subsequent Investigations.....	129
6	Conclusions and Recommendations.....	133
6.1	Conclusions.....	133
6.2	Recommendations.....	134

Appendices

A	Glossary
B	References
C	List of Interviews
D	ACCESS Database Summary

Executive Summary

The Phase 1 Site Assessment of the Muggah Creek Watershed was commissioned by Environment Canada and the Environmental Data Gathering and Remedial Options Working Group (EDGAR) of the Joint Action Group on the Environmental Clean-Up of the Muggah Creek Watershed (JAG), as the first step in the environmental clean-up of industrial lands in this area. The Phase 1 Site Assessment was completed by CBCL Limited and Conestoga-Rovers & Associates Limited. The Study provides a summary and understanding of the environmental conditions which may or do exist within the Muggah Creek Watershed. Information compiled during the Phase I Assessment provides a better understanding of the environmental issues associated with the design and implementation of future investigations to effectively delineating the nature and extent of contamination and to provide background for remedial activities to deal with the environmental issues.

The objectives of the Muggah Creek Watershed Phase 1 Site Assessment were:

- To identify potential surface and subsurface contaminants and environmental concerns and conditions at and adjacent to the Site Area;
- To develop a preliminary site conceptual model for the hydrogeological conditions at the Coke Ovens Site;
- To undertake preliminary particulate deposition modelling;
- To evaluate and recommend any appropriate interim measures which could be undertaken in the short term as the next phases of investigative work are being conducted; and
- To establish a framework for the subsequent investigations at the Site Area.

The Muggah Creek Watershed boundary and two sub-areas were defined. Definition of the watershed and the two areas were developed in consultation with members of JAG and the government partners. The definitions were incorporated into the Memorandum of Understanding (MOU) between JAG and the Federal and Provincial Governments. The definitions are:

- **Muggah Creek Watershed** includes all lands that, from a surface water perspective, drain into the current Muggah Creek estuary.
- **Investigation Area** is defined as “areas within the Muggah Creek Watershed that have, or had, heavy industrial or like uses and are contiguous (in close proximity) to the Site Area”. Included within the Investigation Area are properties such as the SYSCO Steel Plant, the railyards, the Imperial Oil Tank Farm and Distribution Centre; infilled areas within the Muggah Creek Estuary and the former Marsh Dump which incorporates the current municipal landfill and the Incinerator Ash Landfill.
- **Site Area** is defined as “the Tar Ponds, the Coke Ovens Site, and Coke Oven Brook Connection”. The Coke Ovens Site includes the former Coke Ovens Complex, DOMTAR, and Mullins Bank. The Coke Oven Brook Connection is defined as “that portion of the Coke Oven Brook to top of bank between the Coke Ovens Site and Tar Ponds including the Cooling Pond”.

All existing current and historical information was collected, documented and reviewed. The collected information forms the foundation for the Phase I Assessment, as no intrusive work was conducted as part of this study.

Information sources examined included:

- Published and unpublished scientific, demographic and technical information
- Unpublished reports from consultants, site operators, and the municipality
- Municipal Planning Strategies and development policies
- Community based health surveys
- Corporate operational information, including correspondence
- Aerial and ground photography, including historic material
- Topographic maps, site plans, engineering plans, municipal plans, etc.
- Municipal and environmental permits, approvals and directions.

The current and historical information accessed were referenced, screened for relevance and where found to have relevance, assessed and the information incorporated in the Phase I Site Assessment. The information sources are summarized and cited in a searchable electronic information database (MS ACCESS) of which a hard copy is provided in Appendix D of the Phase I ESA.

To supplement existing information, non-intrusive field investigations were conducted in areas within the Watershed identified as significant historic, existing or potential sources of contamination or physical hazards. As well, modelling of particulate deposition was completed to identify the potential zone of impact from airborne particulate emitted from both the Sydney Steel Plant (SYSCO) and the former Coke facility during operations.

Data Summary

The environmental setting of the Muggah Creek Watershed is described. The items that describe the environmental setting are topography, geology, hydrogeology, hydrology, meteorological data, air quality, and natural terrestrial and aquatic habitats (flora and fauna).

The industrial land use in the Investigation Area (including Site Area) is summarized as well the current ownership of the commercial/industrial properties on and immediately adjoining the Investigation Area. The location of potable water wells and the locations and details of monitoring wells installed for previous investigations throughout the Investigation Area are also summarized.

A summary is provided of all the environmental investigations and studies performed and reported related to the Investigation Area over the last 20 years. These include background studies in the early 1980s focussed on the Muggah Creek Watershed, including sediment studies in the Tar Ponds and the effects on the fishery in the South Arm of Sydney Harbour. Between 1984 and 1994 a large number of investigations were performed related to the Tar Ponds Clean-Up Project. These delineated and characterized the contaminated sediments in the estuary but also included background studies such as a hydrogeologic assessment which included the area of the Study Site and stream monitoring studies of Coke Ovens Brook and Wash Brook. Other studies were related to the selection and design of remedial works for the Tar Ponds. A number of studies have performed from the mid-1990s to the current time. These included studies commissioned by JAG, the material sampling program of the

remaining structures and materials on the Coke Oven site and the landfill leachate study; environmental site assessments performed at the railyards; and the recent investigation and risk assessment performed related to the Lower Frederick Street area.

The remediation activities performed to date with respect to the Site Area are summarized in the report. In late March or early April of 1988, demolition of the Coke Ovens Plant and related facilities was begun. Under this program, all above ground structures and piping were to be removed and foundations, underground piping and sewers would remain. The work program did not include remediation of contaminated soils, however any visible surface spills were to be removed. The program was not completed with the water standpipe, two exhaust stacks, the by-products building, the coal pocket, the sulphur building, and other small structures remaining when work stopped. In 1998, JAG commissioned Philips Environmental to begin demolition and removal of some of the remaining structures and materials remaining at the Coke Ovens Site. This work consisted of demolition of several structures, removal of the salvageable scrap recycling and removal and disposal of materials with potential environmental effects. In 1998, JAG also commissioned the design and construction of a collector sewer to pick up and divert the sanitary sewers discharging to Muggah Creek to the South Arm of Sydney Harbour.

Spills, materials handling practices and waste disposal methods have resulted in widespread contamination over the Site Area, which includes the former Coke Ovens and DOMTAR complexes. The contamination in the Muggah Creek Estuary (Tar Ponds) is well documented. Other sources of contamination identified in the information reviewed include:

- Hydrocarbon contamination of soil and groundwater at the railyard
- Former and current waste disposal practices in the area of the Municipal Ash Incinerator Disposal (MAID) Site
- Both municipal and industrial sewer outfalls
- Material storage areas such as Mullins Bank
- Air emissions from the stacks at both the Coke Ovens and SYSCO complexes

Contamination sources identified in previous studies are summarized, including location and volumes. The quality of the data reviewed ranges from well documented scientific data, to general summaries of data sets to rhetorical accounts.

Contaminant Sources, Exposure Pathways and Receptors

A summary of the chemical groups and chemical constituents that are present or suspected to be present at the Site Area and that are important from an environmental and health perspective are identified. Based on the documentation available, five chemical groups reflect the main contamination present at the Site Area. The general characteristics or profiles of each of these chemical groups are presented. The five chemical groups are:

- Polycyclic aromatic hydrocarbons (PAHs);
- Volatile organic compounds (VOCs);
- Heterocyclic compounds (HC);

- Polychlorinated biphenyls (PCBs); and
- Metals.

Sources, Receptors and Exposure Pathways

The contaminants on the Study Site were grouped into 15 sources. These materials, and the areas in which they occur, are termed “sources” because they may be highly concentrated and therefore have potential to persist at their current location for an extended period. Consequently, they have the potential to act as “sources” for ongoing release of contaminants to potential migration pathways such as: groundwater, surface water, soil vapour, airborne vapours and airborne dust migration. The source groupings represent:

1. Coking distillate wastes and coal tars buried throughout the Coke Ovens site
2. Used motor oil used for road dust control on the Coke Ovens site
3. Miscellaneous drain and pipe leaks throughout the Coke Ovens process area
4. Dry and wet fallout from steel and coke manufacturing
5. Acid-generating sulphide minerals associated with coal at the Coal Pile Runway
6. Acid-generating sulphide minerals associated with coal at Mullins Coal Bank
7. Benzol in the vicinity of the Benzol Plant
8. Slag, municipal wastes and ash - located throughout The Marsh Dump
9. Organic contamination around the most recent Coke Batteries
10. Coal tar in Tar Ponds sediment
11. PCB in Tar Ponds sediments
12. Coal tar in Fill throughout the Coke Ovens site
13. Coal Tar deposits on the Domtar site –
14. Coal Tar observed along much of the length of Coke Ovens Brook
15. Coking distillate wastes and coal tars in the vicinity of the *older* Coke Batteries

In general, source composition and form are known with a moderate to high degree of certainty, due to previous investigations, and also due to background knowledge of the general composition of certain contaminants that are common in the Site Area (e.g., coal tar). In most cases the extent of the source material is known with less certainty since much of the investigative work conducted to date has been aimed at identifying the occurrence, not the extent of highly contaminated areas. Substantial source materials may occur in the Site Area that have not been encountered in the assessment work conducted to date.

The contaminant sources have been linked with potential contaminant migration pathways and potential receptors. The degree of certainty associated with each of these components (source, pathway, receptor) was used to develop a framework for subsequent investigations.

Exposure pathways which denote a route whereby contamination may migrate away from contaminated source material were identified. The pathways identified may operate in sequence, or in relatively complicated linkages. The pathways, and the contaminant phases that may migrate through them, include:

- Flow of organic liquid contamination, such as tar, oil or benzol;
- Surface water transport of contaminated particles or dissolved contamination;
- Groundwater transport of dissolved contamination and, to a lesser degree, contaminated particles;
- Subsurface transport of gaseous phase contamination in soil vapour; and
- Airborne transport of contaminated dust or gaseous phase contamination.

Human and ecological groups that may potentially be exposed to contamination either at the source or by migration along a pathway have been identified.

The potential contaminants that enter or leave the Site Area are identified as Inputs and Outputs. An Input represents groundwater, surface water, or air that moves onto the Site Area and that contains a potential contaminant. An example of an Input are the various brooks that flow onto the Coke Ovens Site and join with Coke Ovens Brook. An Output is groundwater, surface water or air that flows out of the Site Area and that may contain a contaminant. The Inputs and Outputs represent potential contaminant sources that either impact the Site Area or the areas adjacent to the Site Area. The inputs may not be significant in nature, but indicate areas that need to be characterized and assessed during Phases 2 and 3.

Air Particulate Modelling

Modelling of particulate deposition was completed to identify the potential zone of impact of air borne particulate emitted from SYSCO and the former Coke Ovens facility. The screening particulate deposition modelling also provided an estimate of the impact of air contaminants associated with the particulate, including metals and PAHs. The time span over which the *worst case* deposition is expected to have occurred from the 1950s through to 1975. During this time period the two facilities were known to be operating at their maximum capacities. The annual deposition modelling presented represents the worst case time period.

The screening deposition results are estimates of the worst case as detailed source specific emission rates were not readily available. The deposition modelling was also simplified by grouping major sources together, neglecting building wake effects and using representative meteorological data.

The deposition modelling for total particulate emissions from both facilities resulted in a maximum deposition rate of 386.84 g/m²/yr. PAH deposition associated with emissions from the Coke Ovens facility was estimated based on particles less than 7 µm. The maximum deposition rate for the 7 µm particle sizes was 10.11 g/m²/yr. The corresponding deposition zones are presented in the report.

Recommended Interim Measures

Interim measures are not considered to be permanent solutions to contaminated areas, but have value as temporary measures that improve safety and reduce the potential for human contact. At the time of the writing of this report, there is no documented evidence of situations within the scope of this Study

that represent a short term risk to human health. In this context, these interim measures are recommended as actions that CAN be taken as opposed to actions that MUST be taken immediately. Some of these recommendations have been commenced in projects commissioned by JAG or are in the planning stages.

An summary of the recommended interim measures are as follows:

- All areas of exposed coal tar should be identified and an interim cover installed followed by regular inspections.
- Testing should be conducted on the former DOMTAR Storage Tank to characterize the contents, to allow proper disposal followed by demolition of the tank.
- Complete removal of above ground structures and general site clean-up after development of a detailed work plan including human health and safety measures and related environmental considerations.
- Develop and implement a surface drainage plan for the Coke Ovens Site to route surface water away from areas of heavy contamination and to prevent ponding of water.
- Prevent further infilling of the Muggah Creek Estuary.
- Re-vegetate existing bare ground areas and implement dust control programs during all remedial operations including construction or maintenance of roads.
- Conduct a detailed inspection of the perimeter fencing and perform any required upgrades. Install fencing at the top of bank on all areas of the Tar Ponds and the Coke Ovens Brook where there is access by the general public. Extend existing fencing to prevent access to the area by the Victoria Road Overpass. Conduct regular inspections and maintenance of the fencing.
- Initiate the process to develop and evaluate criteria and information necessary to define and establish appropriate separation zones to distance residential land use from anticipated investigation and remediation activities..
- Existing monitoring wells should be located and inspected to assess the condition of each well. Serviceable wells should be repaired and protected with lockable, protective steel casings grouted in place. Wells that are no longer serviceable should be properly decommissioned.
- Surface drainage of the MAID Landfill should be mapped and measures installed to prevent discharge of contaminated water to surface water courses. Monitoring of the groundwater at the site should be continued and additional investigation performed to better characterize the geology and hydrogeology at the site.

Framework for Subsequent Investigations

An overall framework for future investigations in the Site Area is provided. The framework represents an outline of a field program intended to increase the degree of certainty in key contaminant and exposure issues including hydraulic properties of the main hydrogeologic units, groundwater and surface water flow systems, extent of contaminated materials. Where the potential for human or ecological receptors to be exposed to contamination was evaluated as high, the source/pathway was included in the framework for additional investigation.

Much of the data currently available for the Site Area was collected during the 1980s and early 1990 and may not be representative of current conditions. Some testing will be required to verify the quality of existing data or place it in a temporal context. The data is also reported in a diverse number of reports and formats and is required to be compiled into one database to facilitate access and use in future work. It is recommended that a comprehensive technical and information databases should be developed using GIS and maintained for the Site Area to ensure efficient and comprehensive usage of the technical data.

The Phase I ESA also recommends that a long-term management approach for the technical investigations/remediation for the Site Area be developed including:

- A long-term investigative and remedial strategy
- Development of an long-term education process related to the project
- Long-term technical support to JAG to provide peer review, guidance and strategic advice

Contents

Executive Summary

1	Study Purpose and Methodology.....	1
1.1	History of Development.....	1
1.2	Environmental Consequences.....	1
1.3	The Process of Remediation.....	3
1.4	The Joint Action Group Mandate and Direction.....	4
1.5	Objective and Scope.....	6
1.5.1	Muggah Creek Watershed.....	7
1.5.2	Investigation Area.....	8
1.5.3	Site Area.....	8
1.6	Information Sources.....	8
1.6.1	Base Map.....	10
1.6.2	Report Organization.....	10
2	Information Assessment.....	12
2.1	Environmental Setting.....	12
2.1.1	Topography.....	12
2.1.2	Bedrock and Overburden.....	12
2.1.2.1	Muggah Creek Watershed.....	14
2.1.3	Hydrology.....	16
2.1.3.1	Coke Ovens Brook Watershed.....	17
2.1.3.1.1	Whitney Pier Brook.....	17
2.1.3.1.2	Radar Brook.....	17
2.1.3.1.3	Frederick Street Brook.....	17
2.1.3.1.4	DOMTAR Brook.....	18
2.1.3.1.5	Incinerator Marsh.....	18
2.1.3.1.6	Cossitt Lake.....	18
2.1.3.1.7	Cagney Brook.....	18
2.1.3.1.8	Coke Ovens Brook.....	19
2.1.3.2	Wash Brook Watershed.....	19
2.1.3.2.1	Mud Lake.....	20
2.1.3.2.2	Gilhomes Lake.....	20
2.1.3.2.3	Wash Brook.....	20
2.1.3.3	Muggah Creek (Tar Ponds).....	20
2.1.4	Hydrogeology.....	20
2.1.4.1	Muggah Creek Watershed.....	21
2.1.5	Climatology.....	24
2.1.6	Air Quality.....	27
2.1.7	Terrestrial Habitats.....	29
2.1.8	Aquatic Habitats.....	29

2.1.9	Sensitive Areas.....	30
2.2	Land Use.....	30
2.2.1	History of Industrial Land Use	31
2.2.2	Ownership.....	34
2.3	Site Area Facilities and Operations	36
2.3.1	Above Ground Facilities	36
2.3.1.1	Coke Ovens Site.....	36
2.3.1.1.1	Coal Stocking Area (22).....	36
2.3.1.1.2	Coal Crushing and Blending.....	36
2.3.1.1.3	Coke Batteries.....	37
2.3.1.1.4	By-Products	37
2.3.1.1.5	DOMTAR Plant	38
2.3.1.1.6	Benzol Plant and Storage Tanks.....	38
2.3.1.1.7	Miscellaneous Structures.....	39
2.3.2	Below Ground Structures	39
2.3.3	Storage	40
2.3.3.1	Coke Storage Area.....	40
2.3.3.2	Mullins Bank.....	40
2.3.3.3	Coal Storage Runway	40
2.3.4	Services.....	40
2.3.5	Wells	40
2.3.6	Waste Disposal and Known Spill Sites – Site Area.....	44
2.3.6.1	Coke Ovens Site.....	44
2.3.6.1.1	Surface Water.....	47
2.3.6.2	DOMTAR.....	49
2.3.7	Waste Disposal and Known Spill Sites – Investigation Area.....	50
2.3.7.1	SYSCO.....	50
2.3.7.1.1	Surface Water.....	50
2.3.7.1.2	Infilling.....	51
2.3.7.2	Muggah Creek Tar Ponds	52
2.3.7.3	Railyards.....	54
2.3.7.4	Marsh Dump and Municipal Landfill	56
2.3.7.5	Additional Disposal Sites	58
2.3.8	Physical Hazards	58
2.3.9	Security	63
2.4	Remedial Investigations and Activities.....	63
2.4.1	Remedial Investigations	63
2.4.1.1	Background Studies.....	64
2.4.1.2	Sydney Tar Ponds Investigations	66
2.4.1.3	Muggah Creek Containment Project.....	67
2.4.1.4	JAG Investigations	68
2.4.1.5	Investigation Area Environmental Studies.....	71
2.4.2	Physical Remediation Activities	72

	2.4.2.1	Tar Ponds.....	72
	2.4.2.2	Coke Ovens and DOMTAR.....	75
	2.4.2.3	SYSCO.....	77
	2.4.2.4	Coke Ovens Demolition Work.....	77
	2.4.2.5	Muggah Creek Collector Sewer.....	78
3		Nature and Extent of Contaminants	79
3.1		Nature of Contaminants	79
3.1.1		Chemical Family Profiles	79
3.1.1.1		Polycyclic Aromatic Hydrocarbons (PAHs).....	80
	3.1.1.1.1	Chemical Identity	80
	3.1.1.1.2	Ambient Concentrations	80
	3.1.1.1.3	Environment Fate	81
	3.1.1.1.4	Toxicity	81
3.1.1.2		Volatile Organic Compounds	82
	3.1.1.2.1	Chemical Identity	82
	3.1.1.2.2	Ambient Concentrations	83
	3.1.1.2.3	Environment Fate	83
	3.1.1.2.4	Toxicity	84
3.1.1.3		Heterocyclic Compounds	84
	3.1.1.3.1	Chemical Identity	84
	3.1.1.3.2	Ambient Concentrations	84
	3.1.1.3.3	Environment Fate	85
	3.1.1.3.4	Toxicity	85
3.1.1.4		Polychlorinated Biphenyls (PCBs).....	85
	3.1.1.4.1	Ambient Concentrations	85
	3.1.1.4.2	Environment Fate	86
	3.1.1.4.3	Toxicity	86
3.1.1.5		Metals.....	87
	3.1.1.5.1	Chemical Identity	87
	3.1.1.5.2	Ambient Concentration	87
	3.1.1.5.3	Environment Fate	88
	3.1.1.5.4	Toxicity	88
3.1.1.6		Radionuclides.....	89
3.2		Sources and Contaminated Areas.....	89
3.3		Pathways of Contaminated Migration.....	93
3.4		Particulate Deposition.....	101
3.4.1		Particulate Emissions Estimates.....	102
3.4.2		Dispersion Model Inputs	103
	3.4.2.1	Meteorological Data	103
	3.4.2.2	Complex Terrain Data and Receptor Grid	103
	3.4.2.3	Emission Source Parameters for SYSCO Steel and Coke Facility.....	104
	3.4.2.4	Emission Source Parameters Coke Facility	

	PAH Emissions	105
3.4.3	Dispersion Modelling Results.....	106
3.4.3.1	Contaminant Concentrations in Particulate	107
3.4.4	Summary	108
3.5	Potential Exposure Locations	110
3.6	Inputs and Outputs.....	110
3.7	Summary – Conceptual model of Contamination and Exposure	115
3.7.1	Widely Dispersed Sources – Solid and Liquid Coking Wastes.....	115
3.7.2	Acid Generating Source Materials	117
3.7.3	Contaminated Source Materials at Previous Coking and Distillation Sites.....	118
3.7.4	Coal Tar in Coke Ovens Brook.....	118
3.7.5	Tar Ponds Sediments	119
3.7.6	Atmospheric Transport – Dry and Wet Fallout; Dust from Contaminant Source Materials	119
4	Recommended Interim Measures	121
4.1	Interim Measures.....	121
4.2	Exposed Coal Tar – Coke Oven Site	121
4.3	Former DOMTAR Storage Tank	122
4.4	Removal of Above Ground Structures and General Site Cleanup	122
4.5	Surface Water Drainage	123
4.6	Infilling of the Muggah Creek Tar Ponds.....	123
4.7	Dust Control Measures.....	123
4.8	Site Area Security.....	124
4.9	Separation Zones	125
4.10	Site Health and Safety Plan	127
4.11	Existing Monitoring Wells	128
4.12	Municipal Ash Incinerator Disposal (MAID) Site	128
5	Framework for Subsequent Investigations.....	129
6	Conclusions and Recommendations.....	133
6.1	Conclusions	133
6.2	Recommendations	134

Appendices

A	Glossary
B	References
C	List of Interviews
D	ACCESS Database Summary

CHAPTER 1 STUDY PURPOSE AND METHODOLOGY

1.1 History of Development

The post-European contact history of Cape Breton Island is one of the oldest in Canada. It is expected that the Island was visited by European fishermen long before the accepted voyages of European explorers. The first colonization of Cape Breton began in the early 1700's with both French and Portuguese settlements. After 1763, when the Island was ceded to the British, Cape Breton was established as a separate colony with its own Lieutenant-Governor and a capital at Sydney (then named Spanish Bay). In the late 18th and early 19th century, there was a significant influx of United Empire Loyalist and Scottish settlers.

According to historic records, the earliest coal mining in the Sydney area was undertaken by the French in the early 1700's. Mining did not become a significant economic venture until 1827 when a British firm, the General Mining Association, started to mine coal near Sydney. The advent of the industrial revolution in Europe fuelled the demand for coal, and by the 1850's new mines had opened at Glace Bay, Port Morien and Lingan, as well as in other areas in Nova Scotia, such as New Glasgow.

The coal mining industry sparked the iron making industry in Nova Scotia with the first manufacturing of steel in 1883 in Trenton, from pig iron imported from Scotland. By 1889 the beginnings of a steel production industry had taken root in Sydney. In the following year, the first of the four original blast furnaces was started (62). In 1901, the first steel was tapped from the new plant. Over the next few decades, the growth of the coal and steel industries caused a similar change in the town. Sydney mushroomed from a population of 2,500 in 1899 to a small city of 20,000 by 1913. Coal production had reached a historic peak of six million tons per year.

In these early years, steel was made using iron ore from Wabana in Newfoundland and coal and limestone from Cape Breton. The coal used in the steel making process was heated at very high temperatures in the absence of oxygen, to produce a purified carbon material known as coke. This activity took place in an area adjacent to the Sydney steel mills that become known locally as the Coke Ovens Site. Also associated with the Coke Ovens Site was a tar recovery plant that stored and marketed coal tar produced by the coking operations.

In the first half of the century, the Steel Plant and the city of Sydney flourished. Beginning in the 1920's, alternative sources of energy increasingly eroded export markets for coal. Over the years, competing energy markets continued to negatively affect the coal industry in Sydney to the point that by the 1950's, government financial intervention was necessary. Since that time, much of Industrial Cape Breton's coal and steel industries have passed into government ownership.

1.2 Environmental Consequences

Located in the heart of the community, the landscape of the Muggah Creek watershed holds a steel making operation, the remains of a coking facility, a derelict rail yard, and numerous active and abandoned waste material dumps. In addition to loss of the jobs created by the coal industry, the legacy of coal now includes over 550,000 m³ of contaminated sediments, and undetermined volumes of

contaminated soils, surface waters and groundwaters. The Muggah Creek estuary, which has become more commonly known as the Sydney Tar Ponds, is now recognized as the most contaminated site in Canada. (Memorandum of Understanding for Environmental Clean-up of the Muggah Creek Watershed, 1998).

Many aspects of the early coal and steel industries used raw materials or produced wastes that contained contaminants. During these early times, little was known of the negative effects of industrial pollution, other than that it was a necessary by-product of prosperity. Coal mining operations were known to have certain physical as well as health hazards, either from explosions caused by methane gas, or lung disease caused by the inhalation of coal dust. Soot was known to cause health issues for chimney sweeps. Even less was known of the potential consequences of chemical contaminants associated with industrial processes.

One of the more significantly polluting operations of the Sydney coal and steel industry was coke production. Byproducts of this process included coal tar, ammonia, sulphur, light oils (benzene, xylene, toluene), and polycyclic aromatic hydrocarbons (PAHs). In the early years of coke production, the contribution of contaminants to the environment was reduced through the internal recycling and recovery of by-products. As the demand for by-products diminished, recycling and recovery operations were no longer economically viable. Materials accumulated as process wastes were dumped into surface waters or deposited straight onto the soil. As a result of these activities, contaminants that were entrained in raw materials and process wastes, are now also present in the soils and groundwater of the Coke Ovens Site, and in the waters and sediments of Coke Oven Brook, Muggah Creek and Sydney Harbour.

Another potential source of environmental degradation was the by-products of the steel making process, including the relatively inert material, slag. Slag was produced in great quantities during the decades of steel production, and often was deposited as infill material in the Muggah Creek estuary and Sydney Harbour, greatly changing the natural shoreline and physical appearance of the estuary.

Contaminants were also entrained in the air emissions from the numerous stacks associated with both coke and steel operations. In the early days of coal and steel, stack emissions were untreated. In addition to airborne dispersion, contaminants may have been deposited as particulate materials in downwind areas of the town and its surrounding environment.

Other sources of contaminants included flue dust from the blast furnaces and ovens, coal tars, waste waters, sulphur (from the sulphuric acid plant), coke and the coal itself.

Steel and coke production facilities were not the only industries operating in the area. Also on this site was a coal tar plant, a cement company, an asphalt paving company, a fuel gas and oil company, metal processors, and a brick company. Any or all of these operations may have contributed to the contaminants in the area soils, surface and groundwater, and air.

After nearly 100 years of coal and steel production, environmental contamination in and around the Sydney Tar Ponds and the Coke Ovens Site is extensive and complex. The Tar Ponds themselves are reported to contain approximately 550,000 m³ of sediments contaminated with PAHs, PCBs, organic compounds and heavy metals. The Coke Ovens Site is considered to be the primary source of PAH

contamination, however it is anticipated that additional on and off-site sources have also contributed to the contamination.

Today the industrial lands of Sydney lie largely derelict. The steel plant is in a process of revitalization and renewal that has seen the demolition and decommissioning of outdated facilities, and the recovery of metals from demolition materials and slag deposits. Much of the surface facilities associated with the coke ovens production area have been decommissioned, but it is questionable as to how much of the subsurface infrastructure remains.

1.3 The Process of Remediation

For over 40 years, the regulatory agencies, Environment Canada and Nova Scotia Department of Environment have initiated many investigations and monitoring programs related to the effects of industrial activities in the Investigation Area. The reports and records form an important group of data for the past, present and future work at the site. In the last decade significant resources have been expended towards cleaning-up portions of the contaminated areas of the former industrial lands. A \$50 million project to excavate and incinerate sediments in the Tar Ponds has been halted, and the incinerator moth-balled. Plans to construct on site containment measures for the contaminants in the Tar Ponds have met serious opposition. In 1996, a community based approach to the identification and evaluation of remedial solutions was initiated. The Joint Action Group (JAG) on the Environmental Clean-Up of the Muggah Creek Watershed was constituted to represent community interests in partnership with three levels of government (Figure 1-1).

Figure 1.1.



The Phase 1 Site Assessment of the Muggah Creek Watershed was commissioned by Environment Canada and the Environmental Data Gathering and Remedial Options Working Group (EDGAR) of the JAG, as the first step in the environmental clean-up of industrial lands in this area. The Phase I Environmental Site Assessment (ESA) is an integral component for understanding the environmental conditions and contamination, which exist on these properties. Information obtained through the Phase I ESA will contribute to the development of a site conceptual model, and to the design and implementation of strategic field sampling programs that will minimize risks to worker and environmental health and safety, while effectively delineating the nature and extent of contamination.

1.4 The Joint Action Group Mandate and Direction

Community refers to all residents and sectors, institutions, businesses, organizations, stakeholders and their governing structures within the County of Cape Breton. - JAG

The Joint Action Group on Environmental Clean-Up of the Muggah Creek Watershed (JAG) was conceived primarily to define and manage a workable solution to the environmental contamination contained within the area known as the Sydney Tar Ponds. JAG has since evolved and broadened its scope to include the former Coke Ovens Site and downstream impacts of the existing Municipal Landfill (Joint Action Group; 1998). The JAG is comprised of local residents, business people, representatives of the three levels of government, First Nations representatives, and youth.

The JAG mandate is to educate, involve and empower the community, through partnerships, to determine and implement acceptable solutions for Canada's worst hazardous waste site and to assess and address the impact on human health (JAG, 1996).

The JAG is supported by a Secretariat, managed by a Steering Committee and reports overall to a Roundtable, which is made up of approximately sixty members representing the community. The JAG organizational structure also includes the following five working groups (JAG, 1998):

- ***Environmental Data Gathering and Remedial Options Working Group (EDGAR)***

Mandated to collect and interpret enough information about the site(s) to recommend a remedial action plan to the Joint Action Group for the clean-up of hazardous waste sites contained within the Muggah Creek Watershed.

- ***Public Education and Participation Working Group (PEP)***

Mandated to develop and oversee the implementation of effective communication and education strategies, methods, tools and vehicles that are tailor-made to fit the Cape Breton community and that will enable the JAG to fulfill its vision.

- ***Health Studies Working Group (HSWG)***

Mandated to study the impact of the Muggah Creek Watershed on the human health of the community and to enhance its health by involving, educating, and empowering the community through partnerships.

- ***Site Security Working Group***

Mandated to give the highest priority to the health and safety of site workers and residents in our community while working in an open and all-inclusive, community-driven process which can provide for the clean-up of Muggah Creek Watershed in an environmentally-safe and cost effective manner.

- ***Governance Working Group***

Mandated to develop the guidelines for operation for the JAG and its Working Groups.

On September 19, 1998, a Memorandum of Understanding (MOU) was signed by the Government of Canada, the Government of the Province of Nova Scotia, the Cape Breton Regional Municipality and the Joint Action Group for Environmental Clean-Up (JAG). The MOU sets out a framework for a community based process known as the JAG process that will express the collective will of all Parties to

seek solutions to the environmental and health risks associated with the Muggah Creek Watershed (Memorandum of Understanding, 1998).

The JAG Process is intended “to establish a governance system which encourages and facilitates participation of members of the Community and representatives of three levels of Government in all aspects of the process through assessment to final Remediation and in a step-wise manner to accomplish the following:

- Enhance the Community’s understanding of the health and environmental risks;
- Community consensus on recommendations to government on remediation projects which are, environmentally sound, socially acceptable, publicly accountable, community driven, health conscious, and economically responsible.

GOALS

“The Parties accept that Canada’s worst contaminated sites are located in the Muggah Creek Watershed and are a human health hazard and is therefore a national issue. The goals of the Parties, as cooperative participants in this innovative venture, are to strive for the achievement, within the Watershed, of:

- a) The Remediation of historical contamination;
- b) Foster a healthy community by finding workable solutions engendered primarily within the Cape Breton community; and
- c) Enhancement and preservation of ecosystems appropriate to final land use; and

MISSION STATEMENT

To educate, involve and empower the community, through partnerships, to determine and implement acceptable solutions for Canada’s worst hazardous waste site and to assess and address the impact on human health.”

To date, the JAG Working Groups have commissioned the following programs of work:

Environmental Data Gathering and Remedial Options Working Group (EDGAR)

- Landfill Leachate Monitoring Program,
- Material Sampling Program for the above ground structures on the Coke Oven Site,
- Aboveground Structure Decommissioning on the Coke Oven Site,
- Vendor Protocol Development;
- QA/QC Policy
- Interceptor Sewer Pre-Design;
- WTI Course on remedial options
- ETV Presentation on bioremediation
- Sewer interceptor project scheduled to be completed in the fall of 2000; and
- Phase 1 Site Assessment of the Muggah Creek Watershed.

Public Participation and Education Working Group (PEP)

- JAG Logo
- PEP/Site Security educational/informational video outlining the hazards on the sites
- Web Site development
- Open houses
- Newsletters
- Orientation Package, and
- Presentation Package.

Health Studies Working Group

- Development of a Public Health Assessment Model
- Garden Sampling Project
- National Mortality Data Base Study
- Nova Scotia Cancer Registry Study
- Nova Scotia Reproductive Care Program Research
- Health Outcome Data Project
- A collection of health, environmental, and occupational studies; and
- Environmental Health Experts workshop

Site Security Working Group

- Fencing installed around the perimeter of the Coke Ovens Site
- 24-hour security in place for the Coke Ovens Site
- Tar Lagoon retaining wall
- Repairs to the existing walkway, and
- North end Brook tested for contamination.

Governance Working Group

- The JAG Governance Model
- Conflict of interest Guidelines, JAG Registration, Code of Conduct
- Memorandum of Association
- Memorandum of Understanding

1.5 Objective and Scope

The primary objectives of the Muggah Creek Watershed Phase 1 ESA are:

- To identify potential surface and subsurface contaminants and environmental concerns and conditions at and adjacent to the Site Area;

- To develop a preliminary site conceptual model for the hydrogeological conditions at the Coke Ovens Site;
- To undertake preliminary particulate deposition modelling;
- To evaluate and recommend any appropriate interim measures which could be undertaken in the short term as the next phases of investigative work are being conducted; and
- To establish a framework for the subsequent investigations at the Site Area.

To accomplish these objectives, focus was placed on following five primary activities:

- Develop a concise and comprehensive description of the environmental setting for the Muggah Creek Watershed and in particular the Investigation Area;
- Document the history of the Muggah Creek Watershed and in particular the Site Area;
- Develop a concise and comprehensive description of the environmental contamination of the Muggah Creek Watershed and in particular the Site Area;
- Develop a preliminary conceptual model for the Site Area; and
- Develop recommendations and conclusions, including interim measures and a framework for future work.

To complete the five primary activities, all existing current and historical information was collected, documented and reviewed. The collected information forms the foundation for this Phase I ESA, as no intrusive work was conducted as part of this Phase I ESA. To facilitate the collection, review and documentation of the information, a clear description of the Muggah Creek Watershed, the Investigation Area and the Site Area was required. Definition of the three items was developed in consultation with JAG and the government partners. These definitions have also been incorporated into the Memorandum of Understanding (MOU) between JAG and the governments. The definitions and locations are provided in the three subsequent sections.

1.5.1 Muggah Creek Watershed

The *Muggah Creek Watershed* is defined by the MOU as “an analytical concept in keeping with the ‘top of the hill down’ approach and therefore, is not a geographical definition”. The Muggah Creek Watershed boundary is shown on Figure 1-2 and on Plan 1 in Appendix E.

In general terms, the Muggah Creek Watershed includes all lands that, from a surface water perspective, drain into the current Muggah Creek estuary (approximately 2410 hectares). The Muggah Creek Watershed boundary was defined through contour mapping and urban environment disturbances, such as redirected surface drainage via municipal stormwater collection infrastructure. Digital topographical mapping of the Muggah Creek Watershed and environs is being completed based on aerial photographs taken in May 1998. The 1998 mapping (using 1992 mapping as a base and updating to 1998 topographical contours in the Investigation Area) provides an up-to-date base plan for the Muggah Creek Watershed and allows the Muggah Creek Watershed boundaries to be more clearly defined.

1.5.2 Investigation Area

The *Investigation Area* is defined by the MOU as “areas within the Muggah Creek Watershed that have, or had, heavy industrial or like uses and are contiguous (in close proximity) to the Site Area”. Included within the Investigation Area are properties such as:

- The SYSCO Steel Plant;
- The Railyards;
- The Imperial Oil Tank Farm and Distribution Centre;
- The Marsh Dump;
- The Municipal Dump; and
- Infilled areas within the Muggah Creek Estuary.

The Investigation Area covers approximately 366.9 hectares and is shown on Figure 1-3.

1.5.3 Site Area

The *Site Area* for the Muggah Creek Watershed Phase I Environmental Site Assessment (ESA) is defined by the MOU as “the Tar Ponds, the Coke Ovens Site, and Coke Oven Brook Connection”. The Site Area encompasses the principal areas where:

- Coke was produced (Coke Ovens Site);
- Coal tar and associated by-products were refined, stored, or disposed of (DOMTAR Operations);
- Where coal was stockpiled (Mullins Coal Bank); and
- That portion of Muggah Creek that received the tar and associated contaminants from these operations.

As noted in the MOU, the Sydney Tar Ponds include that body of water "as defined by the current (1998) high water level". The Coke Ovens Site is defined as “the former Coke Ovens Complex, Domtar Operations, and Mullins Bank”. The Coke Oven Brook Connection is defined as “that portion of the Coke Oven Brook to top of bank between the Coke Ovens Site and Tar Ponds including the Cooling Pond”. The Site Area covers approximately 110.9 hectares and is shown on Figure 1.3.

1.6 Information Sources

A significant volume of information related to industrial activity within the Watershed exists at sources in Sydney, Cape Breton and throughout Nova Scotia. Little of the information has been catalogued, and not all is relevant to environmental conditions in the Watershed. To ensure a valuable and comprehensive examination of conditions in the Muggah Creek Watershed, the Team focussed on information required to define/understand:

- The environmental setting,
- The history of ownership and industrial use, and,
- The existing conditions, including potential problem areas and contaminants of concern.

Information sources were identified in a systematic and verifiable manner and characterized as follows:

- **Primary:** A listing of existing reports, plans, maps and documents catalogued and referenced by the JAG/EDGAR, Environment Canada, the Nova Scotia Department of the Environment, ACAP Cape Breton, Sydney Environmental Resource Limited (SERL, formerly Sydney Tar Ponds Clean-up Inc.), SYSCO, Cape Breton Regional Municipality, the collections of the University College of Cape Breton (the Beaton Institute). Included in the primary information list will be individuals that can contribute personally to the base of knowledge such as scientists, community members, site workers, and government officials.
- **Secondary:** A review of the primary material to identify secondary references and contacts.
- **Tertiary:** A listing of anecdotal and other sources.

Table 1-1 provides an outline of the scope of information reviewed.

Table 1.1: Scope of Information Collection and Assessment

Environmental Setting	
<ul style="list-style-type: none"> • Topography • bedrock and soils • surface water • groundwater • climatology 	<ul style="list-style-type: none"> • terrestrial habitats • aquatic habitats • air quality • political geography and land use • sensitive land use
History of Ownership and Use	
<ul style="list-style-type: none"> • land ownership • facilities • foundations • above/below ground storage • receiving/shipping/transportation • above/below ground services • process areas • chemical production/use 	<ul style="list-style-type: none"> • energy systems • wells • liquid waste management • solid waste management • pollution control measures • landfills/dumps • lagoons/tailings ponds • security
Existing Conditions	
<ul style="list-style-type: none"> • above ground facilities • below ground facilities • active uses • waste disposal • known spill sites • monitoring programs • surface water contaminants • soil contaminants 	<ul style="list-style-type: none"> • groundwater contaminants • air contaminants • exposure pathways • existing/potential receptors • physical hazards • completed remedial works • ongoing remedial works • public issues/concerns

Information sources examined included the following:

- Published and unpublished scientific, demographic and technical information
- Unpublished reports from consultants, site operators, and the municipality
- Municipal Planning Strategies and development policies
- Community based health surveys
- Corporate operational information, including correspondence

- Aerial and ground photography, including historic material
- Topographic maps, site plans, engineering plans, municipal plans, etc.
- Municipal and environmental permits, approvals and directions.

All significant sources of information were accessed, referenced, screened for relevance to the project and where found to have relevance, assessed by appropriate Team members. These sources were summarized and cited in a searchable electronic information database (MS ACCESS) (Appendix D). The data base has been made publicly available through the Internet and can currently be found at <http://www.cbcl.ca/muggah/db>.

To supplement existing information, and where possible, the Team conducted non-intrusive field investigations at sites within the Watershed identified as significant historic, existing or potential sources of contamination or physical hazards. The Team also walked watercourses tributary to the Muggah Creek.

1.6.1 Base Map

Although many studies and evaluations of portions of the Study Site have been conducted over the past several decades, mapping for this area remains relatively disjointed and dated. To assess the compilation of information during the Phase I, and other studies, a detailed Base Map of the Watershed was prepared (Plan 1, Appendix E). Additional Plans locating topographical information, surface drainage, property boundaries and ownership, historic and existing surface facilities, underground services and structures, municipal systems, and environmental monitoring stations have also been compiled.

Historic information related to the Study Site has been summarized on Plan 4 in Appendix E, which characterizes known conditions within the Watershed from approximately 1904 to the early 1980's. Some information is interpretive, rather than geographically referenced, and represents an approximation of location of facilities and services.

1.6.2 Report Organization

The Phase I Site Assessment of the Muggah Creek Watershed Report is organized in six Chapters:

- **Chapter One** provides the background for the study.
- **Chapter Two** presents a summary of available information on the Environmental Setting, and the industrial history.
- **Chapter Three** provides a review of contaminants of concern, their sources, migration pathways and potential exposure locations.
- **Chapter Four** delineates interim measures that may be initiated while the Site Assessment and Remediation Process is underway.
- **Chapter Five** outlines proposed areas and activities for subsequent investigations.
- **Chapter Six** details the conclusions and recommendations of the Phase I Team.

The main body of the Report is supplemented with information contained in five Appendices.

- **Appendix A** provides a glossary of technical terms.
- **Appendix B** provides a list of critical references
- **Appendix C** provides a list of persons interviewed during the course of the Study
- **Appendix D** contains a summary of the information contained within the MS Access database.
- **Appendix E** contains Plans 1 to 4.

CHAPTER 2 INFORMATION ASSESSMENT

2.1 Environmental Setting

The Muggah Creek Watershed falls within the Sydney Coal Field Unit of the Stony and Wet Plain District of the Carboniferous Lowlands Theme Region of Nova Scotia (Nova Scotia Museum, 1997). In the Sydney area, coal mining and steel production has created a highly urbanized landscape with distinct elements related to mining operations. Since the earliest days of European settlement, the Muggah Creek Estuary of Sydney Harbour has been dramatically changed in structure and productivity as a result of industrial and community development.

2.1.1 Topography

The Muggah Creek Watershed is part of relatively level coastal lowland that drains to the ocean via a basin formed by the Muggah Creek and its tributary streams. Natural slopes in the Watershed generally do not exceed 30%, and the maximum elevation is 150 m (Acres, 1991). Approximately 40% of the land area of the Watershed is considered well drained, 40% has some drainage problems and 20% is poorly drained (Acres, 1991). Within the Watershed, the existing landscape is a derivation of a variety of activities, including light and heavy industrial land use, the infilling of the Muggah Creek Estuary with slag and other materials, harbour development, residential and commercial land use and the development of the Municipal landfill (Table 2-1).

2.1.2 Bedrock and Overburden

The Watershed falls within the Sydney coalfield, which is underlain by pre-Carboniferous metamorphic and igneous rocks of the George River and Fourchu Groups. These rocks form a basement complex that likely occurs at depths in excess of 1500m in the Watershed. Locations where the basement complex outcrops forms part of the lateral boundary of the coalfield occur at the Coxheath Hills and the East Bay Hills to the southwest, and beyond the Mira River to the Southwest.

Bedrock of the Windsor, Canso and Morien Groups occurs above the basement complex, in the vicinity of the Watershed and in the order listed. The Windsor Group, at the base of this succession, is comprised primarily of poorly consolidated, poorly-sorted conglomerate (at the base) and a carbonate sequence of argillaceous shales, compact limestone, and increasing amounts of micaceous sandstone towards the top of the unit.

The younger strata of the Canso Group are known as The Point Edward Formation, which is the part of the Group that subcrops under the Watershed, and is in contact with the Morien Group. The Point Edward Formation is comprised of interbedded red siltstone, very fine sandstones with some limestone shale and mudstone (NDA/JWA, 1990).

The base of the Morien Group, known as the South Bar Formation, is the portion of the Group that underlies the Watershed. Drilling by Acres (1985) and NDA/JWA (1990) indicated that the formation in the vicinity of the Watershed is comprised of fine to medium-grained, well-sorted sandstone with variable thin occurrences of pebble conglomerate, shale/mudstone, and coal seams with pyrite mineralization. It should be noted that the geological interpretation provided by Acres and NDA/JWA were based on a

limited number of boreholes over a relatively large area. Consequently, the current characterization of site geology can generally be considered “reconnaissance – level”.

Table 2-1: Summary of Main Surface Features

Surface Feature	Physical Description
Muggah Creek	The Creek is actually a tidal estuary that covers an area of some 33ha. Ferry Street divides the Creek into the North Pond and the South Pond (the 'Tar Ponds'). Water levels are controlled between the two Ponds. A large portion of the estuary has been filled with slag, coal tars and sediments from the adjacent industrial lands.
Coke Ovens Brook Valley	A 3.5km long, east-west trending valley 20-30m in depth, generally flat-bottomed and about 500 m wide.
Marsh Dump	A partial infill of the Coke Ovens Brook Valley, upstream of the Coke Ovens site. The Dump largely consists of slag waste up to 25m thick. The deposit is about 1 km long and 300m wide and runs along the centre of the valley. It is also reported to contain materials such as tar, wood and bricks. Figure 6-1 in the Lower Frederick Street Study by CBOG indicates the area of the Marsh Dump conforms to the area of the Municipal Landfill and the Ash Landfill.
Municipal Solid Waste Disposal Site	The Site is located in the upper reaches of the Coke Ovens Brook Valley, adjacent to the south-west corner of the Marsh Dump. It covers approximately 25.4 ha in area and has been used for uncontrolled waste disposal since at least the early 1900's.
Municipal Ash Landfill	The Landfill is located adjacent to the south-east corner of the Marsh Dump and is about 17.5 ha in area.
Coke Ovens Site	The ground surface of the Site slopes from east to west; bounded to the north and south by topographic highs. The Coke Ovens Site is approximately 71 ha in area. The site has contained coke ovens, a benzol plant, ammonia sulphate by-products plant, sulphuric acid plant, brick plant, two coal-washing facilities; Mullins coal bank, coke and coal storage areas, numerous storage tanks for tar, benzol, and other by-products of coke production. Large areas of the Coke Ovens site are covered with imported fill material including sand, gravel, concrete rubble, coke, coal, cinders and steel plant slag.
Wetlands	Small marsh areas occur north and north-east of the Coke Ovens Site. Many give rise to the small tributary streams of the Muggah Watershed. Over the years wetlands in the Watershed have often fallen prey to infilling and to dumping.
DOMTAR Site	The DOMTAR plant contained a coal tar refining plant (refined coal tar to make tar based products). 17 aboveground storage tanks (for tar and tar related products), and a storage lagoon. Only one aboveground tank remains and the lagoon is filled with slag.
Slag and Fill Deposits	These deposits occur along the north-east shore of Muggah Creek and are widespread on the Steel Plant lands between the Victoria Rd overpass and the Tar Ponds. Slag was dumped into the South Arm of Sydney Harbour over a period of 80 years. In addition to the slag, the fill material also contained clinker, ash, coal debris, brick, garbage, wood fragments and larger debris.
Steel Plant	Begun in the late 1800's, the Plant flourished until the 1950's. It consisted of open hearths, blast furnaces, blooming mill, billet mill, rail mill, bar mill, rod mill, tie plate mill, rail finishing mill, plate mill, wire and nail mills. After the 1950's the demand for steel slumped, and to prevent closure of the Plant, the Provincial government bought it. In the 1980's the government replaced the open hearth and blast furnaces with an electric arc furnace and continuous casting equipment.
Public Roadways	Public roadways and footpaths cross the Muggah Creek Watershed from Sydney to Whitney Pier. Access to the Coke Ovens Site and to SYSCO has been restricted to authorized users.
Railyards and Tracks	Rail transport was a major component of the coal, coke and steel industries, resulting in numerous tracks, and railyards with a range of owners. Most of the lines still exist, even though the facilities they served have been demolished.

The Canso Group underlies the Morien Group and the bedding of each dips 5 to 15 degrees to the Northeast, due to the position of the Watershed on the southern limb of the Bridgeport Anticline (NDA/JWA, 1990). NDA/JWA (1990) indicate that no faults have been confirmed in the immediate vicinity of the current Watershed, but potential extensions of known faults may occur. The Northeast-Southwest trending Coxheath Fault may come in close proximity to the Coke Ovens, according to an interpretation of geophysical data by Boehner et al. (1986). Keppie (1976), suggested that the East Bay Lineament may extend under Muggah Creek, in a direction approximately parallel to the Creek's axis. However, the occurrence of the Lineament and the extension are not supported by the more recent work (Baechler, al., 1986).

Baechler (1986) conducted mapping of joints in the Morien Group throughout the Sydney Coalfield and described two sets of joints: one approximately parallel to bedding and another perpendicular. The author reported that the jointing was relatively persistent in the sandstones and conglomerates of the Group, and less persistent in the siltstone, shale and mudstone.

Plan 3 (Appendix E) provides a plan view of the Investigation Area and Site Area, and three geologic cross-section locations based on the indicated test holes. The three geologic cross-sections (A-A', B-B', C-C') are provided as Figures 2-1, 2-2 and 2-3, respectively. It should be noted that in addition to the indicated testholes, 202 other boreholes were put down in Muggah Creek, in the 1996 JWEL-IT study, to delineate sediment impacted by PCB's. Figure 2-4 shows idealized stratigraphic columns for the vicinity of the Tar Ponds and the Coke Ovens Site.

Baechler (1986) reported that the portion of the Sydney Coal Field included in the current Watershed is underlain by a single till unit that is typically sandy silt to silty sand. Till lithology and texture correspond closely to the underlying bedrock and tend to change quickly across bedrock contacts.

Within Muggah Creek, Acres (1985) reported that bedrock is overlain by a hard gravelly, sandy, silty clay till which, in turn is typically overlain by soft to firm organic clayey silt. Recent coal tar contaminated sediments that extend to the surface overlie this latter unit. Baechler (1986) notes that much of the surficial material on the east side of Muggah Creek and the west side of the Coke Ovens Complex is derived from industrial activity.

2.1.2.1 Muggah Creek Watershed

Descriptions of the main geologic units that occur in the Watershed are summarized in Table 2-2. These units are generally similar in character to the descriptions provided in the earlier discussion of regional geology. The Table is intended to provide more detail, on the basis of site-specific investigations.

In terms of bedrock, only the Canso and the Lower Morien are known to subcrop under the Watershed. The contact between these two Groups weaves approximately parallel to Victoria Road, with the Canso bedrock to the west and Morien to the east. The general location of this contact was assumed by Boehner and Giles (1986) and further refined through drilling by Acres (1985) and NDA/JWA (1990). However, given that only a few boreholes have been advanced in the watershed in the vicinity of the contact, there is still considerable uncertainty associated with the location of the contact within the watershed.

Two general types of till were encountered over bedrock, and their distributions correspond closely to the underlying bedrock. Till overlying Lower Morien bedrock is described as compact to dense, brown, silty sand to sandy silt; the Canso Group is overlain by dense, brown to reddish-brown, clayey silt till (NDA/JWA, 1990).

Fill materials are present over much of the Watershed, typically underlain by till. Much of the Coke Ovens site is covered with imported fill material including sand, gravel, concrete rubble, coke, coal, cinders and steel plant slag. These materials are contaminated with coal tar, and organic by-product derivatives of the coking process. Organic marsh deposits occur to the north and Northeast of the Coke Ovens site.

The bottom of Muggah Creek contains extensive deposits of coal and coke particles containing coal tar.

Table 2-2: Summary of Main Geologic Units

Unit Description and Horizontal Extent	Vertical Extent	Relative Degree of Certainty in Horizontal and Vertical Extent
<p>1. Muggah Creek Deposits - Coal and coke particles containing coal tar (Acres, 1985); distributed over most of the creek bottom</p>	<p>Maximum thickness of 3.53 m in the South Pond; reduces to 0.3-1.5 m toward the upstream end of the Pond; maximum thickness of 4.4 m in the North Pond; total volume of material in both ponds is estimated at 550,000 m³.</p>	<p>High due to field studies and surficial nature of deposits</p>
<p>2. Slag and Fill – along the north-east shore of Muggah Creek and widespread throughout the Steel Plant Complex between Victoria Rd overpass and the Creek; dumped into the South Arm of Sydney Harbour over period of 80 years; also contains iron and steel residues, clinker, ash, coal debris, brick, garbage wood fragments and larger debris; loose to compact, relatively porous (NDA/JWA, 1990)</p>	<p>Known thickness of up to 11 m, possibly as thick as 22 m; bottom of the slag is 4-6 m below sea level (NDA/JWA, 1990)</p>	<p>High due to field studies and surficial nature of deposits</p>
<p>3. Fill - large areas of the Coke Ovens site are covered with imported fill material including sand, gravel, concrete rubble, coke, coal, cinders and steel plant slag (NDA/JWA, 1990); fill materials are extensively contaminated with coal tar and other by-product derivatives of the coking process (Acres, 1985)</p>	<p>Range up to 3.7 m in thickness (NDA/JWA, 1990);</p>	<p>High due to field study and surficial nature of deposits</p>
<p>4. Glacial Till - dense, brown to reddish-brown, clayey silt till; located over the Canso Group mudstone on the west side of the Coke Ovens site (NDA/JWA, 1990); visually more fine-grained than the other major till unit (NDA/JWA, 1990)</p>	<p>Observed thickness ranged up to 8.3 m (NDA/JWA, 1990)</p>	<p>Moderate</p>
<p>5. Glacial Till - compact to dense, brown, silty sand to sandy silt; located over the Morien Group bedrock over the remainder of the Coke Ovens site; two other sandy till subunits were also identified over the Morien bedrock (NDA/JWA, 1990): 1) a dense to very dense silty sand with clay and 2) an extremely stony version of 1), identified in borehole logs as a weathered</p>	<p>Ranges in thickness from 3.7-4.1m on the NE shore of Muggah Creek; 3-5 m thickness in the vicinity of the Steel Plant; 10.7 m thickness encountered at the benzol plant (NDA/JWA, 1990)</p>	<p>Moderate</p>

Unit Description and Horizontal Extent	Vertical Extent	Relative Degree of Certainty in Horizontal and Vertical Extent
bedrock-till		
<p>6. Marsh Deposits – located north and north-east of the Coke Ovens site (Acres, 1985) This area is a partially infilled element of the Coke Ovens Brook Valley, upstream of the Coke Ovens Site. Infill consists of slag waste up to 25 m thick; deposited is about 1 km long and 300 m wide and runs along the centre of the valley (ref 1) also reported to contain materials such as tar, wood and bricks (ref 2)</p>	No known vertical delineation	<p>High</p> <p>for horizontal distribution due to surficial nature of deposits; vertical distribution is not characterized</p>
<p>7. Bedrock - Morien Series - fine to medium-grained, well-sorted, grey to bluish-grey sandstone with thin (<0.3m) lenses of pebble conglomerate, shale-mudstone and coal seams with pyrite mineralization (NDA/JWA, 1990); Victoria Road is aligned approximately along the contact between the Morien and Canso Series; the Morien occurs east of Victoria Road and overlies the Canso; the Morien extends under the Coke Ovens area and Marsh Dump; the unit dips 10-15 degrees towards the east (Acres, 1985); near the subcrop surface, secondary permeability is dominated by near-horizontal bedding plane fracturing, minor vertical jointing is also present; with depth, the horizontal fractures diminish and the vertical set becomes dominant (NDA/JWA, 1990)</p>	Encountered from 1.8-11.0 m depth in the Coke Ovens site; the bedrock surface slopes westward from the Coke Ovens site towards Muggah Creek and the Steel Mill, at an average gradient of 2.5%; the bedrock has an undulating surface under the Coke Ovens site; two major depressions were noted: under the benzol plant area and under the DOMTAR site (NDA/JWA, 1990)	<p>High</p>
<p>8. Bedrock - Canso Series - as encountered in the Watershed, this unit was a soft, weathered, bluish-grey mudstone with red clay seams (NDA/JWA, 1990); this unit occurs west of Victoria Road and extend under Muggah Creek.</p>	Encountered at from 6.4-8.4 m depth along western end of Coke Ovens site (NDA/JWA, 1990)	<p>High</p>

2.1.3 Hydrology

The Muggah Creek Watershed covers an area of approximately 24 km² (Figure 1-2). This major Watershed is divided into two minor watersheds.

- Coke Ovens Brook Watershed 40%
- Wash Brook Watershed 60%

Surface waters in the Watershed drain via municipal sewers and ditches to Wash Brook or Coke Ovens Brook, and empty into Muggah Creek. Although the surrounding topography largely consists of gently rolling hills, the gradient in the Watershed is sufficient to provide for fast flowing, turbulent streams.

The nearest appropriate Water Survey of Canada gauging station is at MacAskills Brook (01FJ002), located east of the Wash Brook Watershed, and for which there are more than 12 years of records.

In May 1990, Washburn Gillis Associates Ltd. was retained by Acres International Ltd. to carry out a Brook monitoring program for the Sydney Tar Ponds Clean-up Project. As well as a sampling program to characterize the level of a selected number of contaminant parameters that are contributed by Wash Brook and Coke Oven Brook, the hydrology of each brook was studied. Two gauge stations were established on

Coke Ovens Brook and one station at Wash Brook. Brook water levels were recorded on a routine basis and discharge rating curves developed during the course of the program. A draft report entitled Coke Ovens Brook: Wash Brook, Monitoring Program, Sydney Tar Ponds Clean-Up Project was submitted in September 1993 which summarized the data collected at both brooks during the period from July 1990 to June 1991. A follow-up report for Wash Brook was prepared in June 1994 which compared results prior to and after construction of the Ferry Street cofferdam, to determine if the cofferdam was having an influence on concentrations along the lower section of Wash Brook. This report did not have additional flow data to that reported in the 1993 report. A subsequent Washburn Gillis report on the Coke Oven Brook Monitoring Program dated January 1996 summarized data collected at the downstream station during the period July 1991 to June 1994.

2.1.3.1 Coke Ovens Brook Watershed

The Coke Ovens Brook Watershed comprises the northern portion of the Muggah Creek Watershed. The brook has its origins in the upper reaches of the Watershed and drains through an urban and industrial landscape some 8.4km² in area. Mean natural annual flows have been calculated at 0.34m³/s, with mean annual flood and 100 year flows estimated at 6.2 and 12.8m³/s, respectively (Acres 1985a).

Watercourses, which drain to the Coke Ovens Brook, are Whitney Pier Brook, Radar Brook, Frederick Street Brook, DOMTAR Brook, Incinerator Brook, Incinerator Marsh, Cositts Lake, Cagney Brook, and Prince Street Brook.

2.1.3.1.1 Whitney Pier Brook

Whitney Pier Brook originates in a small marshy area in the North and flows through Whitney Pier to the Cape Breton Development Corporation Rail lines where it passes beneath the rails near the intersection of Frederick Street and Lingan Road. The Brook remains in a culvert for approximately 180 m, when it emerges and enters Coke Ovens Brook just before the Coke Ovens Brook flows under the Victoria Road Overpass. No water quality studies for this Brook were identified during this project.

2.1.3.1.2 Radar Brook

Radar Brook originates in a small marshy area in the North, where it flows through a largely forested area. At its lower end the Brook flows beneath the Cape Breton Development Corporation Railway where it enters the Coke Ovens Brook at the NE edge of the Municipal Landfill. No water quality studies for this Brook were identified during this project.

2.1.3.1.3 Frederick Street Brook

Frederick Street Brook originates at a spring-fed marsh located along the north side of the Cape Breton Development Corporation Railway. The Brook intersects Whitney Pier Brook just before it passes beneath the rails near the intersection of Frederick Street and Lingan Road. The Brook has a distinctive orange tint, visible even on aerial photographs. In the spring of 1998, surface water and sediment quality in Frederick Street Brook was tested for 68 metallic and inorganic parameters, eight of which exceeded established guidelines (Freshwater Aquatic Life, Aesthetic; Drinking Water and CCME Commercial).

Table 2-3: Water Quality in Frederick Street Brook (CGEB, 1998)

Analyte	Maximum Concentration Recorded	Recommended Maximum	Guideline
Calcium	33.6 mg/L	0.00006 mg/L	Freshwater Aquatic Guidelines
Total Dissolved Solids	588.9mg/L	<500 mg/L	Drinking Water Guidelines – Aesthetics
Aluminum	0.2 mg/L	0.1 mg/L	Freshwater Aquatic Guideline
Manganese	0.39 mg/L	<0.05 mg/L	Drinking Water Guidelines – Aesthetics
Silver	<0.02 mg/L	0.0001 mg/L	Freshwater Aquatic Guideline
Zinc	0.05 mg/L	0.03 mg/L	Freshwater Aquatic Guideline

2.1.3.1.4 DOMTAR Brook

DOMTAR Brook originates in a small marshy area, flows through Whitney Pier (past the Whitney Pier Memorial School), and passes underground through the Cape Breton Development Corporation (DEVCO) railway yards. The Brook remains underground in a culvert for approximately one hundred meters as it flows under the former DOMTAR tar lagoon site. It then empties into the Coke Ovens Brook immediately upstream of Victoria Road Overpass. Samples from DOMTAR Brook adjacent the Whitney Pier Memorial School were analyzed for the 1996 Britten Research Associates Study. The analyses indicated that the samples contained levels of aluminum, copper, iron, selenium and zinc above the CCME guidelines for Freshwater Aquatic Life.

2.1.3.1.5 Incinerator Marsh

Incinerator Marsh is located in the southwestern corner of the Municipal Landfill. The Marsh drains via a small watercourse to Coke Ovens Brook, just before the Brook enters the Coke Ovens Site. Environmental testing was carried out by ADI - Nolan Davis Limited for the Cape Breton Regional Municipality, but the results and interpretation were not available at this time. The results will be discussed in the report to be produced in 1999.

2.1.3.1.6 Cossitt Lake

Cossitt Lake is located at the rear of the Cossitt Lake Industrial Park in the southeast area of the City of Sydney. The Lake is approximately 0.159km in size and drains into Cagney Brook. No studies on environmental quality were identified.

2.1.3.1.7 Cagney Brook

Cagney Brook flows from Cossitt Lake through a developed residential area. It enters the Coke Ovens Site through a 1.8m culvert located at the southern perimeter. During the period of operation of the Coke Ovens, Cagney Brook was diverted north across the site via an underground culvert that emptied into Coke Ovens Brook. During recent remedial work to improve surface drainage on the site, a section of the Cagney Brook culvert was removed and a ditched channel was constructed, allowing the waters of Cagney Brook to once again drain overland across the Coke Ovens site. The ditch curves to the west to the area of the former benzol plant where it turns to the north, entering Coke Ovens Brook just before the Victoria Road Overpass.

Reports of analyses for general chemistry on samples obtained from Cagney Brook on August 17 and 24, 1989 were provided by NSDOE. The only parameter tested that was above the CCME remediation criteria for Freshwater Aquatic Life was iron, at 0.35 mg/L and 0.47 mg/L. The remediation criteria is 0.3 mg/L.

2.1.3.1.8 Coke Ovens Brook

Coke Ovens Brook originates in the East, approximately half way along the North side of the Municipal Landfill. The Brook is joined by the Incinerator Marsh tributary and Radar Brook and flows from East to West through the Coke Ovens Site, joining with Frederick Street Brook, Whitney Pier Brook, DOMTAR Brook and Cagney Brook. The Coke Ovens Brook then flows just Southeast of the SYSCO Site and empties into Muggah Creek.

Three known constructed drains empty into the Brook from the Coke Ovens site:

- 1) A culvert draining the area to the south of the Brook near the abandoned coal washing facility;
- 2) A culvert draining the area to the north of the Brook near the Conveyer Tunnel; and
- 3) A culvert draining an area of the perimeter of the Coke Ovens site.

A natural spring enters the brook from the vicinity of the Benzol plant

Several sewage outfalls enter the Brook downstream of the Victoria Road Overpass.

Today, Coke Ovens Brook drains a highly disturbed urban and industrial landscape of approximately 8.4 km². Over much of its length the riparian habitat has been destroyed, and replaced with channelized banks, debris and infill. It is questionable whether the Brook follows its original course, as it is reported to have been diverted and/or channelized in the past. The Brook has an estimated mean annual flow of 0.34 m³/sec. Generally the Brook stream bed material is comprised of coarse gravels and cobbles, interspersed with occasional boulders. As the Brook traverses the Coke Ovens Site, and in downstream reaches, certain portions of the stream bed are visibly coated with tars. The entire streambed on the Coke Ovens site is also covered with a bright orange precipitate.

The range of flows measured at the downstream gauge in the Washburn Gillis studies, between July 1990 and June 1994, ranged between 0.07 m³/s in the summer to 4.35 m³/s. This monitoring station was located downgradient of the Coke Ovens property at the point the brook exits the Victoria Road culvert. A second monitoring station was located on the east perimeter of the Coke Ovens property at the point the brook enters. Between July 1990 and June 1991 the flows measured at the upstream station ranged from 0.01 m³/s in the summer to 2.41 m³/s in December.

2.1.3.2 Wash Brook Watershed

Wash Brook Watershed, the lower Southern portion of Muggah Creek Watershed, drains an urban and industrial area of 12.6 km². It contains Mud Lake, Gilholmes Lake, an unnamed brook, and Wash Brook.

2.1.3.2.1 Mud Lake

Mud Lake is the most southern lake in Muggah Creek Watershed. It is 0.045 km in surface area and drains through an unnamed stream to Wash Brook. No environmental studies on this system were located.

2.1.3.2.2 Gilholmes Lake

Gilholmes Lake is the most eastern lake in the Muggah Creek Watershed and falls within the boundaries of the Department of National Defense property. It is approximately 0.25km² in area and flows into Wash Brook. No environmental studies were found for this watercourse.

2.1.3.2.3 Wash Brook

Wash Brook flows from South to North, through a residential landscape, and empties into Muggah Creek. Wash Brook has few tributary streams of any size, but there are approximately four sanitary outfalls emptying directly into the watercourse. The catchment area is approximately 25% urban and 75% rural. The brook flows at a gradient between 0.5% along the urban area and 1% along the upstream rural portion. The combined mean annual flow in the Brook has been estimated to be 0.51m³/s. The mean annual flood and 100-year flood flows were estimated at 9.4 and 19.2 m³/s respectively (Acres, 1985). The 1993 Washburn Gillis report indicated the discharge flow measured between July 1990 to June 1991 ranged from 0.00 m³/s during the summer months to 3.68 m³/s in February. This report classified Wash Brook as an ephemeral stream with a base flow absent during extended periods in the summer. During the summer months of 1995, ACAP-Cape Breton in association with a number of organizations, conducted an eight week water quality monitoring project along the Wash Brook. Sampling was performed once a week at eight sampling points along the brook. The sampling parameters monitored were selected based on the context of fish habitat and did not test for metals or organic contaminants. The samples were however sampled for fecal coliforms. Monitoring Sites 1, 2 and 3 had levels of fecal coliform consistently in excess of 600 counts per 100 ml which exceeded the recommended levels for Total Body Contact such as swimming. Sites 1, 2 and 3 were the monitoring stations located closest to Muggah Creek. The high fecal coliform result was attributed to the combined sanitary and storm sewer outfalls in this section of the stream.

2.1.3.3 Muggah Creek (Tar Ponds)

Both the Coke Ovens Brook and Wash Brook empty into Muggah Creek, a tidal estuary that covers an area of 33 ha before emptying to Sydney Harbour. A large portion of the original estuary has been infilled over the years with slag from the Steel Plant operations. Ferry Street divides Muggah Creek into the North Pond and the South Pond. Water levels between these two areas are regulated by a control structure located at Ferry Street. It is estimated that at least 36 piped outfalls exist in the Creek area. Activities at the former Steel Plant, the Coke Ovens and the DOMTAR plant contributed significant sediment and industrial waste to the Creek such that estimates today place the total volume of contaminated sediments in the Creek area at 550,000 m³. Muggah Creek is contaminated with PAHs, PCBs, heavy metals, coal tar, coal and coke fines. The area is now recognized as one of the most contaminated sites in Canada and has become known as the Tar Ponds.

2.1.4 Hydrogeology

Baechler (1986) has conducted a regional scale characterization of hydrogeological features of the Sydney Coalfield. This work can be used to provide a relative indication of the hydraulic conductivity of the major hydrogeological units in the Watershed. Data from 23 pump tests, 10 slug tests, 45 packer tests

and 645 domestic wells in the Lower Morien Group throughout the coalfield indicated that this part of the unit had the highest transmissivity of all the hydrogeological units in the coalfield. The Lower Morien, which underlies much of the current Study Site, was characterized as able to meet water requirements for large institutional, industrial and municipal developments. Eleven groundwater samples collected from throughout this unit (Baechler, 1986) showed the following characteristics: moderately hard to hard, near-neutral pH, excessive iron and manganese (in comparison to Canadian drinking water quality criteria), occurrence of hydrogen sulphide.

On the basis of information from 20 domestic wells in the Canso Group, it was concluded that it could generally supply sufficient water for domestic purpose. A compilation of well yields indicate that this unit is substantially less transmissive than the Lower Morien. Water supply potential of the till unit (sandy silt to silty sand) was also expected to be limited to domestic purposes, although it was noted that little data were available since this unit is not often used as a water supply. Baechler (1986) stated that the unit is expected to show a wide variation in permeability.

2.1.4.1 Muggah Creek Watershed

Table 2-4 provides a summary of the hydrogeologic properties of the main geological units identified in the Watershed. Information on hydrogeologic characteristics of the main geologic units in the Watershed is generally consistent with the regional trends for these units. However, for many of the units, Watershed data are only sufficient to indicate the range of variability in hydraulic properties, not the distribution. Figures 2-1, 2-2, and 2-3, presented earlier in this Chapter, illustrate the typical stratigraphic features of the Coke Ovens Site and the Muggah Creek Tar Ponds.

In general, Lower Morien bedrock displayed greater conductivity than that of the Canso Group. Strong trends in the relative permeability of the till and fill units were not evident although the limited available data indicate the fill may be one or more orders of magnitude more conductive than the two main till units. However, on the basis of one slug test from the weather bedrock - till unit, there is preliminary indication that this unit may have a relatively high conductivity ($3E-3$ cm/sec).

Table 2-5 summarizes the parameters affecting groundwater and surface water movement. In the vicinity of the Coke Ovens Site, groundwater recharge is expected to occur in elevated areas surrounding the Coke Ovens Brook basin. Groundwater flow is expected to occur towards the basin from these areas.

It has been suggested (NDA/JWA, 1990) that within the basin, shallow bedrock is significantly more conductive than either the overlying till or the underlying bedrock. Consequently, shallow bedrock was indicated as an important control on lateral groundwater movement, and may act as either a groundwater sink or a source for the overlying till and the underlying, deeper bedrock, depending on the configuration of hydraulic heads. Available hydraulic data also indicate that much of the groundwater from the vicinity of the Coke Ovens Site converges on, and discharges to, Coke Ovens Brook.

Table 2-4. Summary of Hydrogeologic Properties of Main Geologic Units

Unit	Hydraulic Properties	Relative Degree of Certainty in Range and Distribution of Hydraulic Properties
1. Muggah Creek Deposits	Particle size generally ranges from less than 0.1mm to 2cm (Acres, 1985); largest fraction of material is smaller than 1mm	Moderate - for range Low - for distribution, due to a high degree of variability
2. Slag and Fill (NE shore of the Tar Ponds, throughout the Steel Complex)	Typical grain-size distribution is 25-31% gravel, 41-49% sand, 20-34% silt-clay (NDA/JWA, 1990)	Moderate - for range Low - for distribution, due to a high degree of variability
3. Fill (over large areas of the Coke Ovens site)	K ¹ of 2.2E-4 cm/sec in slug test (NDA/JWA, 1990); K's of 2.74E-5 and 9.74 E-5 cm/sec(Acres, 1985)	Moderate - for range Low - for distribution, due to a high degree of variability
4. Glacial Till - dense, brown to reddish-brown, clayey silt till	Slug test K of <1E-6 cm/sec (NDA/JWA, 1990)	Low - for range Low - for distribution, due to a high degree of variability; several available K test results are inconclusive due to testing over multiple units
5. Glacial Till - compact to dense, brown, silty sand to sandy silt	Slug test K's of 5.1E-7 and 1.3E-4 cm/sec (NDA/JWA, 1990); one slug test of the extremely stony sub-unit (identified as weathered bedrock - till) provided a K measurement of 3E-3 cm/sec	Low - for range Low - for distribution, due to a high degree of variability; several available K test results are inconclusive due to testing over multiple units same as above
6. Marsh Deposits - (N and NE of the Coke Ovens site)	No known information	Hydraulic properties are not characterized
7. Bedrock - Morien Series	Core analysis indicated 2 sets of conjugate joints with spacings of 0.3 and 1.5m; fracture spacing in non-weathered sandstone were 0.1 and 0.5m (Acres, 1985); geometric mean of slug tests at 16 piezometers provided geometric mean K of 4.74E-4 cm/sec and a range of from 1.7E-2 to 7E-6 cm/sec; overall, K was slightly higher near the surface of the bedrock (NDA/JWA, 1990)	High - for range Moderate - for distribution; hypothesis of high-K in the shallow zone is supported by limited available data, but not confirmed
8. Bedrock - Canso Series	In the Coke Ovens area, K values in ranged from <1E-6 to 1.3E-3 cm/sec; higher values may be indicative of the highly weathered surface of the unit (NDA/JWA, 1990)	High - for range Moderate - for distribution; hypothesis of high-K in the shallow zone is supported by limited available data, but not confirmed

¹ K = Hydraulic conductivity; a measure of the rate at which water can flow through a permeable material (such as soil or bedrock).

Table 2-5: Summary of Parameters Affecting Groundwater and Surface Water Movement

Component	Interpretation	Relative Degree of Certainty in Interpretation
Groundwater recharge and discharge in the vicinity of the Coke Ovens site	humid continental climate with 30 year normal precipitation of 1400 mm (NDA/JWA, 1990); recharge to an intermediate groundwater flow system occurs in the highlands to the north and south of Coke Ovens Brook basin and discharges to the basin floor (NDA/JWA, 1990)	Moderate - interpretation based primarily on conceptual understanding of system
Perched groundwater	negligible data available for evaluation	
Water table depth and variation	generally 1.5-4m below grade at the Coke Ovens site (NDA/JWA, 1990)	High - based on straightforward interpretation of hydraulic heads from numerous monitor wells
Horizontal Gradients	groundwater in the vicinity of the Coke Ovens site tends to converge on Coke Ovens Brook from both sides (NDA/JWA, 1990)	same as above
Shallow Groundwater/Surface Water Interaction	there is a tendency for groundwater in the fill, till and bedrock units in the vicinity of the Coke Ovens site to discharge to Coke Ovens Brook (NDA/JWA, 1990)	same as above
Vertical Groundwater Interaction	Gradients at Coke Ovens site are variable between nested well locations and at the same location over time (NDA/JWA, 1990); vertical groundwater movement appears to be influenced by a high conductivity zone in shallow bedrock (NDA/JWA, 1990); in general, flow is upwards and downwards to this zone (i.e., it acts as a "drain"); however, vertical flow is also influenced by hydraulic loading to the groundwater system, and local reversals in gradient direction may occur causing upward or downward flow away from the high conductivity zone (NDA/JWA, 1990)	Moderate – interpretation of vertical interaction of groundwater at the Coke Ovens site (NDA/JWA, 1990) is consistent with most available data but is largely unconfirmed
Groundwater divide	The groundwater flow system on the Coke Ovens site appears to be bounded by recharge areas on the bedrock high occupied by CFS Sydney to the north, the valley flank at Vulcan and Welton Streets to the Southeast and a piezometric high in the vicinity of Victoria Road on the Southwest corner of the site (NDA/JWA, 1990)	Moderate – interpretation is based primarily in a general understanding of the groundwater system; delineation of groundwater divide is largely unconfirmed

2.1.5 Climatology

The regional climate for this area is characteristic of the Nova Scotian Coastal Lowlands, where winter and summer temperatures are modified by the proximity to the Atlantic Ocean. Winters are cold (January mean daily temperature less than 6°C) but not severe. Spring comes later to the immediate coastal areas as a result of the persistently cold water. Daily temperatures are consistently above freezing by the end of March and the growing season begins by the end of April. Although temperatures warm rapidly, summers can remain relatively cool (July mean daily temperature 17°C), again due to the proximity of the ocean. The frost-free period in the Sydney area averages 140 days. Fogs in the Sydney area occur on average 80 days of the year, more frequently in the period from May to July. Prevailing winds are westerlies or northerlies in the fall and winter, switching to south-westerlies or south-south-westerlies in spring and summer (NS Museum, 1997).

Data on climate elements were obtained from Environment Canada Atlantic Region, Atmospheric Environment Branch. All data were recorded at the Sydney Airport. Averages are based on the 30 years period from 1941 to 1993.

Figure 2-5: Average Rainfall.

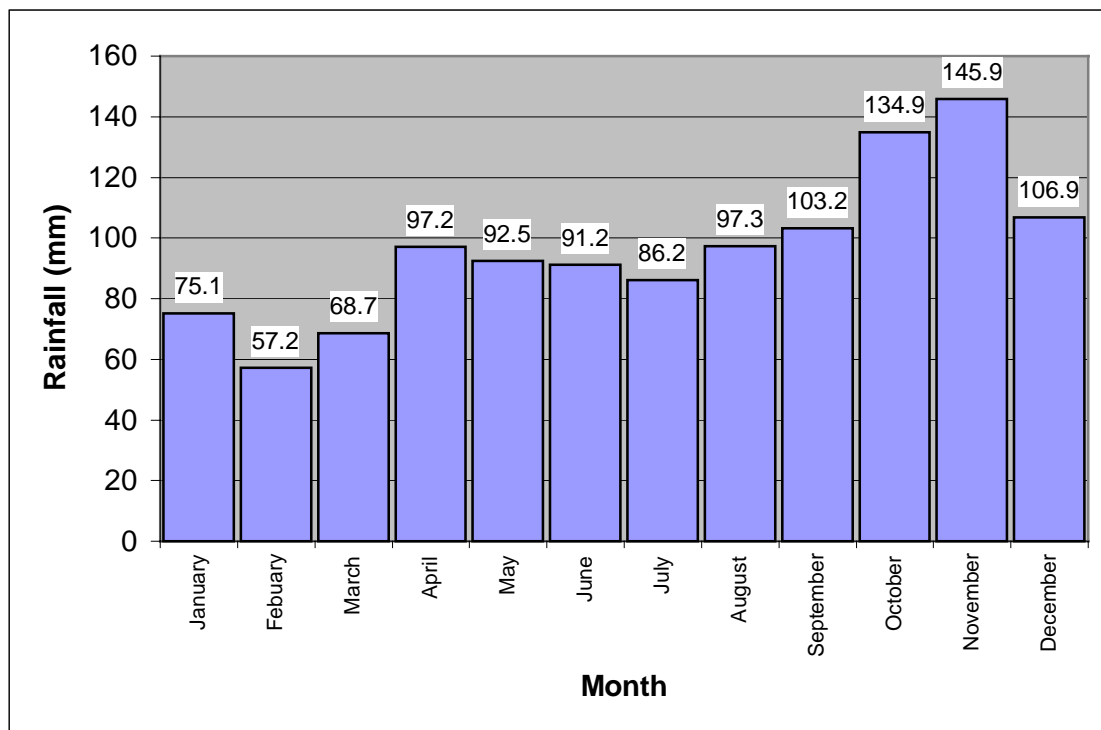


Table 2-6: Maximum Rainfall Extremes

Month	Extreme Rainfall (mm)
January 14, 1948	57.2
February 16, 1988	58.4
March 8, 1992	73.0
April 29, 1982	73.4
May 26, 1967	93.5
June 17, 1973	72.1
July 13, 1969	63.8
August 17, 1981	128.8
September 30, 1947	90.9
October 19, 1992	96.2
November 5, 1944	97.3
December 26, 1979	94.0

Figure 2-6: Average Snowfall

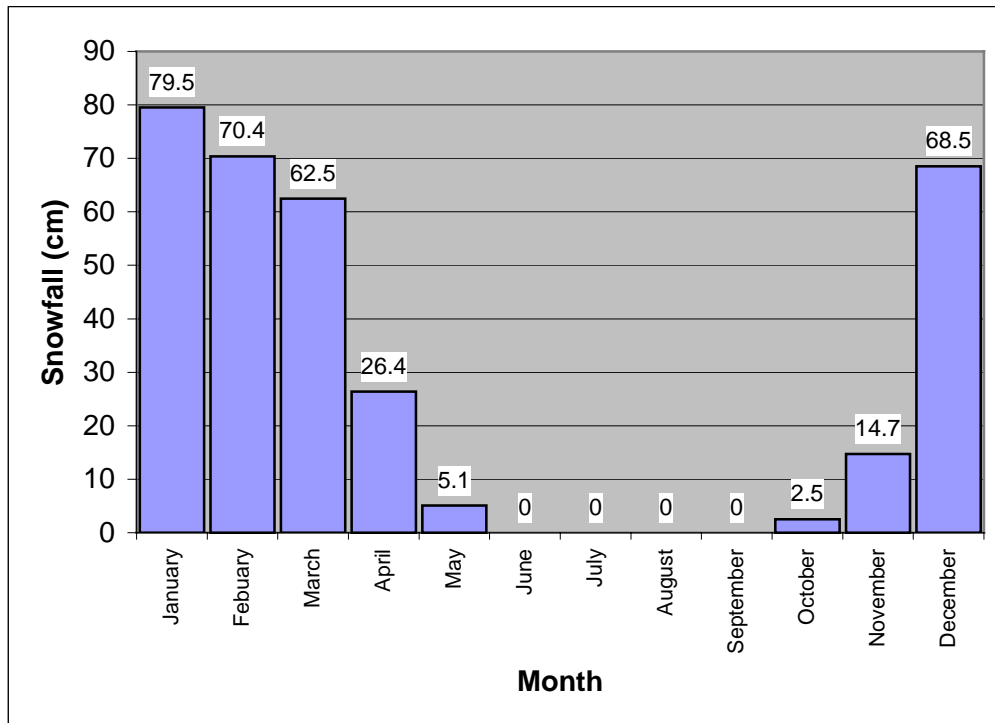


Table 2-7: Maximum Snowfall Extremes

Month	Extreme Snowfall (cm)
January 25, 1965	44.5
February 15, 1959	45.2
March 18, 1993	18.3
April 3, 1965	29.2
May 10, 1972	24.9
June 9, 1975	1.0
October 19, 1972	15.7
November 23, 1989	27.4
December 21, 1964	58.7

Figure 2-7: Average Temperature.

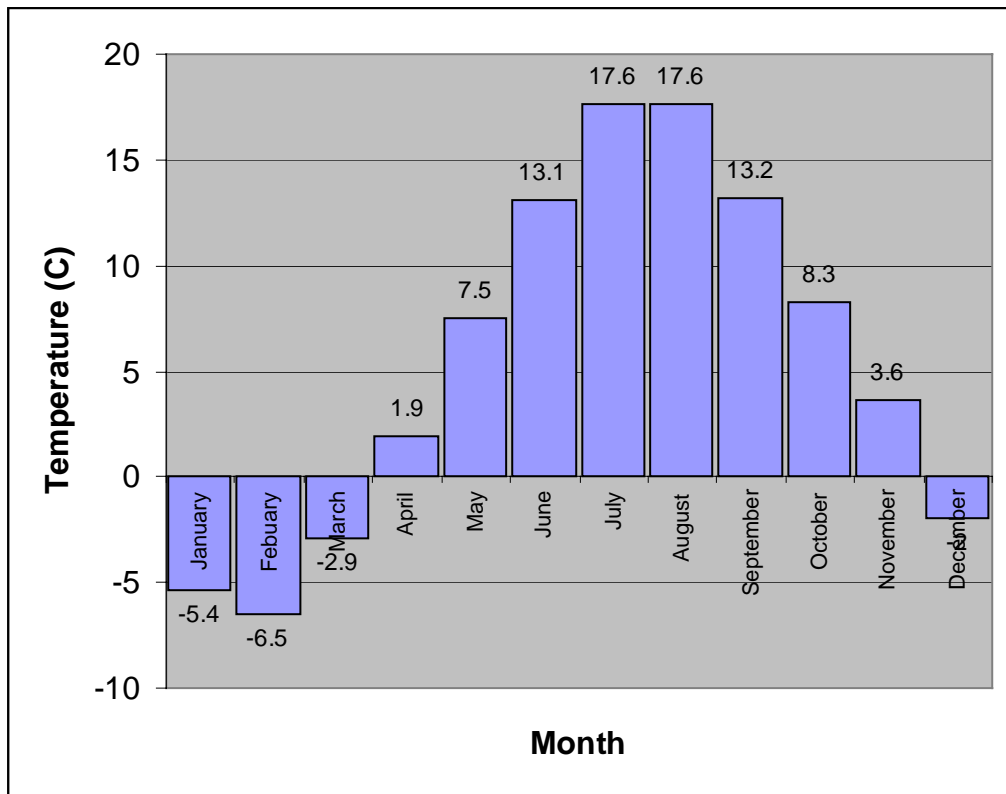


Table 2-8: Temperature Extremes

Month	Temperature Extreme Maximum (°C)	Temperature Extreme Minimum (°C)
January 7, 1946	14.4	
January 18, 1982		-25.0
February 2, 1951	12.8	
February 26, 1972		-25.6
March 29, 1945	17.8	
March 4, 1950		-23.9
April 25, 1942	27.2	
April 2, 1946		-13.3
May 31, 1960	31.1	
May 2, 1972		-7.8
June 18, 1949	34.4	
June 9, 1956		-3.9
July 19, 1975	33.9	
July 15, 1961		2.2
August 14, 1944	35.0	
August 31, 1965		2.8
September 2, 1942	32.2	
September 29, 1971		-2.7
October 20, 1963	25.0	
October 31, 1944		-5.6
November 5, 1961	22.2	
November 30, 1989		-11.7
December 6, 1951	16.7	
December 29, 1993		-22.2

2.1.6 Air Quality

Over the years, various sources of emissions to the atmosphere have been identified as potential sources of contaminants. In 1980 Environmental Canada attributed dramatic increases in iron content in the surface water of Coke Ovens Brook to the landwash of high particulate fallout from the SYSCO plant as iron in any quantity was not stored in the areas of the Coke Ovens. Hildebrand (1982) estimated total particulate emissions to the atmosphere in the Sydney area were in the order of 28,000 tonnes of particulates per year, with 18,500 tonnes of this total attributed to SYSCO operations. The Seaboard thermal generation plant, and dust generated during transportation of coal, were the other major sources identified, each estimated to contribute approximately 4200 tonnes per year.

Rowan Williams Davies & Irwin Inc (1994) in a report on the compliance test program for the Tar Ponds incinerator indicated that long term average ambient air levels measured from September 1989 to November 1993 in the Sydney area had PAH content ranging from 23.1 ng/ m³ to 52 ng/ m³. These results were measured from five compliance sampling Sites: 1) Public information Display Center; 2) Whitney Pier Fire Station; 3) Whitney Pier Retirement Home; 4) County Jail; and 5) Department of National Defence. Limitations or qualifications associated with the data can be found in the referenced report.

The Nova Scotia Department of Public Health (NSDPH) began monitoring air pollution in Sydney in 1958. At this time, they measured the dustfall using dustfall receptors. In 1959, the soiling index was

added and the sulphation rate was included in 1961. During the 1970s, sulphur dioxide (SO₂) and total suspended particulate (TSP) were added to the monitoring program. In the 1980s monitoring of PAH, (specifically benzo(a)pyrene (BaP)), was the focal point of the air monitoring program. In 1988, the Coke Ovens operations, the primary source of PAHs, was shut down. To provide a summary of the air monitoring results for the period 1970 to 1990 the following reports were reviewed and their observations are summarized below:

- Environment Canada, January 1982. "Environment Quality in Sydney and Northeast Industrial Cape Breton, Nova Scotia".
- Environment Canada, June 1984. "Ambient Air Polynuclear Aromatic Hydrocarbons Study, Sydney, Nova Scotia".
- Acres International Limited, November 1986. "Sydney Tar Ponds Clean-Up Air Monitoring Quarterly Report No.1".
- Rowan Williams Davies and Irwin Incorporated, February 1991. "Sydney Tar Ponds Clean-Up Ambient Air Monitoring Program Summary Report No.2".
- Rowan Williams Davies and Irwin Incorporated, February 1994. "Sydney Tar Ponds Clean-Up Ambient Air Monitoring Program Summary Report No.3".

During the period from 1970 -1980, air quality monitoring in the area resulted in the following observations:

- *Average levels of sulphur dioxide (SO₂)* remained essentially constant; 39µg/m³ (1972) to 36µg/m³ (1980) (Sample Locations: Sydney County Jail and Whitney Pier Fire Station) (Environment Canada, 1982).
- *Average total Suspended Particulates (TSP) levels* remained essentially constant; 121 µg/m³ (1975) to 117 µg/m³ (1980) at the Whitney Pier Fire Station (Environment Canada, 1982).
- *Dustfall levels* decreased significantly from 353g/m²/month (1972) to 35g/m²/month (1980) at the Whitney Pier Fire Station. The decrease in dustfall levels can be related to the decrease in SYSCO's production levels during this time (Environment Canada, 1982).
- *The soiling index and sulphation rate* decreased during the span of the 1970s, which can also be related to the decrease in SYSCO's production during this time (Environment Canada, 1982).

During the period from 1980 -1990, air quality monitoring in the area resulted in the following observations:

- At the monitoring stations the highest *PAH levels* were found at the Whitney Pier Fire Station (north-east of the SYSCO plant). Annual average PAH levels measured in 1981-82, 86, 89-90 were 31.16, 52.71, 47.78ng/m³, respectively at the Whitney Pier Fire Station (Environment Canada, 1984; Acres, 1986; RWDI, 1991). Lower PAH concentrations in 1981-82 were likely a result of the shut down of the Coke Ovens No.5 Battery and the partial operation of the No.6 Battery.
- *Benzo-a-pyrene (BaP)*, a known carcinogen, also had the highest concentrations at the Whitney Pier Fire Station. Annual average BaP levels measured in 1981-82, 86, 89-90 were 1.74, 3.93, 0.40 ng/m³, respectively (Environment Canada, 1984; Acres, 1986; RWDI, 1991).
- The *TSP levels* were the highest at the Whitney Pier Fire Station. The TSP levels measured in 1981-82 and 1989-90 were 28.06 and 31.0 µg/m³. This is a significant drop in TSP compared to the 1970-

1980s (approximately 60 µg/m³) and can be contributed to the lower production rates at SYSCO and the shut down of the Coke Ovens facility in 1988 (Environment Canada, 1984; Acres, 1986; RWDI, 1991).

A 25-year wind-rose summary from the Sydney airport indicates that the annual average prevailing winds are from the south to south-west quadrant (52% of the time) and the secondary wind is from the west to northwest (28% of the time). A copy of the wind-rose is provided as Figure 2.8. During the summer months, the winds prevail from the south to south-west and during the months of January and February winds are predominantly from the west to north-west. In all cases the mean monthly wind speeds varied from 18.4 to 24.4 km/hr with an average of wind speed of 21.7 km/hr (Environment Canada, 1984).

2.1.7 Terrestrial Habitats

The Sydney Coalfield Natural History Unit lies within Louck's Sugar Maple-Hemlock-Pine Forest Zone, which is heavily influenced by the warm summers and cold winters, local soil conditions and extensive disturbance of the landscape by human activities. In the Muggah Creek Watershed these disturbances have resulted primarily from industrial related activities, but residential, institutional, and commercial developments have also contributed to the loss or reduction of habitat. What forest communities remain tend to be dominated by White Spruce, Black Spruce, Balsam Fir, and Larch. Birch, Maple and Aspen are common on disturbed areas, and along the margins of coal impacted areas. Small marshy areas exist in poorly draining soils and on the margins of the small lakes.

On the Coke Ovens Site, it was interesting to note the regeneration of vegetation, largely represented by grasses, wildflowers and other herbaceous species. Along some of the wetter areas of the site, Birch groves had begun, with small Cattail wetlands and marshy areas.

The urban conditions and the impacted landscape would limit wildlife in the area. Species that may be encountered include Red Squirrel, Snowshoe Hare, Red Backed Vole, and possibly, deer and or coyote. Gulls and songbirds were evident during site field investigations, but no directed studies or inventories were attempted.

2.1.8 Aquatic Habitats

As is the case for terrestrial habitats, the marine and freshwater aquatic habitats of the Muggah Creek Watershed all have experienced greater or lesser degrees of human disturbance. Many of the streams located within the lower reaches of the Watershed have been channelized, and/or piped. Muggah Creek itself bears little physical resemblance to its original form. The original salt marsh, which formed a considerable portion of the Muggah Creek Estuary, has been replaced with urban and industrial infill. With the possible exception of some of the small lakes and marshes in the upper reaches of the Watershed, most watercourses have been impacted by both physical and chemical factors that affect water quality, stream hydrodynamics and habitat productivity.

Notwithstanding the expected chemical and biological limiting factors, small fish and amphibians have been observed in both the stream and marshy areas of the Watershed, including downstream reaches of Cagney's Brook. Cormorants nest in the Muggah Creek Estuary in the remnant structures of the old SYSCO wharves. A cliff swallow nesting colony exists in the consolidated slag deposits to the east of

SYSCO operations. It must be noted that while welcome, these isolated observations of individual species within the watershed cannot be construed as an indication of ecosystem health.

In 1980 and 1981, investigations undertaken by Fisheries and Oceans Canada on shellfish populations in Sydney Harbour (notably lobsters) determined that mean concentrations of PAHs in heptaopacreas from lobster in the South Arm of the Harbour was considerably above background levels of PAHs in other coastal populations of lobster. Based on this information, the commercial fishing of lobster in South Arm was banned for an indefinite period of time (Travers, 1986). Currently there are no known programs for on-going environmental monitoring of Sydney Harbour.

Despite the attention paid to the Tar Ponds over the years, little information exists on surface water quality and ecosystem health for either the aquatic or marine habitats of the Muggah Creek watershed. Much of what is available is limited in application to specific areas, and for specific time periods. Testing protocols and seasonality vary considerably, making it difficult to compare the information. There are no known continuing ecosystem monitoring programs within the watershed.

2.1.9 Sensitive Areas

The disturbed nature of terrestrial and aquatic habitats in the Watershed has degraded much of the ecological productivity of the Site Area and the Investigation Area, but certain habitats of note remain within the Watershed, and should be included as 'sensitive' to environmental impact, including:

- Small but locally important 'green spaces' or areas of natural habitat within the urban land use areas;
- Upstream stretches of the watercourses and small marshes;
- Nesting populations of seabirds and swallows; and
- The estuarine and marine environments of Muggah Creek and Sydney Harbour.

Although no sensitive species or habitats were identified as part of this review, the general absence of detailed ecological information on the Watershed makes it difficult to assess the existence of, or potential for, rare and endangered species in the area.

The nearest International Biological Program (IBP) Proposed Ecological Site (24) is the offshore Bird Islands which are a considerable distance from Muggah Creek.

In the context of this report, residential areas near the Study Site are considered sensitive, as relates to potential long-term and short-term exposure to contaminants, and nuisance effects commonly associated with physical disturbances, dust and noise.

2.2 Land Use

Over 120,000 people reside in the industrial Cape Breton area, with the greatest density of population occurring in the former city of Sydney. The coal and steel industry attracted immigrants from a wide array of countries, resulting in the unique multiculturalism that is characteristic of today's community. Despite the trend in reduction in population that began in the 1980's, the Sydney area remains the regional capital.

Reliance on the coal and steel industries has been a cornerstone of the industrial base of Cape Breton, which also includes other industries such as retail and wholesale trade, forestry, fish processing and harvesting, and small manufacturing. Cape Breton communities also benefit from growth in the tourism sector, which is anticipated to generate \$1.2 billion in province-wide revenues in 1998.

Within the Muggah Creek Watershed, there is a mix of industrial, commercial, institutional, residential, and recreational land uses. Land use patterns have remained stable over the years with only marginal change in the last few decades. Commercial and industrial lands may have changed ownership but either continues as industrial or commercial lands, or is derelict. Residential areas as well have remained relatively constant.

In order to identify environmental issues associated with the Muggah Creek Watershed, it is necessary to gain an understanding of the history of industrial and community development that led to existing conditions. The following sections provide a summary of the historical development of the coking and steel operations, and the changes in land use and ownership.

2.2.1 History of Industrial Land Use

Although the current steel plant and the remaining industrial lands are currently under government ownership, this is a relatively recent development. Coal and steel operations in Sydney developed as private sector ventures, largely as a result of capital investment by offshore interests. Table 2.9 provides a chronology of important events in the development of the steel and coking facilities, that begins with the first sod turnings for the steel complex and continues to present day.

Table 2-9: Chronology of Events in the Coal and Steel Industry of Sydney, Cape Breton

Date	Activity
1893	Henry Melville Whitney establishes the Dominion Coal Company to solidify ownership of coalfields in Nova Scotia.
1899	July 1, Sod turning for construction of the Steel Plant Complex to be built by Dominion Iron and Steel Co. Ltd. (DISCO). The Plant would become the largest primary iron and steel-making facility in Canada for its time.
1900	No 1 Battery commences operations November 23, employing 400 Otto-Hoffman type ovens located over the present raw coal pile.
1901	First steel tapped at the Plant. Construction of four more blast furnaces and 10 open-hearth furnaces continues.
1902	Whitney sells his shares to James Ross and Sir William Van Horne (the other shareholders)
1903	Dominion Tar and Chemical (DOMTAR) begins its tar recycling plant. DOMTAR was to produce creosote, pitch, sulphate and ammonia. Information on the main waste streams of the operation is sketchy; but it is believed coal tar was produced by the Coke Ovens in quantities that approximated 18,000 to 20,000 IGAL/day. The main waste products of the Coal Tar Plant were reported as naphthalene and ammonia liquor, likely disposed of in Coke Ovens Brook
1904	DISCO builds both rail and rod mills with the hope of increasing sales to Central Canada, but the mills were not large enough to handle the quantity of iron and steel production, and failed.
1905	Sydney Cement Company establishes a plant on the eastern shore of Muggah Creek.
1907	Dominion Iron and Steel Co. Ltd. (DISCO) sues Dominion Coal Co. due to the poor quality of the coal and coke. DISCO wins the court case and takes over ownership of the Coal Company. Dominion Steel Corp (DOSCO) is later formed as a holding company for both corporations (1910).
1909	New blast furnaces are built.
1910	Wire and nail mills are built.
1911	Alexander Cross and Sons Ltd. build a fertilizer plant on site, in the area of the current L. E. Shaw property.

Date	Activity
	No. 2 Battery commences operation February 24
1912	Two mixing furnaces are built at the Steel Plant.
1918	No. 3 Battery commences operations on October 12, utilizing Koppers-Becker type ovens.
1920	Dominion Iron and Steel take over Sydney Cement Company. No. 1 Battery is demolished.
1921	Dominion Steel merges with Nova Scotia Steel and Coal Co. to form the British Empire Steel Co. (BESCO).
1924	City of Sydney leases land for Asphalt Plant and City Dumping Site.
1927	No. 4 Battery commences operation (utilizing Koppers-Becker ovens) constructed in line and east of Battery 3.
1928	Dominion Steel and Coal Corp. (DOSCO) take over BESCO.
1930	Warren Paving Company establishes a plant on site (the year of close is not available) DOSCO is established to run the Steel Plant. in 1931 the President was Sir Newton Moore
1931	Alexander Cross and Sons Ltd. close.
1934	Isle Royal Gas and Oil Company establishes a gasoline station on site (the year of close is not available).
1937	L'Air Liquid Society establishes a plant on site, which is still present.
1940	A Union of SteelWorkers emerges.
1944	Canadian Oil Company Ltd. opens a facility on site, presumed to be for product storage.
1946	Shell Oil Company opens a facility on site, presumed to be for product storage.
1949	No. 5 Battery commences operation in September encompassing 53 Koppers-Becker Underjet low differential type ovens.
1950	DOMTAR tanks are cleaned of their contents.
1951	Canadian Oil Company Ltd. closes and the lands revert to DISCO.
1952	Arthur Lipton Metal Processors Ltd. establishes a plant on the old Sydney Cement Plant site. L.E. Shaw Ltd. establishes a plant on the old fertilizer plant site. Still present.
1953	Shell Oil Company closes and property is absorbed by DISCO. No. 6 Battery commences operations utilizing 61 of the Koppers-Becker type ovens. Batteries 2, 3, and 4 were in operation when No.5 was built, after No.5 commenced operation, No. 2 was shut down. When No.6 began operating, batteries 3 & 4 were demolished.
1957	DOSCO is purchased by A.V. Roe Canada Ltd., a subsidiary to Hawker Sidley Corporation of England.
1959	Arthur Lipton Metal Processors Ltd. closes.
1961	The world steel market undergoes a slump. The Plant workforce falls from 5400 to just under 3000 employees.
1962	June, DOMTAR closes, but the tank farm and tar lagoon remain.
1968	April, Hawker Sidley announces closure of the Steel Plant. October, the "Parade of Concern" takes place to get governments attention and aid The Coke Ovens Complex is sold to the Cape Breton Development Corp (DEVCO), a federal crown corporation that runs the coal mines within the Sydney Coalfield The Sydney Steel Corporation (SYSCO) is incorporated by a special act of the provincial legislature and subsequently is the new owner of the Steel Plant.
1969	SYSCO achieves one million tons of production in one year.
1970	Premier G.I. Smith unveils a \$92 million modernization program for the Plant.
1971	DEVCO fails to provide sufficient coke for SYSCO, forcing SYSCO to buy from European markets. Subsequently SYSCO sues DEVCO for \$46 million.
1974	The Coke Ovens are returned to SYSCO ownership, at a cost of \$10 million.
1975	The Steel Plant downsizes due to market conditions.
1980	First scientific signs that the Tar Ponds are a serious environmental hazard.
1981	No. 5 battery shuts down and No. 6 goes into partial operations.

Date	Activity
1981 (cont'd)	The Tar lagoon, formerly owned and used by DOMTAR, is emptied of coal tar but there is no record of where the material was deposited. The lobster fishery in the South Arm of Sydney Harbour is closed.
1983	No. 6 Battery is taken out of operations in October, but kept on hot underfire using propane.
1984	Modernization Program of the Steel Plant begins rebuilding Blast Furnaces.
1985	September, No.6 Battery begins partial operations. The Federal Government unveils a \$40 million grant for clean up of the Muggah Creek Area, conditional on permanent closure of the Coke Ovens by 1988 Acres undertakes the first groundwater investigations
1986	Federal/provincial agreement for clean-up of the Tar Ponds was signed.
1987	Phase 2 of the modernization continues with conversion to electric arc furnace. (Total cost of modernization, \$290 million) The ten-year, multi-million dollar clean up of the Tar Ponds begins, comprising excavation, pumping, and incineration of the contaminated materials.
1988	February, No. 6 battery closes for the final time. Demolition begins as part of the Tar Ponds Clean up. Nolan Davis and Associates and Jacques Whitford and Associates undertake additional groundwater investigations on the Coke Ovens property. DOMTAR tanks are demolished except for one tank which is still present SYSCO workers go on strike, ceasing all operations at the Plant
1989	January, announcement of closure of the Blast Furnace. June, the Open Hearth Furnaces make their last "heats" and a new electric arc furnace and universal mill are under construction. The Electric Arc Furnace started operation in December, 1989.
1990	January, Premier John Buchanan writes off the Plant's \$785 million debt and says the Province would agree to a plan to sell the Steel Plant to private industry.
1991	Premier Donald Cameron sets up a committee to find a buyer for the Plant. The Tar Ponds Clean-up Incinerator is completed.
1993	April, SYSCO sells about 6000 acres of land to the Nova Scotia Government (land already owned through its Crown Corporation) for \$1.6 million, including 275 acres of surplus land that includes the Coke Ovens Site and the Tar Ponds. (Also included in the sale were lands in North Sydney, Sydney Mines, Point Edward, Port Morien, Grand Narrows, Johnstown, Marble Mountain, Orangedale, Catalone, Irish Cove, Frenchvale, New Campton, Sydney River, Grand Lake, Thorburn, Stellarton, Westville, Springville and Bird Islands.) Mid-year, controversy erupts over the proposed sale of the Plant to Chinese interests. November, an agreement in principle is struck with the Chinese firm Minmetals to purchase the Steel Plant.
1994	The Tar Ponds Clean-up Project is turned over to the Crown Corporation, Sydney Tar Ponds Clean-up Inc. (STPCUI). Original concept is deemed unworkable and new approach is sought. Total costs to date are approximately 52 million dollars.
1995	An additional \$203 million debt is written off SYSCO's books. This amount represented debt that had accumulated since 1990.
1996	Minmetals, apparently dissatisfied with government ownership and plant management pulled out of the deal. Negotiations begin with Global Holdings Inc. (comprised of five Canadian and two American Investors). An Encapsulation Project is proposed, approximate cost \$20 million. This option is rejected and the Tar Ponds Clean-up Project is abandoned. The Joint Action Group on Environmental Clean up begins.
1997	Pre-design for a sanitary sewer interceptor to remove the raw sewage outfalls from Tar Ponds is initiated. A yearlong Leachate study of the City Dump is initiated. A Material Sampling Project of the remaining above ground structures from the Coke Ovens is initiated.
1998	Less contaminated structures are removed from the Coke Ovens Site. The Phase 1 Site Assessment of the Industrial Lands in the Muggah Creek Watershed is initiated.

Date	Activity
1998 (cont'd)	<p>Sydney Tar Ponds Clean-up Inc. (STPCUI) changes its name to Sydney Environmental Resources Limited (SERL). SERL retains ownership of the incinerator, but they no longer have a mandate to clean up the Tar Ponds.</p> <p>Demolition of derelict structures at the SYSCO site, including the blast Furnaces, Open Hearth Furnaces, mills, storage buildings and loading/unloading piers.</p> <p>Management of SYSCO taken over by Hoogovens, for a six month trial period.</p>

2.2.2 Ownership

Within the boundaries of the area designated as the Study Site, federal and/or provincial governments currently own all property. Within the boundaries of the Area of Investigation, some properties that were once owned by the Steel Plant or the City of Sydney may have been leased or bought by other industrial users. Such industries included; Sydney Cement Company, Fertilizer Plant, Alexander Cross and Son, Asphalt Plant, City Dump, Warren Paving, Isle Royal Gas and Oil, Arthur Lipton Metal Processors, and L.E. Shaw. Adjacent, or neighbouring lands that have been, or continue to be, used as industrial lands are largely in private ownership, with the exception of lands held by Federal and Provincial crown corporations.

At present, properties, which abut the Study Site, are owned by various owners and have various commercial industries located on them. Table 2-10 provides a list of commercial properties and owners; the category of property ownership identified in Figure 2-9. A more detailed display of property owners is provided on Plan 2, in Appendix E attached at the back of the report.

It is not anticipated that the existing commercial land uses will contribute any significant contaminants to the area. Contamination that may or may not be present on these sites is more likely to have been generated by past industrial practices than by current operations and activities.

Table 2-10: Summary of Property Ownership

Reference Number	Owner	Activities/Operations
1.	Department of National Defense	Militia Base
2.	Imperial Oil Ltd.	Imperial Oil Tank Farm and Distribution Station
3.	Cape Breton and Central Nova Scotia Railway Ltd.	Rail Station and Waterlot
4.	Canadian National Railways	Rail Station
5.	Atlantic Shopping Centers	Sydney Shopping Center
6.	Atlantic Shopping Centers	Prince Street Plaza
7.	Mr. Tire	Mr. Tire Outlet
8.	Sydney Pensioners Club	Sydney Pensioners Club Building
9.	Sydney Boys and Girls Club	Sydney Boys and Girls Club Building
10.	Emerald Isle Sales Ltd.	Vacant
11.	Northern Holdings Ltd.	Plaza Lincoln Mercury
12.	Airport Transfer Ltd.	Acadian Lines Bus Depot
13.	Ryba Edward	Optometry Office
14.	Cape Breton Regional Municipality	Vacant Land
15.	City of Sydney	Recreational Field
16.	Nova Scotia Department of Supply and Services	Centre Scolaire de L'Acadie
17.	Steel Workers Union (SYSCO)	Steelworkers Union Hall
18.	L.E. Shaw	L.E. Shaw
19.	Frederick Pledge	Light industrial truck lot and garage
20.	Disco Tire	Disco Tire
21.	McIntyre's Chev-Olds Ltd.	McIntyre Chev-Olds Car Dealership
22.	Dumac Ltd.	Atlas Auto Products
23.	Cape Breton Regional Municipality	Cape Breton Regional Municipality Depot
24.	Nova Scotia Economic Renewal Agency	Coke Ovens Site
25.	Vulcan Properties	Schartz Furniture and the Red Cross
26.	Nova Scotia Department of Transportation and Public Works	Registry of Motor Vehicles
27.	Leisure Gardens Investment Ltd.	Leisure Gardens Hall
28.	Hashem's	Scrap Yard
29.	Economic Renewal	Building
30.	Cape Breton Development Corporation	Mullins Bank
31.	SYSCO/Government of Nova Scotia	Vacant
32.	Nova Scotia Power Inc.	Nova Scotia Power Depot
33.	NS Economic Renewal Agency	Tar Ponds Incinerator
34.	SYSCO/Government of Nova Scotia	The SYSCO steel plant and associated lands
35.	Cape Breton Regional Municipality	Municipal Landfill and Incinerator
36.	Seaver Realty Limited	Vacant Lot
37.	CBDC Rail Link	Rail lines

2.3 Site Area Facilities and Operations

This Section provides a description of former and existing facilities in the Site Area, as well as former and existing facilities within the Investigation Area that may have provided contaminant inputs to the Site Area. To better aid understanding of the existing or potential sources of contamination, a brief description of the activities, which took place in each area, is also provided. Numbers beside a facility correspond with numbers on the air photos (circa 1975) contained in Figures 2-10 to 2-12.

2.3.1 Above Ground Facilities

2.3.1.1 Coke Ovens Site

The Coke Ovens facilities (*Figures 2-10 and 2-11*) were located south-east of the main (or lower) steel making and rolling facilities and across a main thoroughfare (Victoria Road). From a logistical and material-flow point of view, it was an unusual layout. In standard steel plant layouts the Coke Ovens would be located before or near the blast furnace facilities. In SYSCO's case, they were at the extreme opposite end of the plant. However, both raw materials and finished products were transported to and from the site by both ship and rail explaining the site layout.

The Coke Ovens plant was laid out in a nominal south-east to north-west alignment with material and process flow in a nominal north-east to south-west direction.

Water for the facilities at the Coke Ovens Site and DOMTAR was supplied by a pipeline from Grand Lake. Grand Lake is located to the east, just outside the Muggah Creek Watershed Boundary.

2.3.1.1.1 Coal Stocking Area (22)

Coal was delivered to the Coke Ovens by rail and by large, off-road handling vehicles. Cape Breton coal was delivered by rail, dumped from a trestle and lifted and stocked by a bridge crane.

In later years front-end loaders and bulldozers replaced the bridge crane. Non-local coal (primarily American and Western Canadian) was delivered by ship to the raw material receiving dock at the lower steel plant, temporarily stockpiled behind the blast furnace and transferred by surface vehicle to the Coke Ovens stockyard.

2.3.1.1.2 Coal Crushing and Blending

Coal was lifted from the stockyard by conveyor (16) to a crushing and blending plant (17) where high-volatile and low-volatile coals were mixed together. The plant consisted of two storage bins at the top of the building (one for high volatile coal, one for low-volatile) which fed via two metering belts to two opposing hammer mills which crushed the coal to approximately 80% -1/8" size. If more than one high volatile coal was used, they were rough-blended in the stockyard and lifted together to the high volatile storage bin.

The crushed and blended coal was then lifted by a continuation of the conveyor system to the storage coal pocket (8) on top of the coking batteries.

2.3.1.1.3 *Coke Batteries*

Coal was fed from the storage pocket to the individual coke ovens by a charging car (Larry car) which travelled on rails on the top of the batteries and charged the ovens by dumping the coal through charging holes at the top of the ovens.

When the coke making operation began in 1899, it consisted of Battery No.1, outfitted with 400 Otto-Hoffman-Type ovens. Battery No.1 was located on the North side of the Coke Ovens Site, approximately in the area most recently used for the raw coal pile. This battery was replaced between 1911 and 1927 with Batteries No.2, 3 and 4, each outfitted with 60 Koppers ovens. These batteries in turn were replaced with the most recent configuration consisting of Battery No.5 (7), built in 1949, and containing 53 ovens; and Battery No. 6 (9), built in 1953, and containing 61 ovens. The batteries were laid out end to end to enable the Larry cars to traverse both batteries. Both were of Koppers-Becker underjet design and contained 114 vertical slot ovens, with a total nominal capacity of 600,000 tons of coke per year.

In the ovens, coal was heated to 1200° C in a low oxygen environment to produce coke. The ovens were heated by coke oven gas, and a charge of coal would take some 18-24 hours to be fully coked. When the ovens were ready to be discharged, the doors were removed from either side and a pushing ram (on the south of the batteries) pushed the coke through the oven into a quench car (on the north side). The red-hot coke was then transferred in the quench car to the Quenching Tower (10) where it was sprayed with water until it had cooled to ambient temperature. Significant volumes of steam were given off by the quenching operation. The quenched coke was transported back to the battery area where it was side-dumped on an inclined brick-filled “wharf” on the north side of, and parallel to, No. 5 battery. From there the coke was fed onto a conveyor to the crushing and screening plant (12) where the coke was sized into its various components:

- Furnace coke, for the blast furnaces
- Nut coke for domestic use
- Pea coke for commercial and domestic use
- Fines, called “braize,” which were used in the sinter plant, boilers, or discarded if there was no use.

The coke was fed from the screening plant directly into rail cars for transport to the blast furnace or elsewhere.

2.3.1.1.4 *By-Products*

As the coal was heated in the ovens, volatile matter was driven off in the form of gas containing tar and other components. Each kilogram of coal used in the coking process produced only 75% of its weight in coke. The remaining 25% were converted to gas by the heating process. Coke oven gas from all of the ovens was drawn into a collector main that ran the length of the south side of the coke oven batteries where it was then extracted by an exhauster fan to the by-product area.

Gases from the coke ovens were sent to a primary cooling tank (4) where coal tar was precipitated and water was condensed from the gas. The water (flushing liquor), that was saturated with ammonia, was used to cool and flush the collector mains, removing any remaining heavy coal tar or other particulate material. The flushing liquor was diverted to a tar decanter area (5) where the coal tar was collected and

the flushing liquor recirculated. The coal tar was stored in tanks for future movement to the DOMTAR Plant.

The coke ovens gas was passed through an exhauster to the ammonium sulphate production area (4), where ammonia was removed from the gas by reacting it with sulphuric acid produced in the sulphuric acid plant (26). The ammonium sulphate produced was stored in the eastern area of the by-products building, for transport to the DOSCO fertilizer plant on Prince Street and use in the production of fertilizer. Later the ammonium sulphate was processed and bagged on site at the Coke Ovens.

From the ammonia absorption area, the coke oven gas was passed through a final cooling tower (2) to further cool the gas and remove naphthalene before final processing in the Light Oil Scrubber (27). In the Light Oil Scrubber, the gas was passed through an absorbent wash oil ("straw oil"), which removed the light oil. The wash oil mixture was circulated to the Benzol Plant (18) where the light oil component was removed by steam distillation. The cleaned wash oil was then re-circulated to the Coke Ovens scrubbing tower. At the Benzol Plant, the light oil was refined into three main products: benzene (benzol), toluene (toluol), and xylene (xylol). (A less pure type of toluene, called 10 toluol, was sometimes made for special orders).

After the light oil had been removed from the coke oven gas, the clean gas was pumped through a gas holder (6). This gas holder had only a nominal storage capacity and was in reality a pressure regulator. Gas was circulated from the gas holder to the Steel Plant as a heating fuel (about 60% was used for battery underfiring and the balance went to the Steel Plant for reheat furnaces, boilers, etc., or was vented to the environment).

2.3.1.1.5 DOMTAR Plant

Dominion Tar and Chemical Company operated a coal tar processing plant on 3.3 hectares of the Coke Ovens property in the period from 1901 to 1963. Coal tars from the coking process were stored on-site in above grade storage tanks, with a possible overflow into a shallow lagoon. One lagoon, covering an area of 0.4 ha, was constructed in the mid-1940's. A second, smaller lagoon was constructed in the early 1960's. Over the operational life of the facility, there were some 17 tanks (21) built to store coal tar prior to sale and shipment off site. The majority of facilities at the DOMTAR plant were demolished in early 1988, however one 500 kilolitre, above-grade tank remains at the site. This tank has been used as a repository for materials (sludges and tank bottoms) taken from the other 16 tanks and other structures as they were demolished. The Tank was sampled (CBEG, 1997) and contains an estimated 1.3 million litres of low level contaminated liquid, 92 thousand litres of sludge, and 2.2 million litres of a solid material. The sludge and solid material was found primarily to be contaminated with PAH's and hydrocarbons. As the tank remains uncovered, during rainfall events it regularly fills with rainwater and spills onto the surrounding ground.

2.3.1.1.6 Benzol Plant and Storage Tanks

Between 1920 and 1940, a light oil and benzene processing plant was constructed on eight hectares in the western area of the Coke Ovens Site. The facility included two 20m diameter above grade benzene storage tanks, and several underground storage tanks for light oils. The underground storage tanks were removed, intact, in 1989. A new above-grade tank, (23 m diameter, 16 m height) for storage of crude light oil was constructed in 1983. This tank remains on the site.

2.3.1.1.7 Miscellaneous Structures

Other structures on the Coke Ovens site included a water stand-pipe (24), exhaust stacks for No. 5 (13) and No. 6 (14) batteries (50 m and 63 m high), a Coal Wash Plant (23) (abandoned in the late 1950's or early 1960's), the Coke Oven Offices (19), and the remains of an old Silica Brick Plant (20).

2.3.2 Below Ground Structures

During the demolition of the structures at the Coke Ovens site, a NSDOE memorandum, dated June 15, 1988, indicated that representatives of Phillips Barratt Kaiser had located and traced most of the underground piping, lines and sewers. No record of this work was found in the current investigation, however the location of storm sewers, outfalls, sanitary sewers, drains and underground product lines have been copied from blueprints located at SYSCO. These services have been shown on the attached Figures 2-13 and Plan 4. The dates of the information on these engineering drawings were difficult to determine. For instance, a blueprint with the date March 1927 showed the new Benzol Tank, which according to the 1997 CBEG report was constructed in 1983. Therefore, it has been assumed that available blueprints of site facilities and below ground structures are records of as-builts continually being updated. Some cross referencing was also required to determine proposed structures from those which had actually been constructed.

The location of sewers on the SYSCO site which drain into Muggah Creek have also been indicated, since these represent inputs to the Site Area. Services from the other areas of the SYSCO site drain to Sydney Harbour.

The 1990 O'Halloran Campbell study identified the outfalls into Muggah Creek, as indicated on Figure 2-14. On the east side of the estuary the outfalls adjacent the Ferry Street bridge correspond to the indicated services for the SYSCO and Coke Ovens sites. On the west side of Muggah Creek, some outfalls may be associated with the Railyards. The 1998 MGI Limited report indicated no details of the underground services were available. In this report two storm drains associated with the Railyards were identified. An outlet east of the repair shop was believed to be the drain from the oil-water separator connected to the drip trays at the refueling area. An outlet west of the repair shop was believed to be connected to a catch basin on the west side of the repair shop.

In addition to underground services, other underground structures were identified at the Coke Ovens site. The foundations for each of the former coke batteries remain in place and, based on field observations, appear flooded. There is no indication that any of the below ground foundations for structures at the site have been removed, after the structures were demolished.

Underground storage tanks at the Benzol plant were reportedly removed during the demolition work carried out in the late 1980s. This was confirmed in telephone conversations with NSDOE personnel who were on site during that time. In an interview with a former laboratory chemist, it was reported that "straw oil", that was mixed with the coke oven gas to extract the light oil, was also stored in underground tanks located near the benzol tanks. In an interview with a former benzol plant operator, it was reported that there were 10 to 12 smaller tanks, which had been buried to the top of the tanks, in addition to the two large above ground tanks. Others described the area of the partially buried tanks was described as a mound.

2.3.3 Storage

The principal materials stored at the Coke Ovens Site were coal, coke, sulphur, ammonium sulphate, and liquid by-products. Coal was stored in the stockyard, the Coal Storage Runway (22), and Mullins Bank (11). Liquid by products of the coking process were stored in buried tanks at the Benzol Plant (light oil, intermediate product, toluol, xylo) and in the Benzol Storage Tanks (11) (finished products). Small amounts of sulphur were stockpiled at the Sulphuric Acid Plant (26).

Coke was not normally stored at the Coke Ovens Site. However, in the latter years of operation, perhaps because of decreased demand at the blast furnace, or to build up stocks because of the impending closure of the ovens, coke was stocked in several areas on the site (25), including the Coke Storage Area.

2.3.3.1 Coke Storage Area

The Coke Storage Area (CSA) was an area of some 6.3 hectares located between the coal wash plant and the coke ovens. Believed to be the site of a battery of ovens (possibly Battery 2) built at about 1911, the CSA was operated from the 1960's to 1988. Foundations for the old batteries may be located beneath the remaining coke, brick and steel debris.

2.3.3.2 Mullins Bank

The Mullins Coal Bank was located on the southern perimeter of the Coke Ovens site, and was used for the storage and transfer of coal during the period from 1930 to the late 1980's. The site covers some 32 hectares and consisted of a rail accessible coal storage and transfer bank. Owned by the Cape Breton Development Corporation, remaining coal has since been removed from the area and the site has been decommissioned, graded and seeded.

This work was actually an exercise to reclaim coal by a local contractor. The storage bed was removed to "brown" earth. The material was taken off site to be processed. The subgrade was regraded to drain with no standing water and seeded. There was no testing to assess the conditions of the soil remaining at the site.

2.3.3.3 Coal Storage Runway

Coal was stored in a nine hectare area on the northern perimeter of the site, from approximately 1920 to 1988. The location was the site of the original coke ovens, which had ten batteries of 40 ovens each. The coke ovens in this location were demolished in about 1920 when Batteries 2 and 3 were constructed. Coal was stored in the area after this time, although there are no direct records. A coal trestle ran the length of the area. The silica brick plant was located in the western end of the site.

2.3.4 Services

In addition to the operating facilities, the Coke Ovens had a full complement of Service Shops (Figure 2-10) (3) and a Boiler Plant (15) whose primary purpose was to produce steam for the Benzol Plant and other process requirements. In earlier years, a brick plant on site (20) produced silica brick for the ovens.

2.3.5 Wells

During the course of the Sydney Tar Ponds Clean-Up Hydrogeologic Assessment (1990), a domestic water well survey was performed by Acres Limited. A total of 476 properties were identified in the area surrounding the Coke Ovens site. Potable water for the majority of the residential properties was supplied

by the City of Sydney municipal services. A total of 17 potable water wells were identified in the immediate area of the Tar Ponds, including two commercial wells. Of these, seven wells were reported to be no longer in use. Ten wells were still in use as the primary domestic water supply.

The 1990 hydrogeologic assessment also identified three relatively large scale groundwater extraction wells within the Coke Ovens Brook watershed: CFB Sydney; the McDonald's Restaurant and the Crystal Springs Commercial Bottler. Two deep wells at CFB Sydney, a Department of Defence facility located on Lingan Road, are located on high ground about four kilometres north of the Coke Ovens site. The report indicates these wells are 180m deep and produce 525 m³ per day. The McDonalds Restaurant is located at 417 Welton Street. This well is 57 m deep. The Crystal Springs well, located at 164 Maloney Street, is an artesian well. These public wells would be expected to have had analyses performed at regular intervals.

It was determined in the course of the current study that the Crystal Springs well is now owned by Sparkling Springs and that the well is being used as a commercial source of water. According to personnel at the McDonalds Restaurant, the well at the Welton Street outlet is no longer in use.

The locations of potable water wells in the Study Area were taken from a map supplied by NSDOE for this study and are indicated on Figure 2-15. There is probably limited analytical data for these wells, if any. In current practise, water samples from the well would be analysed when the well was installed. Additional domestic wells identified in the 1998 Lower Frederick Street study have been added to Figure 2-15.

Monitoring wells from a number of studies in the area of interest have been identified in the data review. The location of the monitoring wells in the area of the Coke Ovens site are indicated on Figure 2-16.

The monitoring wells T2 and T3 were installed in June 1984 during an investigation in which 25 other test holes were put down in and adjacent to Muggah Creek to examine the sediments. Monitoring wells T2 and T3 were put in the area of the DOMTAR plant for the purpose of determining the groundwater levels and obtaining water samples.

In March and April of 1985, 24 additional monitoring wells were installed in the area of the Tar Ponds (Acres 1985). Four of the monitoring wells extend into bedrock. Three of these wells (85-4, 85-8, and 85-10) are open BQ diameter boreholes below the BW steel casing. These holes extend to depths between 13.3m and 16.4m. One bedrock monitoring well, 85-6 consists of a PVC piezometer with the top at 13.57m depth. The remaining monitoring wells are shallow PVC piezometers in the overburden. According to the logs, the screened section of each well is less than 1 m long. The two shallowest wells, 85-13 and 85-20, extend to a depth of 2.5 m and 1.9 m, respectively. Nine monitoring wells extend to a depth of 3 m to 4 m. Seven wells (85-11, 85-14, 85-16, 85-17, 85-19, 85-21, and 85-23) extend to a depth of 4 m to 5 m. The two remaining wells, 85-15 and 85-18, extend to a depth of 7.09 m and 5.94 m, respectively. The details of the 1985 monitoring wells are summarized in Table 2-11.

BQ, NQ and HQ are designations for different sizes of rock coring diamond drilling equipment. BW, NW and HW are the corresponding size of casing through which the core barrel and drill rods extend to

do the sampling. BQ, NQ and HQ coring equipment produce a sample core diameter of 60.0 mm, 75.8 mm and 96 mm respectively.

Another drilling program was performed in 1988 to augment the preliminary groundwater investigations performed by Acres in 1984 and 1985. The details of the monitoring wells are provided in the 1990 Hydrogeologic Assessment Report for the Sydney Tar Ponds Clean-up. A total of 24 piezometers were installed at 16 locations on the Coke Ovens site. In addition, nests of two piezometers were installed at two locations beside Muggah Creek, which had been infilled with slag, (88-101 and 88-102) (Figure 2-16). The piezometers were installed using HQ drilling into bedrock at each site. All the piezometers consisted of PVC materials. It was noted some may need to be replaced with stainless steel due to the potential for degradation in the presence of some coal tars. These wells are designated as the "88 Series" (eg. 88-1, 88-2, etc). Details of the wells are provided in Table 2-12.

Table 2-12: Summary of Piezometer Construction Details.
Sydney Tar Ponds Hydrogeologic Investigation. (1988 Boreholes)

Piezometer Number	Top of* Protector Elevation (m)	Ground* Surface Elevation (m)	Bedrock* Surface Elevation (m)	Total Depth of Borehole (m)	Depth to Top of Sand Filter (m)	Well Point Installation	
						Depth to Screen	
						From (m)	To (m)
88-1	12.96	11.92	5.52	7.62	5.05	6.85	7.62
88-2a	12.56	11.46	3.18	9.81	8.00	8.25	9.18
88-2b	12.65	11.49	-	5.20	2.50	4.50	5.20
88-3a	14.42	13.41	8.81	10.7	9.10	9.18	10.70
88-3b	14.33	13.41	8.81	5.8	4.70	5.05	5.80
88-4a	13.29	12.59	7.41	9.78	7.90	9.00	9.78
88-4b	13.38	12.56	-	4.6	3.70	3.80	4.60
88-5a	12.47	11.68	7.2	20.01	15.05	16.80	18.40
88-5b	12.41	11.65	6.7	9.0	7.60	8.24	9.00
88-5c	12.34	11.55	-	4.6	2.60	3.84	4.00
88-6	17.13	16.22	9.41	8.3	6.80	6.85	8.30
88-7	21.16	20.46	13.16	9.6	7.52	8.84	9.60
88-8a	17.26	16.52	5.52	17.4	15.82	16.64	17.40
88-8b	17.20	16.43	6.68	11.1	9.38	9.58	11.10
88-9	19.66	19.02	15.66	4.9	3.60	4.14	4.90
88-10	15.48	14.66	8.62	8.1	6.45	7.34	8.10
88-11	16.37	15.58	9.58	9.09	6.00	8.33	9.09
88-12	16.37	15.73	8.4	8.91	8.00	8.14	8.91
88-13a	13.90	13.26	3.9	12.8	11.25	11.28	12.80
88-13b	13.81	13.32	-	7.3	5.95	6.54	7.30
88-14a	17.86	16.86	10.2	14.3	12.80	13.54	14.30
88-14b	17.59	17.01	10.3	8.2	6.00	7.44	8.20
88-15	27.56	26.68	23.7	6.7	5.18	5.25	6.70
88-16	17.40	16.43	14.6	4.7	3.08	3.08	4.70

Piezometer Number	Top of* Protector Elevation (m)	Ground* Surface Elevation (m)	Bedrock* Surface Elevation (m)	Total Depth of Borehole (m)	Depth to Top of Sand Filter (m)	Well Point Installation	
						Depth to Screen	
						From (m)	To (m)
88-101a	12.47	11.71	-11.3	24.8	23.80	24.04	24.80
88-101b	12.71	11.65	-	18.8	18.00	18.04	18.80
88-102a	4.05	3.08	-9.5	13.7	12.63	12.80	13.70
88-102b	3.93	3.11	-	9.5	8.00	8.31	9.07

Note *all elevations are geodetic

Only the details of the wells installed in the 1985 and 1988 studies have been listed. The details on the wells from the more recent studies were not readily extractable. The information has been summarized as well as possible in the text.

The locations of monitoring wells to assess the dump sites upgradient of the Coke Ovens site are also indicated on Figure 2-16. Five wells were installed for the 1987 Nolan Davis investigation for the municipal incinerator, PN-1 to PN-5. Six more wells (JAG97GW Series) were installed for the 1997 landfill leachate study. Six monitoring wells installed during the 1998 Frederick Street investigations, are also shown. Three of the Frederick Street wells, MW 1, MW 2 and MW3 were installed in test pits and would not likely be useful for monitoring purposes for a significant length of time.

The Final Draft Report of the 1998 CBEG Landfill Leachate Study indicated that a second, deeper, nested well was installed adjacent JAG97-GW4 and JAG97-GW5. This report also indicated other wells were constructed for study of the Incinerator Ash Disposal Site. Figure 2-1 of the Leachate Study shows that a well PN-2B was used as a background well. This may indicate that a second nested well was installed adjacent 87-2 (labelled PN2 in the 1987 report). Figure 7-1 from this report indicated a monitoring well PN-9. Subsequent investigation determined that ADI Nolan Davis installed five piezometers, numbered sequentially PN-6 to PN-10 in 1995. In 1998, CBEG installed another three piezometers, PN-11, PN-12 and PN-13. The location of these piezometer installations were provided on a sketch and these are shown on Figure 2-16. No other details of these wells, or of the ash disposal site investigations, were available for review.

Ten monitoring wells were installed at the former Canadian National Railyards for the 1994 Porter Dillon Study. These wells were screened from a shallow depth (typically about 1 metre) through the overburden into the surface of the bedrock. The wells were constructed with PVC materials and extended to a depth of 3.2 m to 7 m.

Eighteen monitoring wells were installed at the Railyards in 1997 (MGI Limited, 1998). Two pumping wells were also installed for this study. The monitoring wells were constructed with 50 mm ID PVC materials, while the pumping wells were constructed with 100 mm diameter PVC materials. Fifteen of the monitoring wells were installed in the overburden at depths of 2.1 m to 6.1 m. Three monitoring wells were installed in the weathered bedrock. The bedrock wells were sealed in the bedrock while the overburden wells were screened from about a depth of 0.75 m to the depth of the well. The pumping wells were installed in the overburden at depths ranging from 5 to 5.3 m.

The locations of the monitoring wells on the Railyards property are indicated on Figure 2-17.

2.3.6 Waste Disposal and Known Spill Sites – Site Area

Over the years of operation of both the Steel Plant and the Coke Ovens, by-products which were no longer marketable often became waste. Waste materials were disposed of at a number of locations, both on and off the Site Area. Additionally, interviews with former workers at the site indicates that operational practice at the Coke Ovens made spillage a regular occurrence, one for which accurate records were not kept. The following sections discuss known and potential areas of contaminant concentration on the Site Area.

2.3.6.1 Coke Ovens Site

Earlier studies have indicated that a surficial granular fill from one to two metres thick covered most of the Coke Ovens site (Acres, 1985). The fill was described as fairly pervious, with a gravel texture and composed primarily of slag and brick fragments. Many samples were impregnated with a tar-like residue. Visible tar-like contamination was identified at the following locations:

- Along the north boundary of the site, north of the brick plant (MW85-4)
- Adjacent to the north side of the benzol plant (MW85-5, MW85-6 and MW85-15)
- At Battery 6 (MW85-16 and MW85-17)
- Located adjacent the east side of the coal washing facility (MW85-19)
- At the south-east corner of the sulphuric acid plant (MW85-21).

Most of the visible contamination was in the surficial granular fill, but in the three wells adjacent to the benzol plant the visible contamination was identified in the underlying till.

In the 1985 study, virtually all the shallow groundwater samples within the Coke Ovens site displayed PAH concentrations in the range of 24.5µg/L to 802µg/L. The highest levels were recorded in the wells in the area of the coal stockpile. High concentrations of PAH impact extended to the groundwater samples taken from the four bedrock wells at depths of up to 15 m. The four deep monitoring wells (MW85-4, MW85-6, MW85-8 and MW85-10) had groundwater PAH concentrations ranging between 24.5 µg/L to 210.2 µg/L.

It should be noted that a later resampling and analysis of the groundwater in MW85-5, in the area of the benzol plant displayed a total PAH content of 890.8 µg/L, increased over the 107.2 µg/L in the 1985 sample.

The entire Coke Oven complex, including the DOMTAR plant site and the Mullins Bank, has been characterized as a non-point source of contamination as oils, coke braize and slag are distributed throughout the area (Nolan Davis and Associates and Jacques Whitford and Associates, 1990). The shallow bedrock aquifer was typified by hard, high TDS, calcium sulfate water influenced by long term acidic drainage from the coal storage areas and organic contamination from the various site operations. The ranges in concentrations of total organic indicators in the groundwater at the Coke Ovens site included:

- Total phenols <0.05 to 86 mg/L;

- Benzene <0.04 to 107,630 µg/L;
- Toluene <0.04 to 26,990 µg/L;
- Ethylbenzene <0.04 to 16,510 µg/L;
- Total xylenes <0.04 to 116,790 µg/L;
- Napthalene <0.04 to 209,680 µg/L;
- Total PAH 0.46 to 57469 µg/L;
- Total HNC 0.16 to 5575 µg/L.

Background concentrations for the compounds as provided by the report were:

- Total phenols <50 µg/L;
- Total BTEX <3 µg/L;
- Total PAH <0.4 µg/L
- Total HNC <0.4 µg/L.

BTEX refers to the compounds benzene, toluene, ethylbenzene and xylenes, while HNC are heterocyclic nitrogenous compounds.

Free LNAPL contaminants were also observed in a tributary to the site surface water drainage system which drains the Coke Storage area. The LNAPLs such as benzene and naphthalene appear to be associated with the benzol plant. LNAPLs are less dense than water and will float on top of the water table. Petroleum fuel mixtures are the most common LNAPLs.

The coal storage areas are considered to be very minor sources of organic contamination. High total PAH concentrations were identified through the fill around the coke batteries 2 to 6, but the report indicated that bedrock in this area was not heavily contaminated, attributed this to the relatively thick till cover and the low solubility and mobility of the PAH compounds.

The report stated that the solid sludge phase samples were typically compared with the CCME Guidelines for commercial/industrial sites in the soil category. Liquid phase samples were compared to the CCME Guidelines for the Protection of Freshwater Aquatic Life.

In 1997 the CBEG sampled a total of 21 locations over the area of the Coke Ovens site. The purpose of the study was to determine the extent of existing contamination associated with selective materials and structures which remained on the property. On the Coke Ovens site, the following areas were sampled:

- *Benzol Tank* - The tank contained a layer of wet sludge, roughly 5 cm deep, contaminated with hydrocarbons, PAHs and other organic compounds
- *Coal Pile Runway* - The sample of coal was within the CCME guidelines for a soil in a commercial industrial site, with the exception of a pH of 5.1
- *Coke Pile* - The composite sample displayed detectable levels of BTEX and all PAH compounds with benzo(a)pyrene above the 1997 CCME guidelines.

- *Sulphur Building* - The bright yellow material stored on the site was tested for PAHs, moisture content and sulphur content. The sulphur content was 98.4%. The PAHs were within acceptable levels when compared to the CCME Guidelines for soil for commercial/industrial sites.
- *Cooling Tower Grids* - Samples of the wooden baffles were analysed and displayed high hydrocarbon contents and elevated levels of phenols.
- *Steam Line between the Benzol Plant and the Steel Plant* – Samples of the insulation were tested but found no asbestos.
- *Two Stacks for Batteries 5 and 6* - Samples of the residue were analysed and displayed elevated levels of PAHs and phenols
- *Benzol Plant Area Tank* – Samples of water and sludge were analysed. The water displayed metal compounds above the CCME guidelines for freshwater aquatic life.
- *Coal Transfer Building*- A composite sample of the coal residue in the structure was sampled. In the composite coal sample only the copper and zinc compounds exceeded the CCME guidelines for an industrial site. Elevated levels of phenols and toluene were identified.
- *By-Products Building*- Four samples of dust were obtained from various locations in the building, a sample was taken from the side of the vessel and the siding material was sampled for asbestos. The dust samples had copper, lead and zinc above CCME criteria, as well as elevated toluene levels. The residue from the vessel had six PAH compounds in excess of CCME guideline and also displayed elevated BTEX levels. The siding tested as 35% asbestos.
- *Standpipe*- An open 20 cm diameter standpipe extending about 30 cm above grade and located in roughly the centre of the site adjacent Coke Ovens Brook has a constant flow of water which flows into the brook. The effluent from the standpipe was sampled and analysed for hydrocarbons, metals and general chemistry. The analyses displayed the presence of BTEX, TPH and uranium. The content of aluminium, selenium, BTEX, pH, iron and zinc were above the CCME Guidelines.
- *The lead content of samples of paint from the Water Standpipe and the Coal Transfer Building* exceeded the level of 10,000 mg/kg set by the N.S. Department of Labour.

The listing above indicates that various structures were contaminated with phenols. It should be noted, that this contamination has not been confirmed but it could not be ruled out due to the elevated detection limits in the analyses performed.

The 1997 Materials Sampling program by CBEG also sampled the Brick Storage area and timber from the wooden rail trestle which provided the main rail line for delivery of coal to the Coal Pile Runway. The bricks were disposed of above grade at the extreme eastern edge of the coal pile runway. Due to a breach in the bank of Coke Ovens Brook, stream flow contaminated with landfill leachate was directed into the brick storage area and ponded there. A composite sample of bricks collected from areas impacted from the Brook water were submitted for analyses. BTEX compounds were detected but at levels below CCME Guidelines. Phenols were detected but as indicated above, the elevated detection levels would not allow determination whether these levels were above acceptable levels. PCB levels were below the detection limits of the analysis. Samples of the wood from the trestle were tested for PAHs but the CBEG report concluded the results were within acceptable limits. The PAH contents were compared to the CCME criteria for soil. The report had indicated dioxins and furans were marginally over the CCME

Guidelines for soil in a residential/parkland area, however this was in error. Subsequent reviewers identified a mathematical error in conversion of the analytical results and it was determined that the actual dioxin and furan results were well below the CCME guideline of 0.001 ppm.

2.3.6.1.1 Surface Water

Contaminants entrained in coal tars and other substances were discharged to the Coke Ovens Brook from the coking operations. Some of the point and non-point sources of pollution which discharged to the Brook include (Acres 1991):

- The coke ovens site
- The tar plant (dismantled)
- The sulphuric acid plant (dismantled)
- The byproducts plant (mostly ammonium sulfate)
- The benzol plant
- Non-point source urban stormwater runoff
- Sanitary and storm sewers

Earlier studies on the water quality of Coke Ovens Brook have determined that it was contaminated with PAHs (dominated by; Naphthalene, Phenanthrene, Fluorene, and Acenaphthene), Benzene, Toluene, Ethyl Benzene, Xylene, Total BTEX, heavy metals, coal and coke fines, coal tar, and other material (Acres 1985).

Surface water discharges were sampled at ten locations on the Coke Ovens site in the Environment Canada (1980) study of the liquid effluent streams at SYSCO.

The drainage from the coal stockpile, located on the north side of the Coke Ovens site, adjacent to the DEVCO rail line and Frederick Street, displayed total suspended solids (average of 59 ppm) considerably below the range typical range for industry standards in Canada. The average total iron content in the run-off from the coal pile was 82 ppm, ten times the industry standard. The concentration of iron was attributed to landwash of high particulate fallout materials from the SYSCO plant, following a high precipitation event. The run-off waters from the coal stock pile were acidic (pH 3.1).

Quench water effluent from the coking operation exhibited no significant elevated levels of pollutants, however the average total phenol content of 7 ppb was above the current Freshwater Aquatic Life guideline of 1 ppb (Environment Canada, 1980). The average pH of the quench water effluent was 6.8.

Elevated levels of ammonia, phenol, cyanide, sulphide and thiocyanate were identified in the effluent from the final coolers at the coke plant located at the west side of Battery 5. The report noted that, although thiocyanate is only mildly toxic, in acid conditions cyanide emission can occur.

The 1980 study indicated that toxic levels of ammonia (1214 ppm), phenol (438 ppm), cyanide (41 ppm) and thiocyanate (275.7 ppm) were present in the effluent from the ammonia building. The average pH of this discharge was 8.6.

Since there was no direct contact with the process stream, the non-contact cooling waters from the benzol condenser and the benzol oil cooler at the benzol plant were not expected to be contaminated. Based on the analytical results reported in 1980, it is suspected that some leakage occurred (low pH at 4.9 and 5.0; and relatively high phenol content at 21 and 85 ppb). The discharge from the benzol crude separator contained a number of toxic substances, ammonia (14.4 ppm), phenol (5.55 ppm), cyanide (21.1 ppm), chloride (126 ppm) and thiocyanate (17.7 ppm). The report indicated the discharge from the benzol crude separator, 5000 Igpd, was relatively low compared to other sources of discharge from the SYSCO operations volume, but would require treatment.

The inflow of Coke Ovens Brook to the Coke Ovens site was sampled, and the results have been included in Table 2-13. The results are compared to the results of the water sample analyses in Coke Ovens Brook downstream of the Coke Oven site. This information can be considered only in the context of a snapshot in time, as concentrations may/will vary.

Table 2-13: 1979 Water Samples from Coke Ovens Brook

Parameter	Upstream of Coke Ovens Site 1979 (ppm)	Downstream of Coke Ovens Site 1979 (ppm)
PH	6.1	9.3
Suspended Solids	106	66
Total Dissolved Solids	459	173
Total Organic Carbon	8	71
Ammonia	0.9	269.3
Phenol	0.474	18.855
Cyanide	0.12	23.54
Oil and Grease	8.0	25.
Iron	5.36	8.07
Sulfide	0.2	119.6
Thiocyanate	1.4	52.7

Elevated levels of certain parameters in waters of the Coke Ovens Brook sampled upgradient of the Coke Ovens site were attributed to leachates from the municipal dump and the coal piles, and to leakage and spillage from mechanical equipment at these sites. The impact of the Coke Ovens site on water quality in Coke Ovens Brook is apparent when upstream and downstream samples are compared. Environment Canada (1980) calculated that the daily discharges during operating conditions from the Coke Ovens site to the Coke Ovens Brook included 334 kg of phenol, 4750 kg of ammonia, 418 kg of cyanide, 935 kg of thiocyanide and 450 kg of oil and grease.

It was noted that during the 1979 sampling period of this study, the By-products Plant was only partially in operation, resulting in a significant increase in the volume of pollutants discharged from the Coke Ovens site.

The most recent sampling work performed in Coke Ovens Brook was performed in the Washburn Gillis study with data collected between July 1990 and June 1994. The water samples were tested for pH, BOD, COD, TKN, suspended solids, PAHs, arsenic, cadmium, chromium, mercury, zinc, copper and lead. The

mean annual value of the pH increased from 6.2 to 7.0 over the last 3 years monitored. The annual mean mass flow rate of PAHs was relatively consistent for that period at 317.5 kg/year to 350.3 kg/year and consisted mainly of naphthalene. The metals monitored were generally below the CCME criteria or within the Canadian Water Quality Guidelines environmental range for typical surface waters in the Atlantic region. Review of the data indicates the number of samples exceeding the cited criteria for metals was less than 17 % per year, with the number of samples exceeding the criteria generally dropping each year. The sample size ranged from 54 to 24 samples per year.

2.3.6.2 DOMTAR

The DOMTAR Plant had operated from 1901 to 1963. During its history this Plant included 17 above-ground storage tanks and a 0.4 hectare above-grade lagoon. The 1997 CBEG report indicates the lagoon, constructed in 1945, was not always filled with tar, but was used periodically as a temporary storage lagoon. Although the Plant buildings had been demolished by 1966, coal tar remained in the lagoon until 1981, at which time most of the coal tar was removed. Some volume of the tar was left and encapsulated beneath a granular fill cover. Some of the tar has seeped out of the sidewalls of the lagoon, adjacent to the Victoria Road Overpass. Evidence of further seepage was observed in the surface of the fill cover during a walk-over inspection of the site conducted for this study.

The 1985 Acres report identified visible tar-like contamination in four of the five testholes put down at the DOMTAR site (85-T2, 85-T3, 85-12 and 85-13). The groundwater samples tested displayed total PAH contents ranging from 1.4 ppm to 78.1 ppm. The most heavily contaminated soil sample, from 85-13, displayed a total PAH content of 52.4 ppm.

The 1990 Nolan Davis/Jacques Whitford report concluded that the DOMTAR Plant is the most heavily contaminated area on the Coke Ovens site, with the highest concentrations of PAH, HNC and phenol. Contamination is reported to extend through the granular fill and the till to the bedrock in this area. Free coal tar as a DNAPL (dense non-aqueous phase liquid) was encountered in four piezometers at the DOMTAR site. The thickest accumulation (1.0 m) was located beneath the demolished tar tank farm. DNAPLs are slightly soluble and more dense and less soluble than water, properties which cause DNAPLs to sink through water. Various freons and several commonly used solvents including trichloroethene (TCE), perchloroethene (PCE) and methylene chloride are other examples of DNAPLs.

The 1997 Materials Sampling program by CBEG sampled materials contained within the remaining DOMTAR Tank. The tank is the only tank remaining of the 17 above ground tanks at the former DOMTAR Plant, and was the largest in capacity (500,000 L). This tank was used to store residual materials taken from other tanks on the DOMTAR and Coke Ovens sites when those structures were demolished. Since the remaining tank is not covered, the material contained within it is often covered with water from precipitation. The tank periodically overflows onto the ground. Solid material in the bottom of the tank is some 3.65 m thick, overlain by 14.4 cm of sludge and 2.2 m of liquid. Samples of the water in the tanks displayed twelve parameters in excess of CCME Guidelines including aluminium, lead, mercury, zinc, PCBs, BTEX, hexachlorobutadiene and 1,1,2-trichloro ethane. Test conducted on sludge and solids from the tank displayed BTEX, TPH, PAHs and phenol concentrations in excess of CCME/NSDOE guidelines.

2.3.7 Waste Disposal and Known Spill Sites – Investigation Area

Within the Study Area, and in consideration of past methods of waste disposal and spillage, there exists the potential for contaminant inputs from the industrial land uses, as well as from municipal sewers. Activities which may have contributed contaminants to the Site Area are discussed in the following Sections.

2.3.7.1 SYSCO

Since the 1980's a modernization program has been in effect at the SYSCO Steel Plant. The Program includes the construction of an electric arc furnace and universal mill, and the closure of the blast furnace, open hearth furnace, mills, and storage buildings, and the implementation of environmental controls. However, the Steel Plant has operated in one context or another for the better part of 100 years. During that period of time a considerable volume of material was deposited in the Study Area as slag, wastes, and air and water emissions.

2.3.7.1.1 Surface Water

As described previously, a monitoring study of the wastewater discharges from SYSCO was performed in 1979 by Environment Canada, and are summarized in a 1980 report. Samples were collected at 31 stations in the plant including the Coke Ovens operation. The location of the sampling stations are indicated on the attached flow schematic (Figure 2-18) and their locations are indicated on Figure 2-19. The results of the sampling were compared to the average Canadian data in the Preliminary Discussion Paper on Effluent Controls for the Steel Industry (1978).

The coke stockpile and iron ore stockpiles at SYSCO were located in the stockyard east of the blast furnaces. This area drained directly to Sydney Harbour and probably did not directly affect the Study Area. Water quality in the coke pile runoff generally compared favourably with the Canadian industry standards, however cyanide levels exceeded the current Canadian Water Quality Guidelines. Cyanide levels in the drainage from the iron ore stockpile were also slightly elevated, when compared with the coke stockpile, (0.8 ppm versus 0.6 ppm). The pH of the run-off from the coke and iron ore stockpiles was relatively basic at about 8.3.

Data obtained for the rolling mills during the 1979 sampling program was based on a two-shift-per-day operation. The report noted that at three shifts-per-day, the flows and daily discharge would be 50% higher. The Bloom Mill Scale pit has an independent discharge to Muggah Creek downstream of the Coke Ovens Brook. The pH of this discharge was 7.2. The average flow was 900,000 Igpd. The report indicated that the only contaminant of concern from the bloom mill scale pit was oil and grease at an average of 57 ppm, a daily discharge of 230 kg. The rod and bar, billet and rail mill scale pits all discharged to the cooling pond. The cooling pond effluent had a mean discharge of about 201,700 Igpd. The cooling pond effluent also displayed elevated levels of oil and grease averaging 1680 kg per day during the 1979 sampling period. The report recommended that the rolling mill discharges should have some form of oil and grease removal.

Current surface water discharges have changed from the time of the 1979 report. Both the blooming mill and rail mill are on a re-circulating water system. Neither mill normally discharge directly. Any effluent from these areas is from a blowdown off the water treatment plant. The quantity of this effluent is normally an order of magnitude lower than the quantity reported in the 1979 report, and the oil and grease

content is normally an order of magnitude lower. The water treatment effluent discharges to outfall '30' of Figure 2-14. Although the rod and bar mill are no longer in operation (since many years), there is still sometimes an effluent near the cooling pond. Since the pumping of Sydney River water is via fixed pumps, excess water is discharged via the bar mill to the outfall near cooling pond when demand is low. This flow can sometimes be substantial but the water is relatively clean. There is no 'industrial' discharge to the cooling pond any more.

The 1997 Materials Sampling program by CBEG sampled the cooling pond liquid. The Cooling Pond contained 20,400,000 l of water and 29,400 m³ of sludge. The analyses of the water sample indicated aluminium, copper, iron, lead, zinc and mercury at levels in excess of the Fresh Water Aquatic Guidelines. Elevated levels of seven phenolic compounds were also present. The sludge sample exhibited copper, lead, tin, toluene and TPH in excess of CCME Soil Remediation Guidelines for commercial/industrial sites. Elevated levels of PAHs and phenols were also detected.

SYSCO also had a significant wet lab. The waste drains for the lab discharged to Outfall #30.

2.3.7.1.2 Infilling

Slag has been produced at the SYSCO site since 1901, reaching an annual output of 300,000 tonnes by 1954. In the early days of steel production, slag was dumped into the Muggah Creek estuary, resulting in dramatic changes to the physical and biological shoreline. The slag piles also contained indiscriminate industrial wastes including scrap metal and other materials. Currently, recovery operations are reprocessing metals separated from the old slag area. Modern production processes have also reduced the volume of slag produced. In 1997 approximately 15,000 tons of slag were generated. During the same time period approximately 100,000 tons of slag were processed and sold. Slag is currently disposed of at the north end of the steel mill, southeast of the docks.

It should be noted that clean slag is a suitable aggregate for use as construction fill.

Since about 1989, after the blast furnace was taken out of service, the following materials are the primary refuse disposed at the slag dump or "High Dump":

- Mill scale – iron oxides that flake off of steel at high temperatures
- Slag
- Spent refractory brick – resulting from the reheat and electric arc furnaces and ladles
- Industrial refuse – wood, concrete and any other materials from demolition of structures

SYSCO has also had problems with employees dumping domestic waste at the site, however this practice has been discouraged. Any domestic refuse produced at SYSCO is transported to the municipal incinerator for disposal.

Dumping at the site was not closely monitored prior to 1989, therefore all of the various types of materials disposed at the slag dump before then are unknown, except for blast furnace flue dust and the materials discussed above.

A 1989 report by Acres detailed the results of a subsurface investigation performed to determine whether contaminated sediments occurred beneath the fill bordering the south-east shoreline of the South Pond of

Muggah Creek. It was acknowledged that the presence of contaminated sediments in the shoreline infill could present a long term contamination problem.

To examine this concern nine boreholes (Phase I) were put down at the locations indicated on Figure 2-20. The holes included two test holes put down in the area surrounding the Centennial Mall shopping Centre. Twenty samples were tested for PAH content. Five of the nine test holes displayed PAH contents above the CCME Remediation Guidelines for commercial/industrial sites. The sample tested from each of the two test holes at the mall location displayed elevated PAH content but the levels were below the commercial/industrial criteria.

It was concluded that the test holes confirmed the presence of tar pond materials under, but not within, the overlying fill. A phase II investigation was then performed in October 1989 by Acres and detailed in the Shoreline Investigation Report Phase II (March 1990). Twenty-six additional boreholes were put down at the locations indicated on Figure 2-20. The purpose of this investigation was to better delineate the extent and thickness of the both the contaminated material and the overlying fill. In addition, other goals were to obtain hydraulic information on the local groundwater system and determine whether the contaminated material under the fill is similar in its thermal characteristics to the tar pond materials.

The Phase II investigation confirmed contaminated sediments underlay the fill materials bordering the northeast and southwest shorelines of the North Tar Pond and that they also extend from Wash Brook up to the west side of the structure of the Sydney Shopping Centre as constructed in 1990. The report indicated the fill, along the northeast shoreline of the North Tar Pond, is underlain by 1 to 2 m of very loose to compact contaminated sediment. The fill thickness ranged from 7 m in BH-34 and MW 88-102, to in excess of 15 m at MW 88-101. Along the south west shoreline of the North Tar Pond, occupied by the rail yard, a layer of fill generally 1 to 2 m thick, close to the shoreline, was underlain by 1 m to 1.7 m of very loose to compact, fine, sand size, contaminated sediment. No contaminated sediments were encountered along the south west shoreline of the South Tar Pond. On the south east shoreline of the South Tar Pond, the layer of fill was found to be underlain by contaminated sediment in BH-2, 3, 4, 5, 8, 9, 18, 20, 21, 22, 26, 28 and likely 31. The contaminated sediments were about 1.5 m thick along the present shoreline of the South Tar Pond and along the former channel of Coke Oven Brook.

The information from the Phase II investigation also allowed the pre-Tar pond shoreline along the southeast side of the South Tar Pond to be better defined. The original shoreline is indicated on Plan 4 including the modifications from the 1990 report.

2.3.7.2 Muggah Creek Tar Ponds

In the 1985 study of the Tar Ponds by Acres, it was estimated a total volume of 765,000 m³ of contaminated sediment overlies the original bed materials of Muggah Creek. This estimate of the volume was revised in a 1988 Acres study to 550,000 m³. The thickness of the contaminated sediments measured in 31 boreholes ranged from 0.5 m to 4 m. The estimates of the volume of contaminated sediment do not include the volume of sediment covered by infilling along the shores of Muggah Creek particularly the large area infilled by slag.

Chemical analyses was performed on samples of the contaminated sediment in 1985 and 1987. The samples were analysed for, polycyclic aromatic hydrocarbons (PAHs), hetrocyclic nitrogen compounds (HNCs), and heavy metals content.

A total of 40 samples were analysed for PAHs for the 1985 Study. The average total PAHs by location were:

Area	Average total PAH (mg/kg)
Wash Brook Arm	3,700
Remainder of South	12,000
North Pond to Narrows	8,000
North Pond beyond	5,500

It was noted in the report that there was very little variation in PAH levels in the top 1.2m depth, with a noticeable reduction below this depth. Napthalene and phenanthrene accounted for 60% to 80% of the total PAH content with benzo(a)anthracene, pyrene, fluoranthene and anthracene next in order of relative abundance.

Coal tar is a by-product of the “coking” of bituminous coal. It is the primary distillate, and contains high concentrations of aromatic and polycyclic aromatic hydrocarbons (PAHs). Some coal tar has been known to consist of up to 48.5 % PAHs. Coal tar was included in the effluents discharged by the coking operation into Coke Ovens Brook, which discharges into the Tar Ponds and is the primary source of the contaminated sediments. Other sources of coal tar included the Dominion Tar and Chemical Plant (dismantled in 1963), two tar storage ponds and the Coke Ovens Chemical Plant.

The Muggah Creek Tar Ponds have been identified as the major source of PAH release to the Sydney Harbour environment. PAH contamination of the Harbour led to the closure in 1982 of the local lobster fishery in the South Arm.

In 1992 testing on the first quantities of sediment excavated, in the compliance sediment sampling program by Washburn Gillis, as part of the Tar Ponds Clean-up, displayed unexpected concentrations of PCBs in excess of 50 ppm. A field sampling program was performed to delineate the area of PCB contaminated sediment (Acres, 1992). Sampling was performed on a grid and the results of the analyses are summarized on Figure 2-21. The results are reported on a dry weight basis which would be higher, therefore more conservative, than the in-situ concentration measured on the wet weight. The sampling was normally performed over the top 0.38 m depth. The PCB concentration appeared to drop off with increasing depth with the highest concentrations occurring in the top 8 cm to 28 cm depth. The volume of the sediment contaminated in excess of 50 ppm PCBs was determined to be in the order of 4800 m³ distributed over a 1.2 hectare area.

Additional field studies were performed in 1995 and 1996 to delineate the extent of the PCB contaminated sediments. The PCB Delineation Report (JWEL-IT, 1996c) defined and estimated the extent of PCB contaminated sediments (concentrations greater than 50 mg/kg. The report augmented existing data with 764 samples from 235 boreholes, and estimated the volume of PCB contaminated

sediment. A total of eight areas of PCB concentrations in excess of 50 mg/kg were identified. The locations of the eight areas are indicated on Figure 2-22.

Based on this work the estimate of the amount of PCB contaminated sediment was increased. The four areas in the North Pond are estimated to contain 33,400 tonnes of PCB contaminated material above 50 mg/kg, while the four areas in the South Pond are estimated to contain 11,200 tonnes of PCB contaminated material above this concentration. Two thirds of the estimated total PCB sediments were reported to occur in Area 5, between the former Canadian National Railways railyard and Battery Point, and along the north-west shore of the South Pond. In this area, the PCB contaminated sediments are present in a thin seam, at depths ranging from 0.2 m to 2.0 m below the creek bottom. Due to the depth of burial, excavation of the PCB sediment was estimated to require excavation of 97,000 m³ of sediment.

In Areas 1 and 2, identified in the Acres report, the horizontal extent was slightly increased and the estimate of vertical extent determined to be much greater than previously thought. A maximum depth of PCB contamination of 1.7 m was found near holes AH02 and AH03 in Area 2 with an average depth of 0.6 m. In Area 1 the depth of PCB contaminated ranged from 0.2 m to 1.6 m.

In the JWEL-IT work 50 samples of sediment were taken for PAH analyses. When compared to the 1985/87 data sets it appeared there had been a slight decrease in the total PAH concentrations. The amounts of naphthalene and phenanthrene appeared to have reduced to about 46% of the total PAH attributed to the higher solubilities of these compounds. In the upper depth interval, the top 0.6 m of sediment, the PAH concentration appeared to have dropped in the South Pond, with an average of 7590 mg/kg, and increased in the North Pond, with an average of 13970 mg/kg.

The 1996 JWEL-IT report indicates the PCBs detected were identified by the lab as resembling Arochlor 1260.

A study by O'Halloran Campbell (1990) indicated there were 36 piped sanitary or storm sewer outfalls into Muggah Creek (Figure 2-14). Twenty-eight of these outfalls are located on the west side of Muggah Creek. Fifteen of these 28 (No.1 to 4, 13 to 15, 17 and 22 to 28) are either part of the Sydney sewer system, or display significant flows. The remaining 13 pipes displayed no significant flow and often appeared to be silted in.

Only one of the eight outfalls (No. 33) on the east shore of Muggah Creek appeared to be inactive.

Two outfalls (No. 15 and 29) showed evidence of flow containing chemical/industrial waste. Outfall No.15 showed traces of hydrocarbons. Outfall No.29 contained calcium hydroxide, a by-product from the process at the Liquid Air plant. The report indicated the calcium hydroxide is non-toxic. The Emergency Response Guide for Dangerous Goods (1979) confirms that there is little health hazard to CaOH but indicates it is toxic to fish.

2.3.7.3 Railyards

In 1993, the Emergencies and Enforcement Branch of Environment Canada conducted an investigation of the former Canadian National Railways property on the west shore of Muggah Creek, currently owned by Cape Breton and Central Nova Scotia Railway. The investigation was conducted in response to a CEPA

section 118 complaint, and was very small in scale. The only compounds evaluated were PCBs and petroleum hydrocarbons, and only surface samples were collected. The investigation concluded that the site was not contaminated with PCBs or other substances regulated by the Canadian Environmental Protection Act. Soil samples from this investigation did however indicate petroleum hydrocarbon contamination in excess of Provincial guidelines.

As a result of the Environment Canada investigation, the field work for a Phase II environmental site assessment (ESA) was performed by Porter Dillon in November 1993, with the results detailed in a 1994 report. A total of 19 boreholes were put down during the investigation. Hydrocarbon odours were detected in 16 of the 19 holes. Soil samples with petroleum hydrocarbon contents above the N.S. provincial remediation guidelines were detected in five boreholes. Soil samples from boreholes BH-5 and BH-6, located west of the former fuelling area on the west side of the Equipment Repair Shop, displayed 8800 ppm TPH and 6060 ppm TPH, respectively. A soil sample from BH-10, located within the containment dyke around the existing above ground tanks, just east of this fuelling area, displayed 30000 ppm TPH. A soil sample from BH-12 located in the former fuelling area on the east side of the Equipment Repair Shop had 4480 ppm TPH. A soil sample from BH-16, located halfway between the two former fuelling areas adjacent the Equipment Repair Shop had a hydrocarbon content of 13600 ppm TPH. Hydrocarbon content was detected in the groundwater samples from five of the ten monitoring wells sampled (Figure 2-23).

Based on the results of the Porter Dillon investigation, a Phase III ESA was performed at the site by MGI Limited in August 1997 and the results were summarized in a 1998 report. To delineate the areas of hydrocarbon impacts a total of eighteen boreholes were put down and monitoring wells constructed in each hole. Two pumping wells were also constructed. This investigation delineated four separate areas on the site in which the TPH content in the soil and groundwater exceeded NSDOE Level II remediation criteria. The interpreted areal extent of the impacted soil and groundwater are indicated on the attached Figures 2-23 and 2-24.

Conversation with an NSDOE field inspector indicates that Nova Scotia has only set remediation criteria for soil and that CCME criteria for BTEX are used for groundwater. The soil remediation criteria are set in three levels to represent the sensitivity of the subject site. Level I is a residential or institutional site, or the site is located within 30 m of a third party well. A Level II site is a commercial site or a Level I site, or a third party well is located within 50 metres upgradient or 100 m down gradient of the subject site. A Level III site is an industrial site or no Level I or Level II sites are located within 50 metres upgradient or 100 m down gradient of the subject site. The NSDOE soil remediation guidelines in 1997 are indicated below:

NSDOE Soil Remediation Levels (ppm)

Parameter	Level I	Level II	Level III
Total BTEX	1.0	2.0	200
Benzene	0.05	0.5	2.0
TPH	100	400	2000

There are no CCME criteria for TPH in water but draft guidelines for the remediation of petroleum contaminated sites in the Atlantic Provinces, dated May 1995, set remediation criteria of 50 ppb benzene

and 1000 ppb TPH for a Level II site. Under these guidelines, a Level II site is a site serviced by a piped municipal water supply and is remote from possible receptors or unlikely to be used as a future groundwater source.

The MGI report determined that in the former fuelling area on the west side of the Equipment Repair Shop, a volume of soil of roughly 18000 m³ had a hydrocarbon content above the Provincial criteria. Some 8000 m² of contaminated soil was identified with an estimated depth ranging from 1.8 to 4.1 metres. The report identified free product on the groundwater surface in this area and estimated the volume of material to be 364 m³ over an area of 2250 m².

In the former fuelling area east of the repair shop, the MGI report estimated the volume of soil with a hydrocarbon content above the Provincial remediation criteria was 11,600 m³. The impacted soil extended from ground surface to a depth of 2 m. No free product was found in this area in the investigation but the report indicated that it was anticipated due to a high hydrocarbon content of 123 mg/L, analysed in the groundwater sample from the monitoring well.

Two other areas of hydrocarbon contaminated subsurface soil and/or groundwater above Provincial remediation criteria were identified. These were at MW97-11 and MW-8 located about 40 m from the shoreline of Muggah Creek. The MGI report interpreted these two areas as small discrete spill sites, that may have been sourced from spills at the former refuelling areas, through groundwater flow or through drains.

The groundwater and surface water (including drains) flow towards Muggah Creek and it is likely that the spill sites at the railyard may have an effect on the Site Area.

Regarding the use of pesticides or weed control, representatives of Environment Canada indicated that at various times CN (when they operated the facility) used to treat their rail lines (presumably within the rail yard and across the Coke Ovens site) with:

- Soil sterilant (Carmex - active ingredients bromocil and diuron)
- Spike (active ingredient - tebuthiuron)
- Atrazine

DEVCO took advantage of the contractor being in the area and often had the ballast associated with their lines (e.g. parallel to Frederick Street) treated at the same time as CN. Theoretically, these products would not be applied over open water (e.g. brooks).

Environment Canada had no information on what may have occurred once the operation of the rail yard was privatized.

2.3.7.4 Marsh Dump and Municipal Landfill

The waste disposal area occupied by the Municipal-Ash-Incinerator Disposal Site has received waste since the early 1900's. The site is comprised of three disposal areas, the Marsh Dump, the Sydney Municipal Landfill and the Incinerator Landfill.

The Marsh Dump encompassed the entire area of the current Municipal and Incinerator Landfills. The Marsh Dump was used since the early 1900's for disposal of materials from the steel plant and the Coke Ovens operations. Wastes included solidified slag, refractory bricks, scrap metal, municipal wastes, ash/rubble and coking distillate wastes (Nolan Davis, 1988).

The Sydney Municipal Landfill is located at the western end of the MAID site. All municipal, commercial and industrial solid wastes generated in the City of Sydney since the early 1950's were disposed here until 1997. The waste was deposited above ground and over the last 10 years, ash taken from the Marsh Dump was used as cover material.

A municipal solid waste incinerator was constructed by the former County of Cape Breton in 1987. Disposal of waste from the incinerator was performed in the ash disposal site on the eastern end of the former Marsh Dump. The incinerator continues in use as the main feature of the waste management program for the Cape Breton Regional Municipality. There are four principal waste streams in the ash landfill:

- Bottom and fly ash from the incinerator
- Non-burnable wastes, primarily construction/demolition wastes
- White metals which are recycled
- Special wastes including asbestos and hydrocarbon contaminated soils.

Ash from the Marsh Dump is again used as cover material for the non-burnable waste stream.

The 1985 Acres report indicated thick accumulations of waste material up to 20 m thick were present in the Marsh Dump. Slag and brick fragments together with a high proportion of granular coal and coke made up most of the waste. Metallic and wooden refuse was present at many locations. Visible tar-like contamination was identified in the fill in MW-21 on the west edge of the dump. The three monitoring wells at the downstream edge of the dump displayed elevated PAH levels in the groundwater sampled from each well.

As indicated, 1979 monitoring of the Coke Ovens Brook influent to the Coke Ovens site from the area of the dumps displayed elevated levels of compounds including phenol, ammonia, iron and cyanide. The entire bed of the Coke Ovens Brook is covered with orange precipitate which the 1990 Nolan Davis Associates Limited and Jacques Whitford Environment Limited hydrogeological report identified as caused by acid drainage from the marsh dump, the coal storage areas, and the municipal dump.

Some of the analytical results of the samples obtained in 1979 and 1990 from Coke Ovens Brook upstream of the Coke Ovens site are provided in Table 2-14 for comparison. It should be noted that these are intended as snapshots and that the chemistry of the brook could vary significantly over time and with varying flows.

Table 2-14: Water Samples from Coke Ovens Brook

Parameter	Upstream of Coke Ovens Site 1979 (ppm)	Upstream of Coke Ovens Site 1990 (ppm)
PH	6.1	6.8
Suspended Solids	106	15
Total Dissolved Solids	459	364
Total Organic Carbon	8	3.7
Ammonia	0.9	0.78
Iron	5.36	0.10

The Landfill Leachate study performed by the Cape Breton Environmental Group in 1997 determined that groundwater impacted by leachate from the Municipal Ash Industrial Disposal (MAID) site may be impacting some residences on Frederick Street. According to the August 1997 report, the well nearest the residences (JAG97GW-1) displayed 21 contaminants above background levels and five of these were above Canadian Drinking Water Standards. Analyses of samples from domestic wells at these residences indicated all the analyzed compounds were within Canadian Drinking Water Standards, except iron and manganese. Elevated iron and manganese levels in water are common throughout the Sydney Coalfield, as well as in many areas of the Maritime Provinces. The report indicated that four of the seven domestic wells sampled did appear to be influenced by an outside source with concentrations of compounds in excess of background levels. The MAID landfill was suggested by the report to be the most likely source.

In connection, with the sampling of the domestic wells, a monitoring program was performed by CANMET to check the six residences for methane, potentially originating from the landfill. No methane had been detected at any of the sites by August 1997.

2.3.7.5 Additional Disposal Sites

In the 1990 Phase II Shoreline Investigation report, it was indicated that the area adjacent the southwest shoreline of the South Tar Pond, west of the Bus Depot was used as a municipal dump shortly after the turn of the century. At the time of the investigation, the area was found to be infilled with a variety of materials such as slag, coal, brick and scrap wood. Much of the wood had been burned.

2.3.8 Physical Hazards

During the field walk-overs undertaken by members of the Study team, numerous instances of physical hazards were observed throughout the Site Area, most of which are located on the former Coke Ovens Site. This site, as a result of demolition and disturbance over the years, may have unidentified areas of subsidence and/or underground voids. Additionally, a range of other physical hazards were noted, including the following:

- Not all the Site is fenced.
- There is an existing ramp up the side of the remaining by-products tank, which is uncovered. At the time of the inspection performed for the current study, a small portion of the ramp immediately adjacent the tank had been removed.
- The pipeline crossing the property is a hazard to the curious, although much of the pipeline has been removed.

2.3.9 Security

When the Coke Ovens Site was closed, the Site was not completely fenced. Over the years, sections of the existing fencing were illegally removed by individuals. The Site became accessible, especially to curious children. Some individuals are known to have entered the site to remove coal, coke, bricks (possibly contaminated) and any other articles of salvage that was of interest. Children would enter the Site and vandalize the buildings and tanks (graffiti), setting fires, and carrying out general mischief. All areas of the Site Area pose some degree of danger, whether from physical hazards noted above or from short and/or long term exposure to contaminants.

One of the earlier tasks of the JAG Site Security Working Group was the construction of a perimeter security fence for the entire Site, and the employment of security personnel to patrol the Site. Despite the implementation of these security measures, it was noted during the field investigations, that individuals continue to breach the perimeter fencing and gain access to the Site.

The Tar Ponds, as a whole, are not protected by perimeter fencing. SYSCO fencing borders the area on the east. The western side of the Tar Ponds, bordered by the Railyards is not fenced. The south end of the Ponds is completely accessible to the public, including an unfenced bridge which crosses the Ponds from west to east. At the north end, near the mouth of the Muggah Creek Estuary, there are no measures in place to discourage boaters from entering the Tar Ponds. However, discussions are ongoing with Coast Guard to establish a marker for the inlet to Muggah Creek.

Within the Investigation Area, the SYSCO Plant is secured by manned access gates, and perimeter fencing. The site does have a considerable waterfront area that is not protected by fencing. No major concerns regarding unauthorized access of the SYSCO property have been reported.

2.4 Remedial Investigations and Activities

Within the last 25 years, a number of environmental investigations, studies and remedial activities have been conducted in and around the Muggah Creek Watershed that are directly or indirectly related to the historical operations conducted at the Site Area and Investigation Area. This section of the report provides a historical overview of the investigations and physical remediation completed in relation to the Site Area, as well as documenting the main conclusions of these activities where applicable.

2.4.1 Remedial Investigations

In general terms, the investigations and studies are separated into several distinct groups that are related by the type of work conducted or the area investigated. These groups are summarized as follows:

- **Background Studies**

Studies completed during the 1970s and early 1980s that identified PAH problems in the Sydney area. These studies assessed the air, water quality and waste effluent streams, as well as the areas of the main disposal area. These studies identified the Muggah Creek estuary as the principal source of PAH contamination in the Sydney area.

- **Sydney Tar Ponds Investigations**

Studies and assessments conducted between 1984 and 1994. The studies focussed on the Muggah Creek Tar Ponds, collected data on the Tar Ponds, assessed the Tar Ponds and selected a remedial approach. The work included the installation of an incinerator to deal with the sediments and some removal of tar sediments.

- **Muggah Creek Containment Project**

Studies and assessments conducted in 1995/96 assessed the remedial option of containment of the tar pond sediments under slag and the channelization of the Coke Oven and Wash Brook outfalls.

- **JAG Investigations**

The JAG studies and undertakings to date have focussed on gaining an understanding of conditions at the Coke Ovens Site and Muggah Creek, demolition of above grade structures, and removal of recoverable products.

- **Investigation Area Environmental Studies**

Within the Investigation Area, certain property owners have undertaken a range of environmental studies at their facilities, such as the review of hydrocarbon issues conducted by Canadian National Railways, the studies of the Marsh Dump and Regional Landfill, and the shoreline infill studies.

- **Lower Frederick Street Investigation**

In the spring of 1998, a seepage was noted flowing into the Frederick Street Brook. The Lower Frederick Street Investigation (CBEG, 1998) was undertaken to determine the source and characterization of the seep and the implications of the seep on the environment. Associated with the seepage studies are health studies of the local residents.

A complete listing of environmental reports, historical drawings and information pages that are associated with the Muggah Creek Watershed, and in particular the Site Area, is provided in the electronic database. A summary of the contents of the database is provided in Appendix D.

2.4.1.1 Background Studies

Studies conducted during the 1970s and early 1980s that focused the concerns on the Muggah Creek watershed include the following:

- Environment Canada, 1980. An Assessment of Liquid Effluent Streams at Sydney Steel Corporation, December 1980;
- Jacques Whitford and Associates Ltd .1981. Soils investigation Muggah Creek, Sydney, Nova Scotia
- Environment Canada. 1982. Environmental Quality in Sydney and Northeast Industrial Cape Breton, January; 1982.
- Can Test Ltd. 1982. Chemical Characterization of Sediment Core Samples from the Sydney Tar Ponds, March 1982.
- Guilcher, M. et al. 1982. Sources of Polycyclic Aromatic Hydrocarbons, Sydney, Nova Scotia, Environment Canada, August 1982.

- Matheson, R.A.F. et al, 1983. Investigation of Polynuclear Aromatic Hydrocarbon Contamination of Sydney Harbour, Nova Scotia, Environment Canada,. October 1983.
- Sirota, G.R. et al. 1983. Polycyclic Aromatic Hydrocarbons in Lobster (*Homarus americanus*) and Sediments in the Vicinity of a Coking Facility, Department of Fisheries and Oceans and Environment Canada, December 1983.
- Sirota, G.R. et al. 1984. Polycyclic Aromatic Hydrocarbons in Lobster (*Homarus Americanus*) and Blue Mussel (*Mytilus Edulis*) Collected in the Area of Sydney Harbour, Nova Scotia, Department of Fisheries and Oceans dated June 1984;

Fishery and sediment studies of the Sydney Harbour area were conducted in 1980 and again in 1981 (Sirota et al, 1983). These studies assessed PAH levels in lobsters and Sydney Harbour sediments and concluded that lobster populations in the south arm of Sydney Harbour had elevated PAH concentrations in body tissues. The PAH concentrations were sufficient to warrant closure of the lobster fishery within Sydney Harbour. Later studies confirmed the conclusions of the initial work and concluded that the fishery would remain closed for sometime.

Studies associated with the Muggah Creek estuary, and the effluent streams of SYSCO, were conducted in 1982/83. Guilcher et al (1982) assessed various potential sources of PAH contamination in the Sydney Harbour area. These studies concluded that the only significant source of the PAH contamination in Sydney Harbour was the effluent streams of SYSCO operations, specifically the Coke Ovens. Effluent from the Coke Ovens final cooler and the main sewer were determined to be the main sources of PAHs with total levels of PAHs recorded for each stream at 266.8 and 566.2 ug/L respectively. The studies concluded that:

- The Coke Ovens by-product effluent alone could contribute up to an estimated one metric tonne of PAHs into the Muggah Creek estuary each year;
- Continuous discharge of PAHs to Muggah Creek, and tidal action in the Harbour area have contributed to contamination of the sediments of the South Arm of Sydney Harbour
- Biota samples, taken in the Harbour, had elevated levels of PAHs
- The fate of the Tar Ponds needs to be addressed; without remedial action, PAH releases to the Harbour will continue.

A field sampling program was conducted in Sydney Harbour by JWEL-IT and Environment Canada in December 1995 to assess the levels of PAHs, PCBs, and metals in sediment, the levels of PAHs in lobsters and mussels and PCBs in lobsters. The results of the study were presented in Site Investigation of Contaminants in Sediment and Biota of Sydney Harbour (JWEL-IT, 1996). The report concluded that the levels of PAHs in the sediment and lobster in Sydney Harbour had generally declined since the initial levels were determined in 1981, however the levels of PAHs in the mussels were significantly elevated when compared to previous studies. PAH contamination was present everywhere within the harbour but the highest levels occurred in the South Arm, with a general trend of decreasing PAH contamination with distance from Muggah Creek. The distribution of levels of metals measured in the Sydney Harbour sediment did not show obvious trends except for copper, lead and zinc, which showed decreasing concentrations with distance from Muggah Creek. The highest levels of metals were typically observed south of Muggah Creek which, the report suggested, indicated Sydney River or industrial activities within

the harbour as possible contributing sources. PCBs levels in the sediment at several locations in the South Arm exceeded the Marine Sediment Guideline of 0.025 mg/kg. The PCB levels in the lobsters were higher but in the same order of magnitude, as the levels of PCBs measured in lobsters in Halifax Harbour, where the report notes commercial harvesting is permitted.

It was noted that 26 of the samples in 1995 were taken from the top 1.5 cm of sediment with an additional 13 samples analysed on sediment below this top layer. The report indicated that the difference in sampling methods from the 1981 work, in which a grab was used to collect an unspecified depth of sediment, should be considered when comparing the results of the two reports.

2.4.1.2 Sydney Tar Ponds Investigations

In 1984, Acres International Limited was retained by the Nova Scotia Department of the Environment to carry out the Sydney Tar Ponds Study (Acres International Limited, 1985a). The Sydney Tar Ponds Study consisted of:

- Preliminary assessment of the problem (Phase 1)
- Data collection and assessment (Phase 2)
- Development and selection of remediation alternatives (Phase 3).

Subsequent to the selection of the appropriate remedial alternative, focussed investigative work was undertaken, and remediation of the Site was initiated.

The main reports that were generated during this portion of the investigative work are as follows:

- OceanChem Ltd. 1984. Examination of Dredged Material Disposal Alternatives, Sydney, Nova Scotia (Final Report), March 1984.
- Acres International Limited. 1985. Sydney Tar Pond Study, Final Project Report (Volumes 1, 2 and 3), June 1985.
- Acres International Limited. 1988. Sydney Tar Ponds Clean Up Sampling Program, July 1988.
- Nolan, Davis and Associates Limited and Jacques, Whitford and Associates Limited. 1990. Sydney Tar Ponds Clean-Up, Hydrogeologic Assessment., April 1990.
- Keystone Environmental Resources, Inc. 1990. Risk Assessment: PAH Sediment Criteria Definition Sydney Tar Ponds Clean-up, September 1990.
- Acres International Limited. 1990. Environmental Support Document, Ferry Street Cofferdam. September 1990.
- Acres International Limited. 1991. Environmental Summary Report. January 1986.
- Acres International Limited. 1993. PCB Contamination Interim Report No. 2. February 1993
- Washburn & Gillis Associates Ltd. 1992. Cofferdam Discharge Monitoring “Background Concentrations”. September 1992.
- Washburn & Gillis Associates Ltd. 1993. Coke Oven Brook: Wash Brook Monitoring Program (Draft) September 1993.

- Washburn & Gillis Associates Ltd. 1994. Wash Brook Monitoring Program, Ferry Street Cofferdam Pre & Post Construction Periods. June 1994.
- Washburn & Gillis Associates Ltd. 1996. Coke Oven Brook Monitoring Program,. January 1996.

These studies focused on the Tar Ponds area of Muggah Creek, with some work being conducted on the Coke Ovens Site. The main work conducted on the Coke Ovens Site during this period was the hydrogeologic investigation (Nolan, Davis and Associates, 1990). In general, the hydrogeologic investigation identified various areas of the Coke Ovens Site and the Tar Ponds where groundwater had been impacted or where subsurface contamination was present.

Based on the collected data, and the review of remediation alternatives, a preferred remedial technology was selected; excavation and incineration of contaminated sediments in the Tar Ponds (Acres International, 1985a). Environmental assessment of the proposed remediation program addressed effects on the estuarine ecosystem, changes to the water quality in the Creek and the estuary, and effects on tidal movements and ice conditions in the estuary. A public participation program was also conducted (Acres International, 1991).

The incinerator and the sludge processing and piping system was constructed and remediation of the sediments was initiated. Difficulties encountered in mounting costs, the operation of the pipeline, and concerns regarding the incineration of PCB contaminated sediments led to the halting of the project, which is discussed in more detail in Section 2.4.3.

2.4.1.3 Muggah Creek Containment Project

In 1996, as an alternative to excavation and incineration, an *in situ* containment option for the contaminated sediments of the Tar Ponds was proposed. The principal documents associated with this work effort are:

- Jacques Whitford Environmental Limited – International Technology Corporation Joint Venture. 1996. In Situ Containment of Muggah Creek PAH Sediments. May 7, 1996.
- Jacques Whitford Environmental Limited – International Technology Corporation Joint Venture. 1996. PCB Delineation and Remedial Options for the Muggah Creek Containment Project. May 31, 1996.
- Jacques Whitford Environmental Limited – International Technology Corporation Joint Venture. 1996. Risk Analysis of PAH Hazards for the Muggah Creek Containment Project. May 17, 1996.
- Jacques Whitford Environmental Limited – International Technology Corporation Joint Venture. 1996. Site Investigation of Contaminants in Sediment and Biota of Sydney Harbour. August 23, 1996.

The PAH containment design proposal (JEWL-IT, 1996a) consisted of the following:

- Removal and disposal of PCB sediments with concentrations greater than 50 mg/kg;
- Covering of the PAH contaminated sediments with 1.3 m of slag and 0.3 m of till and grading and revegetation of the surface;
- Construction of two stream channels for the Coke Ovens Brook and Wash Brook, including excavation of existing sediments; and

- Construction of a dam at Battery Point to protect the infill from wave action and ice scour.

The Risk Analysis Study (JEWL-IT, 1996b) weighted the reduction of risk associated with the proposed containment design, against the risk associated with a Do Nothing option. Six potential PAH exposure pathways to human receptors were considered

- Dermal contact with water
- Dermal contact with sediments
- Ingestion of sediments
- Ingestion of water
- Air inhalation
- Lobster consumption.

The risk analysis concluded that the risk quotient for the Do Nothing option was 5.9, as compared with the risk quotient for the containment option which was 0.07, a potential reduction of risk of exposure to PAHs of over 80-fold.

The PCB Delineation Report (JEWL-IT, 1996c), as discussed in Section 2.3.7.2, defined and estimated the extent of PCB contaminated sediments (concentrations greater than 50 mg/kg) and assessed remedial alternatives. The report reviewed historical data for PCB concentration in the Tar Ponds, augmented existing data with 764 samples from 235 boreholes, and estimated the volume of PCB contaminated sediment. A total of eight areas of PCB concentrations in excess of 50 mg/kg were identified. There are four areas in the North Pond that are estimated to contain 33,400 tonnes of PCB contaminated material. There are four areas in the South Pond that are estimated to contain 11,200 tonnes of PCB contaminated material. The largest concentrations of PCB contaminated material occur in the area between the former Canadian National Railways railyard and Battery Point, and along the north-west shore of the South Pond. Nine remedial options were assessed. The report indicated the preferred remedial option for the PCB contaminated sediment was excavation and on-site indirectly heated thermal desorption.

2.4.1.4 JAG Investigations

A material sampling program was conducted at the Coke Ovens Site in 1997. The objective of the sampling program was to determine the extent of existing contamination associated with selective remaining materials and structures. The results of the sampling program are presented in the report titled “Material Sampling Program - Coke Ovens - Final Report” prepared by the Cape Breton Environmental Group (1997). Twenty-one areas were sampled for selected chemical parameters that included general chemistry, metals, PAHs, PCBs, and VOCs.

The report provides a historical overview of activities for each area, a summary of the sampling programs, the contaminants detected, the kind and estimated quantity of contaminated material, and the options for demolition and/or disposal. Table 2.15 provides a summary of the material sampling program results (Cape Breton Environmental Group, 1997).

Table 2-15: Summary of 1997 Material Sampling Program

Location	Current Condition	Contaminants	Volumes
DOMTAR Tank (Station ID# 1-97-DT)	16 tanks removed in 1988 as part of Coke Ovens decommissioning. Tars and other chemicals dumped into the remaining open top tank The remaining open top tank, containing tar & other chemical substances and sludge mixture, collects rainwater that periodically overflows onto the ground.	Liquid : metals, PCBs, BTEX, VOCs Solid/sludge: BTEX, TPH, PAH, phenolic compounds ¹	Liquid: 1,355 m ³ Sludge: 92 m ³ Solid: 2,247 m ³
DOMTAR Tar Cell/Lagoon (Station ID#2-97-DTCL)	In 1981, coal tar was removed from tar cell/lagoon. The primary lagoon was infilled with slag. Test pits indicate fine black sand with coal tar lenses. Tar was oozing out the side walls at time of investigation. Groundwater contains floating unknown material and strong odours.	Solids: BTEX, hydrocarbons (C6-C10), PAH	Solids: unknown
Benzol Tank (Station ID#3-97-BT)	Tank constructed in 1983 to replace other storage tanks. Currently remains empty except for thin layer of liquid/ sludge.	Liquid: BTEX, hydrocarbons (C6-C24), PAH, phenols, VOCs Sludge: BTEX, C6-C24, PAH, phenols, VOCs Metals	High moisture sludge: 21 m ³
Coal Pile (Station ID#4a-97-CLP) Coke Pile (Station ID#4b-97-CKP)	Unknown volume of coal remains. Foundations for Battery No. 1 located under the coal piles(4a) Underground piping discharges water with organic odours and floating product to former Coke Pile area (4b)	pH (4a) BTEX, hydrocarbons (C11-C24), PAH (4b)	8,000 – 29,000 tonnes of coal (4a) 8,000 – 10,000 m ³ of coke (4b)
Sulphur Building (Station ID#5-97-SB)	The building consists of a highly-deteriorated concrete walls and a partially demolished roof. Sulphur (98.4%) is present	None	The building contains an estimated 473 tonnes of sulphur material.
Cooling Tower Grids (Station ID#6-97-CTG)	The grids are currently being stored along the perimeter fence and perimeter road. They have an odour due to the contaminants saturated in the wood.	Soil: BTEX, C11-C24, metals, phenolic compounds	Wood: approximately the volume of one trailer truckload.
Steam Lines (Station ID#7-97-SL)	Elevated remnants of steam line are still present.	None	Approximately 34 tonnes of salvageable steel pipe.
Stacks (2) (Station ID#8-97-ST1; 8-97-ST2)	Two abandoned stacks (originally for waste gas emissions), 50m and 63m high.	Solids: phenolic compounds, and PAH assumed to be present due to elevated detection limits	N/A

¹ Compound assumed to be present above CCME Guidelines due to elevated detection limits. Confirmation testing would be required.

Location	Current Condition	Contaminants	Volumes
Benzol Plant Area (Tank) (Station ID#9-97-BV)	One tanks remains from the Benzol plant; its use is unknown.	Liquid: hydrocarbons (C11-C14), metals Sludge: Toluene, hydrocarbons (C11-C24), metals, phenolic compounds	Sludge/Liquid: approx. 2 m ³
Coal Transfer Building (Pocket) (Station ID#10-97-CTB)	The pocket is partially demolished and is currently resting on its side. There is remnant coal material in the structure.	Solid: metals, toluene, phenolic compounds, and PAH assumed to be present due to elevated detection limits	N/A
By-Products Building (Station ID#11-97-BBES; 11-97-BBWS; 11-97-BBV)	In the late 1980s, PCBs were temporarily stored at the By-Products Building during demolition. The structure has deteriorated and is unsafe (ie. falling debris).	Solid: BTEX, metals, asbestos, PAHs, phenols, TPH	N/A
Water Standpipe (Station ID#12-97-WS)	The standpipe is currently empty, and has no bottom or top.	Paint: lead	N/A
Timber Rail Trestles (3) (Station ID#13-97-TRT1; 13-97-TRT2; 13-97-TRT3)	There are three deteriorated timber rail trestles at separate crossings of the Coke Ovens Brook.	Solid: PAH	N/A
Coal Unloading & Storage Runway (Station ID#14-97-CPR)	It was demolished in the past. Currently there is groundwater discharge in the area.	Liquid: mercury, iron	N/A
Eastern Rail Trestle (Station ID#15a-97-ERT)	The trestle is comprised of 34 concrete abutments, steel members and rails, and timber sections.	None	N/A
Coke Batteries 5&6 (Station ID#15b-97-CBE/ 15b-97-CBW)	In the late 1980s, the batteries were demolished. Remaining is a mass of concrete, brick and steel, and flooded basements. There are numerous holes and weak spots.	Liquid: metals Solids: metals, PAHs	N/A
Brick Storage Area (Station ID#15c-97-BSA1; 15c-97-BSA2)	The Coke Ovens Brook, contaminated with landfill leachate, overflows and ponds within the storage area.	Solid: metals, BTEX, phenols	Brick storage: estimated total volume of 8300 m ³ .
Wooden Loading Ramp (Station ID#15d-97-WLR)	Currently, a deteriorated wooden ramp remains.	None	N/A
Access Road Bridge (Station ID#15e-97-ARB)	Currently, a deteriorated and collapsed bridge and a deteriorated culvert remain.	None	N/A
Standpipe (Station ID#15f-97-SP)	A constant flow of water (source unknown) is discharging from the standpipe.	Liquid: pH, metals, TOC, BTEX, TPH	N/A
SYSCO Cooling Pond (Station ID#16-97-SCP)	The pond used to receive process water and now overflows into Coke Ovens Brook.	Liquid: metals, phenols Solid: metals, TPH, phenols, PAHs	Liquid: 20,400 m ³ Sludge: 29,400 m ³ Lumber: 200,000 board ft

As indicated previously, contamination of some of the structures with phenols has not been confirmed but it could not be ruled out due to the elevated detection limits in the analyses performed.

JAG has also commissioned a landfill leachate monitoring program for the municipal landfill, is in the process of completing above-ground structure decommissioning of the Coke Oven Site and has commenced a municipal sewer interceptor project.

2.4.1.5 Investigation Area Environmental Studies

Phase 2 and Phase 3 environmental site assessments were conducted on the former Canadian National Railway Railyards, located to the south of the Muggah Creek estuary. The Phase 2 and Phase 3 ESA are documented in the following reports:

- Porter Dillon Limited. 1994. Phase 2 Environmental Site Assessment, Former CN Equipment Repair Property, Sydney, Nova Scotia. July 1994.
- MGI Limited. 1998. Phase 3 Environmental Site Assessment, Former CN Rail Yard, Sydney, Nova Scotia. February 1998.

The objective of these investigations was to delineate the subsurface plume of petroleum hydrocarbon contamination (fuel oil and lubricating oil) at the facility that occurred as a result of spills from several underground storage tanks. Recommended remediation measures included through high vacuum pumping.

Following the April, 1998 report by residents in the lower Frederick Street area, of a yellowish substance leaching from the bank of Frederick Street Brook an investigation of the area was undertaken by the Cape Breton Environmental Group (1998). The investigation consisted of a historical review of information, a visual survey of the area, installation of test pits and monitoring wells, and collection and analysis of sediment, soil, surface water and groundwater samples.

The report concluded that:

- Groundwater (shallow and bedrock) is providing base flow to the Frederick Street Brook. This groundwater is contaminated with iron, aluminum, lead, benzo(a)pyrene. An abandoned infilled culvert, an existing culvert and flow (south to north) through the CBDC rail line bedding, influences the groundwater flow.
- One source of the original seepage zones is the groundwater flowing out of the fill material placed in the former Frederick Street Brook (located on the Coke Ovens complex side of the Cape Breton Development Company rail line) that is contaminated with antimony, molybdenum, arsenic, benzo(a)pyrene.
- The Coke Ovens site, principally the coal storage area, the CBDC railine and the Landfill were identified as other possible sources of contamination
- Frederick Street Brook sediment is contaminated with arsenic, zinc, phenanthrene, pyrene, chrysene and naphthalene.
- Surficial soils in the area are contaminated with arsenic, lead, copper, molybdenum and up to seven PAH compounds. The source of the contamination is suspected to be airborne fallout, fill placement and/or coal ash disposal.

The Nova Scotia Department of Health and Health Canada retained CanTox Environmental Inc. to conduct a health risk assessment of the Frederick Street seep. CanTox reviewed available data, conducted a site visit, assessed exposure and toxicity, and characterized the risk. The study report (CanTox, 1998) concluded that:

- The seep located across from 36-44 Frederick Street proposes a low likelihood of residents incurring any adverse health effects.
- Potential risks for children playing in the Frederick Street Brook are not significantly elevated when compared to children who do not.
- Data associated with coal removal activities at the Coke Ovens Site were not available, but the dust may cause irritation if the dust levels were high.
- The coal ash pile adjacent to 36 Frederick Street increases the potential risk for children who play in the pile, but chemical characterization of the pile is limited.
- Other chemical exposures in the Frederick Street area are not expected to pose a potential health risk to the local residents.

2.4.2 Physical Remediation Activities

From the beginning, closure of industrial facilities at the Site Area and in the Investigation Area carried some degree of decommissioning, even if it was the sale of remaining marketable products, or the removal of structures. Records of decommissioning activities are scarce, and are often limited to individual recollections of the actions taken. It was evident during the interview process that the potential exists at the Site Area for hazardous substances and conditions resulting from incomplete decommissioning efforts.

It was not until the 1980's that actual physical and environmental remediation of derelict and abandoned facilities began in earnest. The following sections present a summary of recorded remedial activities in the Site Area and on selected properties of the Investigation Area.

2.4.2.1 Tar Ponds

In 1984 Acres International Limited was contracted to examine the type and extent of contamination in Muggah Creek and to investigate methods of clean-up. Three alternatives for the clean-up of the Tar Ponds were identified:

- Encapsulation of the contaminated sediments on site.
- Excavation of the contaminated sediments for transfer for storage at a hazardous waste disposal site.
- Excavation of the contaminated sediments and incineration with possible utilization for generation of electrical energy.

The third option was selected based on a predicted 99.99% efficiency for the removal of PAHs, and also because this option was seen as the most economically viable since it was planned to generate and sell electricity generated from steam produced with the incineration energy. An environmental screening of the proposed project was performed by Environment Canada (Travers, 1986) and recommended that the proposed remediation program proceed. A federal/provincial subsidiary agreement for the Sydney Tar Ponds Clean-up project was signed in November 1986.

The incinerator and related excavation plan is a large part of the previous efforts to accomplish some mitigation and the incinerator could be a significant part of any future remediation work, therefore a summary of the related studies is important.

The proposed remediation program would excavate contaminated sediment in the "wet" and transfer the material by pipeline to a specially constructed incinerator. Wet excavation does not require the site to be de-watered. Sediment would be excavated below water by a clam-shell dragline or a hydraulic dredge, a more economic option than de-watering, that would also reduce health risks by reducing the volatilization of the PAHs during excavation and handling. The enclosed system piping the sediment was considered preferable to trucking the material since it would minimize exposure to the environment. Less than 20% dilution of the sediment was required to allow it to be transferred by piping. A hydraulic dredge was considered superior to mechanical dredging using an excavator since it would minimize agitation and dilution of the sediment and also reduce the need for direct worker/sediment contact.

To maintain and control water levels during the excavation work it was proposed to construct a coffer dam first at the Ferry Street bridge to allow excavation in the South Pond. A second coffer dam would be constructed across Muggah Creek at Battery Point to allow excavation of the sediments in the North Pond. Silt curtains would be used to create isolated cells for excavation to minimize movement of sediment agitated into suspension by the excavation work.

Ash streams from the incinerator would consist of bottom ash from the fluidized bed furnaces, ash from the boiler and baghouse ash. The 1991 Acres study characterized the ash types. The bottom ash was described as coarse ash, sand bed material and rocks from the sludge. The bed material would be separated and reused. The baghouse and boiler would make up about 95% of the total ash. It was planned that the ash could be suitable for use with slag in infilling of the remediated Tar Ponds. It was anticipated that some mixing with cement might be required to control leaching of metals including lead and arsenic. Infilling of the channel would be performed to control the flows through Muggah Creek.

The total cost of the program was estimated at \$34.25 million in 1987. By 1991 development and operating cost estimates had been revised to \$71 million (in 1990 dollars).

The Tar Ponds incinerator uses a revolving fluidized bed technology to destroy the hazardous organic compounds. Lime is fed to the fluid bed in order to capture oxides of sulphur and convert them to calcium sulphate and sulphite. Waste heat produced by cooling the incinerator off-gas is used to generate electricity for use in the SYSCO Plant. The cooled gas is passed through a bag house to remove particulates. Treated gas passes through a final heat recovery unit before being emitted to the atmosphere through a stack.

The average calorific content of the contaminated sediment, for use as a fuel, was determined to be 9000 BTU/lb (dry weight) (Acres, 1988).

A study by Dearborn Chemical Company (1988) had investigated the effect of combustion, of samples of the sediment, carried out in the range of temperatures from 550 °C to 1050 °C at 0.5, 1, 2 and 4 seconds residence in a high temperature reactor. This report noted that the complex matrices of both the samples

tested prevented detailed study of thermal destruction of individual parent compounds. It stated that in such a complex mixture of chemical species, at a given temperature, some of the compounds are being destroyed while others are being formed while other species remain stable. The study concluded that, under laboratory conditions, the destruction temperature required to achieve 99.99% destruction of the organic compounds in the two Tar Pond samples was 884 °C to 887 °C with a retention time of 2 seconds. For a one-second retention time the required temperature was in the range of 910 to 915 °C. The Tar Ponds incinerator was constructed to have a 3.5 second gas residence time. (Acres 1991).

The NSDOE operating permit for the incinerator stipulated that no material was to be incinerated unless it was analysed for PCB content and shown to have less than 50 ppm, the threshold at which the sediment would be considered a PCB contaminated hazardous waste. The permit specified that testing was to be performed regularly at one test per 300 m³ of material. In 1992, testing during initial sediment removal from the Tar Ponds indicated PCB contents above the 50 ppm limit in the northeast corner of the South Pond.

In 1993, escalating costs, project delays, equipment problems, the unexpected levels of PCB contamination of the Tar Pond sediments, and public concerns, led to the retention of R.V. Anderson by the Province of Nova Scotia to carry out an independent review of the Tar Ponds remediation program. The terms of reference for the study were:

- Review of the infrastructure to identify areas where financial requirements could be reduced and identify reasons for project financial changes during the design and construction phase
- Examine the ability of the existing systems to treat/dispose of the Tar Ponds sediments in a satisfactory manner.
- Examine options and make recommendations for managing the PCB contaminated sediments.

The 1994 R.V. Anderson report stated that the system and units installed for decontamination of the Tar Pond sediments were appropriate for the task. Performance of the total system could be optimized to meet the most rigid emission standards. The report could not identify any equipment or process substitutions that would significantly improve the system performance. Some recommendations for operation and maintenance of the system to improve performance were presented. It was felt the monitoring and controls were adequate to meet the environmental standards of the operating permit but would have to be upgraded if it was planned to process the PCB contaminated sediments in the incinerator or to meet new environmental performance criteria that were under development. The report indicated that the installed system could potentially be used to destroy PCBs in the sediments and recommended test burns be performed to determine if the incinerator could destroy PCBs with a 99.9999% efficiency. Another option proposed for management of the PCB contaminated sediments was to remove the sediment with PCB concentrations greater than 50 ppm for storage in a PCB secure landfill. The report indicated that remaining sediment at concentrations less than 50 ppm could be handled in the PAH sediment treatment. The Anderson report stated that the estimated cost of the Tar Pond remediation project had increased to \$104.2 million and that the reasons for the escalations were well documented and appeared largely unavoidable.

The incinerator for the Sydney Tar Ponds Clean Up project was required to undergo testing for compliance with stipulations set forth by NSDOE. The stipulations and the regulated emission limits are

specified in the Operating Conditions in the Letter of Authorization to Acres and in the Industrial Waste Permit. The stack test program comprised six tests, three at 100% load and three at a reduced load condition of 80%, the minimum operating level of the incinerator. Samples were obtained from the stack and at six locations around the stack location ranging from 680 m to 2630 m away for ambient air quality. The sites were the five used in the routine monitoring program plus an additional site in the residential area of Whitney Pier. The report by Rowan Williams Davies & Irwin Inc (1994) indicated testing did not display results significantly above the long term average ambient air levels at the monitoring stations and concluded that there was no evidence of impact to the ambient air of Sydney during the compliance test program.

Despite the positive results from the test burns the Project was running into problems related to sediment transportation and mounting costs. The consistency of the sediment was clogging the pipeline, and solutions to this problem were both costly and controversial. In 1994 the project was halted. Total costs to that date were estimated at \$53 million. Presently the incinerator is managed by the Sydney Environmental Resources Limited (SERL) who are examining alternative uses for the facility.

In 1996 an encapsulation project was proposed at an estimated cost of \$20 million. The plan proposed to use slag from the SYSCO site to cover the Tar Ponds to a depth ranging from 1 to 1.5 m. PCB contaminated materials would first be removed for disposal at another location, but the sediments contaminated with other materials would remain in place. This plan did not gain public support and was never implemented.

2.4.2.2 Coke Ovens and DOMTAR

In late March or early April of 1988, demolition of the Coke Ovens Plant and related facilities was begun. Phillips Barratt Kaiser were retained to provide expert assistance to SYSCO and to administer the contract. Kaiser Engineering had previous experience in the demolition and clean-up of coke plants in the United States. A work plan was devised to enable a crew of Sydney Steel workers to be utilized and a stated objective of the plan was to employ the maximum number of local people.

Under this program, all above ground structures and piping were to be removed. Foundations, underground piping and sewers would remain. The work plan also did not include remediation of contaminated soils however any visible surface spills were to be removed. The program was never completed. Left in place were the water standpipe, two exhaust stacks, the by-products building, the coal pocket, the sulphur building, and other structures. In 1997, the JAG commissioned a status report on the remaining structures, and contracted decommissioning of those deemed only mildly contaminated. Details of the work completed, and observations of interest, are provided in Section 2.4.1.4.

By early 1988, 13 of 14 abandoned coal tar storage tanks were demolished at the DOMTAR site. The contents of these tanks were transferred to the remaining tank prior to demolition with the plan that the contents would be transferred to the new incinerator for destruction. This tank was also used as the depository for residues collected during decommissioning of the Coke Oven site. The contents of this tank were never removed and remain to this day.

Aztec Insulation removed asbestos from structures, wetted and bagged the material which was temporarily stored at the Salt Room. The asbestos had been taken off site by March 1990 by Guildford's and taken to the River Denys holding area.

NSDOE correspondence dated June 15, 1990, indicated PBK located and traced most of the underground piping, lines and sewers during the week of June 6. No record of this work was located at SYSCO. Another memorandum, dated September 29, 1988, indicated in the course of the demolition work, a drainage ditch was constructed to help to lower the water table on the site. The ditch extended from Mullins Bank on the south side of the site to Coke Ovens Brook where it enters the site on the east side.

Equipment was removed from some structures, such as the hammer mills from the blending plant, to facilitate the demolition. Structures were also cleaned in order to prepare for demolition. A crane with a wrecking ball was used to knock down some structures. The steel was then cut up by workers with cutting torches. Scrap steel from the demolition of structures was loaded into railcars and transported to the steel plant for use in the process. Concrete from the blending plant area was taken to the SYSCO slag dump to be used as road base material. Concrete and rubble from the coal wash building was taken to the high dump for disposal.

At the Benzol Plant the remaining crude BTX (light oil) was pumped to the loading dock of the plant for transfer into tanker trucks. The benzol lines from the coolers to the plant and in the plant had been blown out. The remnants of the tanks from the benzol area had then been steamed.

In demolition of the final scrubbers/coolant towers it was planned to cut the rivet heads on the towers to allow the towers to be dismantled. This work plan was intended to prevent the oil-soaked grating inside the tower being set on fire during cutting of the plates. It had been planned to dispose of the wood gratings at SYSCO's "high dump" and under the right conditions burned. In cutting the rivets, however, by error some wood grating was set on fire on December 15, 1988. The fire department had difficulty finding a source of water and finally used the water from the flooded battery basements. The fire was judged to be too intense to be extinguished and therefore water was only applied to slow the fire and the fire was allowed to burn itself out. The fire burned until December 18. Samples of the ambient air downwind of the fire were obtained for testing after complaints from residents. No records of the analyses were found in the current study.

The minutes from the quarterly project review meeting on January 20, 1989 contained a list of tasks completed to that date. The asbestos had been removed from the coal blending plant, the benzol plant, the exhauster/booster building and the exposed insulation on the battery. The tar tanks had been cut down to the two foot level. The boiler house was 7/8 demolished. The benzol storage tanks had been moved to the concrete laydown area for water pressure cleaning. The quench tower, blending plant, gas holder and piping, the pumphouse, the vessels and piping in the exhauster building and one of the two benzol towers, with scrubbers had all been demolished or removed.

PCB transformers and waste drains were transferred to the Coke Plant Interior PCB Waste Storage. This was a storage area constructed in the Salt Room. A concrete storage pad was poured in the salt room for the PCB storage. The pad was painted with epoxy urethane resin paint to ensure impermeability. Transfer of PCB material began in the week of February 20 with two transformers. In an October memorandum it was indicated that the storage location for PCBs would be moved from the Salt Room to the Old Open Hearth Pumphouse at the steel mill. This move was due to a lack of adequate space and concerns about site security.

On February 2, 1989 a second fire broke out at the site when sludge in the gas collection main was accidentally ignited during removal. This fire was extinguished within an hour by covering with soil with bulldozers.

Hydraulic shears arrived on site in the week of May 1 to be used in the demolition work. This was used in the demolition of the Number 5 and Number 6 Batteries and the Benzol Plant.

Minutes of a November 28, 1989 meeting indicated demolition of the six tar cars was performed in an area covered with a foot of coke braize. The area was also surrounded by a berm of coke braize. The purpose of the braize was to intercept any spilt tar. The demolition was performed on the rail tracks in the Coke Ovens Site.

Meeting minutes indicated the demolition work was winding down in May 1990. One issue of concern at that time was the disposal of cooling grids. These were considered a fire hazard. One option of disposal at a site in Sarnia, Ontario was rejected as too expensive. NSDOE had rejected a PBK proposal to store the grids in the flooded basement of the batteries. A fire subsequently occurred in the grids on November 10, 1990.

At the conclusion of the remediation project some structures were left on the site in addition to the cooling grids. No remediation of the soil had taken place.

2.4.2.3 SYSCO

By 1980, it was apparent that the steel works in Sydney would require significant capital improvement for modernization. It was also identified that environmental issues would need to be given a high priority in the modernization. In 1981, a Canada/Nova Scotia Subsidiary Agreement authorized a program to modernize the facilities at SYSCO. To administer the agreement, a management committee, a program management group and an environmental subcommittee were established.

Between 1981 and 1985, in a first phase \$92.6 million modernization program funded by the federal and provincial governments, close to \$14 million was spent on upgrading pollution controls in the blast furnaces and rolling mills.

A second phase \$157 million modernization program to convert the steel mill to an electric arc furnace operation was agreed to by the federal and provincial governments in 1986. The electric arc furnace went into operation in December 1989.

2.4.2.4 Coke Ovens Demolition Work

In 1998, JAG commissioned Philips Environmental to begin demolition and removal of some of the structures and materials remaining at the Coke Ovens Site. This work consisted of the following elements:

- Sulphur Pile and Building – The structure was demolished with the rebar salvaged for scrap, the roof materials disposed off-site and the concrete and masonry disposed on site as inert backfill. It was intended to excavate the sulphur and transfer it off site for disposal but that aspect has not been performed at this time.

- Coal Piles and Coke Piles – This material was to be excavated and transported off site for recycling. Only part of the work was been completed at the time of this report.
- Steam Lines – The pipe and steel pedestal frames were dismantled and processed for salvage. The concrete footings were demolished and disposed on site as inert backfill.
- Coal Transfer Building (Pocket) - The structure was demolished with the steel salvaged for scrap, and the concrete disposed on site as inert backfill. The coal material was stock-piled on site for later recycling off-site.
- Water Standpipe – The tower was notched and allowed to fall in a controlled manner. The base of the building was demolished. The steel was salvaged for scrap, and the concrete disposed on site as inert backfill.
- Timber Rail Trestles – The steel rails and support frames were dismantled and processed for salvage. The timbers were transferred to an approved disposal location.

Maintenance work was also performed on the Access Road Bridge.

2.4.2.5 Muggah Creek Collector Sewer

In 1998, JAG also commissioned the design and construction of a collector sewer to pick up and divert the sanitary sewers discharging to Muggah Creek. Referring to Figure 2-13, on the west side of the estuary the pipes leading to outfalls 1, 2, 3, 4, 10 and 25 will be picked up. Interceptions will be made adjacent the pipes to Outfalls 22 and 23, although there is no flow at these outfalls currently. The remaining outfalls on the west side are storm sewers.

On the east side of Muggah Creek, the collector sewer will pick up the flow to Outfall 30 and a collector sewer just south of Ferry Street, which it is anticipated will pick up the flow to Outfalls 32 and 33.

At the south end of Muggah Creek, the collector sewer will pick up the sanitary sewers on Falmouth Street, Townsend Street, Styles Lane and Brooklyn Street. The sewers on Falmouth Street, Townsend Street and Styles Lane currently discharge to Wash Brook.

Upgradient of Muggah Creek the collector sewer will pick up the Massey Drive sewer and the sewer from Whitney Pier, at the north end of Victoria Road. As part of this project, the sanitary sewer from the south end of Victoria Road will be piped to Massey Drive.

CHAPTER 3 NATURE AND EXTENT OF CONTAMINANTS

3.1 Nature of Contaminants

The investigations and studies conducted to-date on Muggah Creek Watershed, and in particular the Site Area, have identified an extensive list of chemical constituents that are present within the water, soils, sediments, and by-product materials (e.g. coal tar). The chemical constituents can be grouped into families of compounds. The families or groups of compounds relate to the chemical structure of the constituents. In general the compound group has similar chemical characteristics and physical properties, as well as similar environmental and health concerns.

For chemical constituents that are in general use or of significant environmental or health concerns, risk studies have been conducted to determine a concentration level for the chemical constituent that is considered to provide an acceptable risk for various media, such as air, soil and water.

Section 2.3.6 provides an overview of the Site Area locations where contamination is known or suspected to occur based on historical use, operations, waste disposal practices, previous investigations and/or chemical testing. Table 3.1 provides a summary of the chemical groups and chemical constituents that are present or suspected to be present at the Study Area and that are important from an environmental and health perspective. Table 3.1 also provides the media in which the chemical constituent is located; the concentration ranges reported and documents the reference for the higher levels. The chemical parameters presented in Table 3.1 reflect the chemical constituents that significantly exceed the CCME Guidelines or other applicable criteria. The data presented in Table 3.1 has been compiled from a number of reports and may have been collected by different method or analyzed by different means. The data does provide an estimate of the main chemical parameters.

Based on the documentation available, four chemical groups reflect the main contamination present at the Site Area, these are:

- Polycyclic aromatic hydrocarbons (PAHs);
- Volatile organic compounds (VOCs);
- Heterocyclic compounds (HC);
- Polychlorinated biphenyls (PCBs); and
- Metals.

The general characteristics or profiles of each of these chemical groups is presented in Section 3.1.1, while Section 3.1.2 provides information on the individual chemical constituents noted in Table 3.1.

3.1.1 Chemical Family Profiles

Table 3.2 provides a summary of the chemical information that is critical to the understanding of a chemical parameter and the behaviour of the parameter. The information includes physical information (molecular weight, boiling and melting points, etc.); and CCME Guideline levels (air, water, soil) for each of the chemical parameters that were noted on Table 3.1.

3.1.1.1 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic Aromatic Hydrocarbons (PAHs) are a group of chemicals formed during the incomplete combustion of virtually all forms of organic materials. Human sources of PAHs include combustion of fuels in cars and furnaces, as well as such common occurrences as barbecuing. Natural occurring sources of PAHs include volcanoes, forest fires, crude oil and shale oil. PAHs are found in substances such as crude oil, coal tar pitch, creosote, road and roofing tar. Other sources of exposure for humans include smoked meats, car and chimney exhaust, and cigarette smoking, both as an active smoker and through second hand smoke inhalation. PAHs are ubiquitous in the environment and the increasing levels found in the environment parallel industrial and urban development.

With respect to the Muggah Creek Watershed Area, the main source of PAHs being released to the environment were the operations that occurred at the Coke Ovens and the Steel Plant. The PAHs were released to the atmosphere through the combustion process, or released to soils and surface waters through leaks or disposal practices. The Muggah Creek Tar Ponds represent the largest mass of PAHs found within the Study Area, with other known areas of PAH concentration occurring at the former DOMTAR Plant. Deposition of airborne particulate material in the Study Area has also created elevated ambient PAHs levels within the surface soils. In addition, ambient PAH levels in surface soils would be impacted by the local/domestic use of coal in the general area.

3.1.1.1.1 Chemical Identity

As pure chemicals, PAHs generally exist as colorless, white, or pale yellow-green solids. Most PAHs do not occur alone in the environment, rather they are found as mixtures of two or more PAHs. The PAHs are not commercially produced in the United States or Canada, nor are there any known uses for them except as research chemicals. Based on molecular weights, PAHs can be sub-grouped as follows [Agency for Toxic Substances and Disease Registry (ATSDR),1994]:

- *Low molecular weight compounds* (140 -178 g/mol): acenaphthene, acenaphthylene, anthracene, fluorene, 2-methylnaphthalene, phenanthrene and naphthalene;
- *Medium molecular weight compounds* (202 g/mol): fluoranthene and pyrene; and
- *High molecular weight compounds* (228-278 g/mol): benz(a)anthracene, benzo(a)pyrene [b(a)p], benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene.

3.1.1.1.2 Ambient Concentrations

PAHs occur naturally and anthropogenically (occurring due to human activity). PAH background levels are higher in industrial and urban locales than in rural areas. Background levels in rural areas are influenced by natural sources such as forest fires and coal deposits.

Much of the study of PAHs has focussed on the presence of Benzo(a)pyrene (B(a)P) because it is one of the most toxic. Monitoring its presence has been used to monitor the general level of PAHs in the environment. B(a)P has been reported in rural or agricultural soil at concentrations ranging from 40 to 1,300 µg/kg, dry weight. Annual oral intake of B(a)P is estimated at 0.35-1.5 mg/year. This is equivalent to 0.96 to 4.1 µg B(a)P per day.

The source of B(a)P in soils is due to a large degree to emissions from internal combustion vehicles. A resident near the freeway is estimated to have an intake of 0.02 µg per day. Cigarette smoke is a major source of PAHs in the indoor environment. It is estimated that smoking one cigarette releases 0.10 to 0.15 µg B(a)P into room air and a smoking one cigarette results in an intake of 0.4 µg B(a)P. These are only a few examples of the potential sources of PAHs to which an individual is exposed each day.

3.1.1.1.3 Environmental Fate

PAHs released to the atmosphere are present in the gaseous phase or sorbed to particulate; are subject to short and long-range transport; and are removed from the atmosphere by wet and dry deposition. The atmospheric residence time and transport distances depend on the size of the particles to which PAHs are adsorbed. PAHs can undergo photochemical oxidation in the atmosphere, forming nitrated PAHs, phenols, and other compounds. Atmospheric half-lives of PAHs are generally less than 30 days.

PAHs tend to be removed from the water column by volatilization to the atmosphere, photodegradation, oxidation, adsorption to particulates or sediments, biodegradation by aquatic organisms. The PAH medium and high molecular weight compounds are considered to have limited volatilization potential from water, while the lower molecular weight compounds have a volatilization potential. In addition, the medium and higher molecular weight compounds have a stronger tendency to adsorb to organic carbon particles, while the lower molecular weight compounds have a lower tendency. PAHs have low water solubility. In general PAHs are primarily found adsorbed to soils or sediments that either have settled to the bottom or are suspended in the water column.

PAHs have been reported in groundwater as a result of migration directly from contaminated surface waters or through the soil (ATSDR, 1994). The environmental fate of PAHs is described by USEPA in the document "Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons" which states: *"PAH will adsorb strongly onto suspended particulates and biota and their (PAH) transport will be determined largely by the hydrogeologic condition of the aquatic system. PAH dissolved in the water column will probably undergo direct photolysis at a rapid rate. The ultimate fate of those which accumulate in the sediment is believed to be biodegradation and biotransformation by benthic organisms (USEPA, 1979)."*

Since PAHs are most likely to stay in the sediment or soil, microbial degradation is the most likely ultimate environmental fate in contrast to photolysis and volatilization. Compounds with four cyclic rings or less are most amenable to microbial degradation. B(a)P (five cyclic rings) has a half-life in soil inoculated with bacteria of less than eight days. The half-life reported for B(a)P in soil reported in Superfund Public Health Evaluation Manual (SPHEM, 1986) is 420 to 480 days but there is no reference to the microbial content in the soil.

3.1.1.1.4 Toxicity

Epidemiological data from occupational studies of workers exposed to mixtures of PAHs, as a result of their involvement in such processes as coke production, roofing, oil refining, or coal gasification, indicate carcinogenic effects to humans as a result of the exposure (ATSDR, 1994). However, it is not clear whether PAHs were the only causative agent or if one particular PAH compound was the causative agent for the carcinogenic effects.

USEPA has performed weight-of-evidence evaluations of several of the PAHs compounds. The carcinogenicity classifications currently verified by USEPA's Carcinogenicity Risk Assessment Verification Endeavor Work Group identifies benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, B(a)P, chrysene and indeno(1,2,3-cd)pyrene as probable human carcinogens (Group B2) with sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans. USEPA identifies acenaphthene, anthracene, benzo(g,h,i)perylene, fluoranthene, fluorene, phenanthrene and pyrene as not classifiable (Group D) as to human carcinogenicity due to inadequate evidence or lack of evidence. USEPA identifies naphthalene as a possible human carcinogen (Group C) with limited evidence of carcinogenicity in animals.

The Site Area has identified the presence of Group B2 carcinogenic compounds (benzo(a)anthrene, benzo(b)fluoranthene, B(a)P, chrysene, indeno (1,2,3-cd)pyrene). The compounds are present in the coal tar located at the Coke Ovens Site and within the Tar Ponds. In addition, the compounds are present in the groundwater at the Coke Ovens.

3.1.1.2 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are a group of chemicals comprised of carbon and hydrogen, as well as other elements, that readily change to vapour at normal temperatures and pressures. Apart from their volatility, VOCs are a group of chemicals with varying chemical properties that are not easily grouped under the same category. Natural sources of VOCs include natural gas (methane), volcanoes, forest fires, crude oil and shale oil. Therefore, VOCs are ubiquitous in the environment and the increasing levels found in the environment parallel industrial and urban development. Examples of VOCs are benzene, toluene and xylenes. These three VOCs were extracted from the coal gas and used commercially.

VOCs are often used as intermediates in the manufacture of other chemicals and end products. For example, the major uses of the VOC benzene are in the production of ethylbenzene, cumene, and cyclohexane. Benzene is especially important for unleaded gasoline because of its "anti-knock" characteristics (ATSDR, 1992). Benzene enters the environment from production, storage, transport, venting, and combustion of gasoline, and from production, storage, and transport of benzene itself. Other sources result from its use as a solvent; from spills, including oil spills; from its indirect production in coke ovens; from non-ferrous metal manufacture, ore mining, wood processing, coal mining and textile manufacture; and from cigarette smoke (Howard, 1990).

Another VOC, trichloroethene (TCE) is an excellent extraction solvent for greases, oils, fats, waxes, and tars and is used by the textile processing industry to scour cotton, wool, and other fabrics. The textile industry also uses TCE as a solvent in waterless dyeing and finishing operations. As a general solvent or as a component of solvent blends, TCE is used with adhesives, lubricants, paints, varnishes, paint strippers, pesticides, and cold metal cleaners (ATSDR, 1992). Testing to-date has not indicated the presence of TCE or other chlorinated VOCs at the Site.

3.1.1.2.1 Chemical Identity

As pure chemicals, VOCs generally exist as liquids at room temperature that quickly volatilize if left in the open atmosphere. Non-chlorinated VOCs that are of concern due to their potential to cause adverse human health and environmental effects include: benzene, ethylbenzene, toluene, and xylene. Chlorinated

VOCs that are of concern due to their potential to cause adverse human health and environmental effects include: chloroethanes, chloroethenes, chloromethanes, chlorobenzenes, chloropropanes, and carbon tetrachloride. Other VOCs that are less toxic include: ethane, methane, butane, propane, and hexane. Some VOCs can be categorized as monoaromatic hydrocarbons (MAHs) (ringed), such as benzene, toluene, ethylbenzene, and xylenes, while others can be categorized as aliphatic (straight-chained), such as chloroethenes and chloroethanes.

The VOCs at the Site are the non-chlorinated VOCs, however chlorinated VOCs may be present to industrial uses not associated with production.

3.1.1.2.2 Ambient Concentrations

VOCs occur naturally and anthropogenically. VOC background levels are higher in industrial and urban locales than in rural areas. Background levels in rural areas are influenced by natural sources such as forest fires and coal deposits.

Benzene, an aromatic VOC, is ubiquitous in the atmosphere where it has been identified in outdoor air samples of both rural and urban environments and in indoor air. The following daily median benzene air concentrations were reported by the Volatile Organic Compound National Ambient Database (1975-85): remote (0.16 ppb), rural (0.47 ppb), suburban (1.8 ppb), urban (1.8 ppb), indoor air (1.8 ppb), and workplace air (2.1 ppb) (ATSDR, 1992). Benzene was detected in 15% of the surface water samples collected at 1271 observation stations at a median concentration of 5 ppb. Benzene levels in water in the vicinity of five industrial facilities using or producing benzene ranged from <1 ppb to a high of 179 ppb (ATSDR, 1992).

3.1.1.2.3 Environmental Fate

Generally, VOCs released to soil will be subject to rapid volatilization near the surface, while that which doesn't evaporate will be highly to very highly mobile in soil and may leach to the groundwater (Howard, 1990). Factors influencing VOC leaching potential include the VOCs water solubility, soil type (e.g., sand versus clay), the amount of rainfall, the depth of the groundwater, and the extent of degradation. Most VOCs, such as benzene, can be biodegraded in soil under aerobic conditions (ATSDR, 1992).

VOCs released to water will generally be subject to rapid volatilization. It has been estimated that the volatilization half-life for benzene is 4.81 hours for a 1-metre-deep body of water at 25°C. Benzene is biodegradable in surface water and groundwater. VOCs are not expected to significantly adsorb to sediment, bioconcentrate in aquatic organisms, or hydrolyze (Howard, 1990).

When released to the atmosphere, many VOCs will exist predominantly in the vapor phase due to their high vapor pressures. Gas-phase benzene will not be subject to direct photolysis but will react with sunlight-produced hydroxyl radicals. Benzene is quite water soluble and is removed from the atmosphere in rain (Howard, 1990). The dominant transformation process for TCE in the atmosphere is reaction with sunlight-produced hydroxyl radicals (ATSDR, 1992).

3.1.1.2.4 Toxicity

VOC exposure to humans and animals can cause a range of toxic effects from skin irritations to cancer to reproductive effects, depending on the VOC in question, the dose, and the route of exposure.

USEPA has performed weight-of-evidence evaluations for several of the VOC compounds. The carcinogenicity classifications currently verified by USEPA's Carcinogenicity Risk Assessment Verification Endeavor Work Group identifies benzene and vinyl chloride as probable human carcinogens (Group A) with sufficient evidence of carcinogenicity in humans. USEPA identifies carbon tetrachloride, 1,2-dichloroethane, methylene chloride, tetrachloroethene and trichloroethene as probable human carcinogens (Group B2). USEPA identifies 1,1-dichloroethane, 1,1-dichloroethene, 1,1,2,2-tetrachloroethane and 1,1,2-trichloroethane as possible human carcinogens (Group C) with limited evidence of carcinogenicity in animals. USEPA identifies cis-1,2-dichloroethene, ethyl benzene, toluene, 1,1,1-trichloroethane and xylene as not classifiable (Group D) as to human carcinogenicity due to inadequate or lack of evidence.

3.1.1.3 Heterocyclic Compounds

Heterocyclic Compounds (HCs) are a group of compounds that contain one or more nitrogen, sulphur or oxygen atoms in their ring structure along with selected chemicals such as the non-aromatic hydrazines (Patty's 1994). HCs are constituents of crude oil and coal tar. At the Coke Ovens Site, heterocyclic nitrogen compounds (HNCs) have been tested for and have been noted to be present, particularly at the former DOMTAR plant location. The oxygen and sulphur HCs have not been tested for, but several of the compounds are known to be constituents of coal tar.

Two HNCs, pyridine and pyrrole, are commonly found in coal tar. HNCs are used extensively in agriculture as fungicides and herbicides, as well as in the drug manufacturing industry. The majority of pyridine that is manufactured is converted into the herbicides paraquat and diquat. Pyridine may be released to the environment during its production and use. Pyridine is produced during shale oil gasification and in coke ovens, where it is recovered from the resulting coal tar (Howard, 1990).

The remainder of the discussions of HCs focuses on the HNC parameters since these compounds have been detected at the Site. HCs are a widely diverse group of chemicals and their chemical profiles, ambient concentrations, environmental fate and toxicity will vary significantly.

3.1.1.3.1 Chemical Identity

HNCs are a diverse group of nitrogen containing compounds that differ widely both chemically and structurally. There are three main classes of HNCs: three-membered rings, five-membered rings, and six-membered rings. For this chemical profile, only those HNCs associated with coal tar/oil are considered. Pyrrole is an aromatic five-membered ring compound that is a colorless liquid at ambient temperatures. Pyridine is a six-membered aromatic ring compound that is a flammable, colorless liquid with a characteristic, disagreeable odour (Patty's 1994).

3.1.1.3.2 Ambient Concentrations

Energy-related processes such as coal and shale oil gasification is an important source of pyridine release to the environment. There is very little information regarding the ambient concentration of HNCs in the environment. Pyridine has been detected in indoor and outdoor air near a shale oil wastewater treatment

facility in Logan, Washington at concentrations of 41 and 13 ug/m³, respectively. Two aquifers under a coal gasification plant contained 0.82 to 53 ppb of pyridine. Pyridine has also been identified as a volatile flavor compound in bacon, boiled beef, Beaufort cheese, fired chicken, and roasted coffee (Howard, 1990).

3.1.1.3.3 Environmental Fate

HNCs such as pyridine will leach into the ground and biodegrade and it is absorbed to acidic clay to a moderate extent. Complete degradation of pyridine in one case occurred in less than 8 days. If released to water, pyridine should biodegrade after an acclimation period and be slowly lost through volatilization. If released to the atmosphere, pyridine will react slowly with photochemically produced hydroxyl radicals and be removed by rain (Howard, 1990).

3.1.1.3.4 Toxicity

HNCs such as pyridine are slightly to moderately toxic, causing anesthesia and mild skin and eye irritation after administration by any route. Effects to the liver and kidneys of rats were observed in a chronic 90-day oral laboratory experiments using high doses of pyridine (>25 ppm/day) (Patty's 1994).

USEPA has not classified the HNC pyridine and it is not classified as a carcinogen by OSHA or ACGIH.

3.1.1.4 Polychlorinated Biphenyls (PCBs)

PCBs are man-made chemicals which are not known to occur naturally in the environment (ATSDR, 1992). PCBs were used both for nominally closed (e.g. capacitors and transformers) and in open-end (e.g. plasticizers, surface coatings, inks, adhesives, pesticide extenders, and carbonless duplicating paper) applications. By 1974, use of PCBs in the United States was restricted to closed applications such as the production of capacitors and transformers. PCBs were banned from use in 1977 in the United States and in 1980 in Canada. PCBs entered the air, water, and soil during their manufacture and use, and accidental spills and leaks. Today, PCBs can be released from waste sites that contain PCBs; improper disposal of PCB wastes; and leaks or releases from electrical transformers containing PCBs (ATSDR, 1992).

3.1.1.4.1 Ambient Concentrations

PCBs are a result of anthropogenic activities. Studies conducted in the late 1970's and early 1980's indicated that PCB concentrations in the atmosphere ranged from 0.02 (remote) to 30 ng/m³ (urban) with the averages being 0.1 (remote) to 10 ng/m³ (urban). Recent monitoring data from a few locations indicate that the atmospheric concentration may have slightly decreased from the pre-1980 to post-1980 period (ATSDR, 1992). (Note : 1 ng = 0.001 µg = 0.000001 mg)

Although PCBs are widely found in surface water, their low solubility generally prevents them from reaching high concentrations in drinking water supplies (ATSDR, 1992). The average PCB concentration in Lake Michigan was 1.8 ng/L, with concentrations higher in near shore samples (3.2 ng/L). Mean PCB concentrations of 0.63 to 3.3 ng/L were detected in the waters of western Lake Superior during 1978 to 1983. A mean level of 0.49 ng/L was detected in the water columns of Lake Huron in 1981.

In a comprehensive national soil monitoring program conducted in the United States, the maximum soil PCB concentration was 1500 µg/kg, while the mean concentration varied in the range of <10 to 40 µg/kg (ATSDR, 1992).

3.1.1.4.2 Environmental Fate

The low water solubility, high octanol-water partition coefficients of the PCBs, and demonstrated strong adsorption of PCBs to soils and sediment indicate that leaching should not occur in soil under most conditions. Volatilization does occur, the rate being greater from soil with low organic carbon and with increasing moisture. Biodegradation of PCBs in soil is slow, especially in soils that have high organic carbon content (ATSDR, 1992). Generally, it is the lower chlorinated PCBs that are degraded aerobically, although there is evidence that some types of microorganisms can degrade larger PCB congeners.

In water, adsorption to sediments or other organic matter is a major fate process for PCBs. Re-dissolution into the water column has been shown to occur in the environment. PCBs are expected to bioconcentrate and bioaccumulate in aquatic organisms. Photolysis appears to be the only viable chemical degradation process in water (ATSDR, 1992).

In the atmosphere, the vapour-phase reaction of PCBs with hydroxyl radicals may be the dominant transformation process. Photolytic degradation of PCBs in the atmosphere is also possible (ATSDR, 1992).

In humans, PCBs distribute preferentially to adipose (fatty) tissue. Due to its high fat content, human milk concentrates PCBs, which are then transferred to children through lactation (breast-feeding) (ATSDR, 1992). Information regarding the metabolism of PCBs in humans is limited. Analysis of adipose tissue samples of volunteers revealed almost 60 individual PCB components. Examination of these results showed that <12 congeners accounted for ≈80% of the total PCBs (ATSDR, 1992).

3.1.1.4.3 Toxicity

No studies were located regarding death in humans after exposure to PCBs by any route. The intermediate- and chronic-duration animal data suggest that relatively low oral doses of PCBs could shorten the lifespan of humans if ingested continually over a long period of time. The studies indicate that single dermal and oral lethal doses of PCBs in animals are similar in magnitude, suggesting that skin contact with liquid PCBs at waste sites would not be acutely toxic for humans (ATSDR, 1992).

Effects such as upper respiratory tract irritation, tightness of the chest, and possible impaired lung function have been reported in people occupationally exposed to various Aroclors for >5 years at mean concentrations of 0.007 to 11 mg/m³ (7,000 to 11 x 10⁶ ng/m³). Existing data suggest that the respiratory tract is a target in humans exposed via inhalation (ATSDR, 1992). The 1996 JWEL-IT report indicates the PCBs detected in the Tar Ponds were identified by the lab as resembling Arochlor 1260.

Hypertension was detected in a population whose only known source of PCB exposure was contaminated fish. However, the evidence is limited, and the population was also exposed to DDT via consumption of the contaminated fish (ATSDR, 1992). Although the human data for gastrointestinal effects of PCBs are inconclusive, the preponderance of animal evidence indicates that PCBs could possibly produce adverse

gastrointestinal effects in humans following prolonged oral exposure at adequate dosage levels (ATSDR, 1992).

Existing epidemiological data do not indicate a consistent tumorigenic effect among people exposed to PCBs. Occupational studies suggest possible PCB-related liver, gastrointestinal tract, and hematopoietic system, and skin carcinogenicity. Occupational exposure largely involves the inhalation route, although dermal contact is likely to significantly contribute to overall exposure. Oral carcinogenicity studies with rats and mice indicate that Aroclor 1254, Aroclor 1260, Clophen A-30, and Clophen A-60 are hepatocarcinogens. Additionally, there is suggestive evidence that Aroclor 1254 induced gastric adenocarcinomas in rats. The highly chlorinated PCB mixtures (Aroclor 1260, Clophen A-60) appear to be more potent than the lower chlorinated PCB mixtures (Aroclor 1254, Clophen A-30) as indicated by higher incidences of malignant tumors (hepatocellular carcinoma) (ATSDR, 1992).

USEPA has classified PCBs as a probable human carcinogen (Group B2) with sufficient evidence in animal studies and inadequate evidence in humans. USEPA Integrated Risk Information Systems (IRIS) database recently revised the toxicity profile for PCBs (IRIS, 1996).

3.1.1.5 Metals

Metals are chemical elements that occur naturally in the environment in varying abundance and in various forms. Of the more than 100 elements, 77 are metals. Metals are characterized by properties such as luster, malleability, ductility, and conductivity of heat and electricity (McQuarrie and Rock, 1984). Many metals can be considered industrially or economically important. Because of the importance of metals to industrialized nations, they are used and often released into the environment in relatively large quantities. Heavy metals are, in general, the metals in the lower right-hand corner of the periodic table, and include arsenic, chromium, manganese, iron, cobalt, nickel, copper, zinc, lead, silver, antimony, cadmium, and mercury. Many of the heavy metals are in large demand because of their importance to industrialized societies such as iron. Metals are used in almost all industries, from electronics, to steel making, to pharmaceuticals, and can be found in innumerable industrial and consumer products. Certain elements such as sodium, potassium, calcium, and magnesium are metals, strictly speaking, but are generally low in toxicity, even at large concentrations. Asbestos is a mineral silicate that is used for fire proofing and heat resistance and has specific handling requirements due to its specific health issues.

3.1.1.5.1 Chemical Identity

As pure chemicals, metals are individual elements that vary by their atomic structure, and hence, their atomic number. Each metal has different properties and reacts differently from the others because of their differing atomic structure. All the metals except mercury are solids at room temperature. Metals are not usually found in the natural environment in pure form, but rather are complexed with various other elements and molecules.

3.1.1.5.2 Ambient Concentrations

Metals are naturally occurring elements that can be found in varying concentrations throughout the world. Therefore, all areas have "background" concentrations of metals. Some metals such as aluminum and iron are abundant in the earth's crust. Oppositely, other metals such as gold, silver, copper, and platinum are relatively scarce and much in demand, resulting in their label as precious metals. Metals, such as copper, are mined today from low-grade ores containing 2 percent or less of the metal (Patty's, 1994).

Metals used in industrial processes can often be found in the environment of urban areas in elevated concentrations relative to natural or background levels. Lead, for example, was used as an additive in gasoline for many years, and therefore, lead is often found at elevated levels in soils along roadways.

3.1.1.5.3 Environmental Fate

The fate of metals that enter the environment through industrial processes is dependent on the type of release action. Metals that are released through combustion processes are generally sorbed to particulates in the air stream that settle out of the atmosphere by both wet and dry deposition.

Metals in pure elemental form are generally insoluble in water. However, trace metals present in mining or landfill waste will often undergo chemical reactions with other compounds, becoming soluble and potentially leaching into soils and groundwater. Metal complexes that are released to the aquatic environment usually adsorb to suspended solids and become deposited, sometimes at elevated levels, in sediments. Some metals, such as mercury and cadmium, have the potential to bioconcentrate in animals such as fish and mussels that are in contact with sediments. Once these metals become dissolved in animal tissue, they can be biomagnified up the food chain, ultimately impacting higher animals such as birds-of-prey and humans.

Because metals are elemental, they do not degrade in the environment. However, they do undergo chemical reaction and will change forms and speciation. For instance, lead can be found in the environment as elemental lead, lead acetate, lead chloride, lead sulphide, tetraethyl lead, and tetramethyl lead, to name a few.

3.1.1.5.4 Toxicity

Metals on an individual basis can be beneficial or toxic to biological species. Some metals are essential for biological cell production, but at high levels are toxic or inhibitory to cell production (American Public Health Association, 1995). The metals as a group tend to accumulate in the kidneys and the bones (Patty's, 1994). The route of exposure and the essentiality of the metal are important considerations in the difference between occupational and environmental hazards. The metals arsenic, beryllium, cadmium, chromium, copper, manganese, mercury, nickel, lead, selenium, and zinc are generally more toxic than other metals such as aluminum and iron.

USEPA has performed weight-of-evidence evaluations for many of the metals. The carcinogenicity classifications currently verified by USEPA's Carcinogenicity Risk Assessment Verification Endeavor Work Group identifies arsenic, nickel, and chromium IV as human carcinogens (Group A) with sufficient evidence of carcinogenicity in humans. USEPA identifies beryllium as a probable human carcinogen (Group B1) with limited evidence of carcinogenicity in humans. USEPA identifies lead as a probable human carcinogen (Group B2) with sufficient evidence of carcinogenicity in animals. USEPA identifies iron as a possible human carcinogen (Group C) with limited evidence of carcinogenicity in animals. USEPA identifies barium, copper, manganese, mercury, selenium, silver, thallium, and zinc as not classifiable (Group D) as to human carcinogenicity due to inadequate or lack of evidence. USEPA has not performed weight-of-evidence evaluations for the metals aluminum, antimony or chromium III.

3.1.1.6 Radionuclides

Radionuclides are a radioactive species of atom (unstable) characterized by the constitution of its nucleus. An atom can be naturally radioactive, it can be made radioactive by naturally occurring processes in the environment, or it can be made radioactive by humans. Any material that contains radioactive atoms is considered to be radioactive material. Each radioactive atom will transform into another element through a reaction that will take place in the nucleus to stabilize the atom. Depending on the type of reaction taking place, alpha, beta, or gamma particles will be released. The release of these particles is termed ionizing radiation. Examples of radionuclides are cobalt-60, potassium-40, uranium-238, plutonium-239, manganese-54, and cesium-137, among others.

People are most likely to be exposed to ionizing radiation emitted from radionuclides from natural sources, such as cosmic radiation (ATSDR, 1997). Ionizing radiation can also come from industrial produced radioactive materials, nuclear medicine, the nuclear fuel cycle, and the production and testing of nuclear bombs. Radionuclides are present in coal, crude oil and natural gas, and can be released to air or concentrated in ash when these fuel materials are combusted (ATSDR, 1997). Groundwater and surface water can contain radionuclides that it dissolves from the soil as it passes over or through.

Natural radionuclides are found in small amounts in rocks, soil, surface and groundwater, air, and plants and animals. Exposure to radionuclides occurs during the mining and use of coal. Coal mine exhaust typically contains radon, to which workers can be exposed. About 280 million tons of coal ash are produced by power plants each year. The radioactive content of coal tends to concentrate in the ash, resulting in 5- to 10-fold increases in the concentrations of lead-210 as compared to unburned coal (ATSDR, 1997).

Radionuclides released to the air can be transported by wind currents or can be deposited to the ground through rain events. Radioactive material on the ground can be incorporated into plants and animals. Radioactive material that is deposited or enters into surface water may settle along the banks, or in the bottom of lakes and rivers. Radioactive material moves very slowly in soil compared to movement in air and water. Radioactive material will often adhere to the surface of the soil. The organic material in soils can bind radioactive material, which slows its movement through the soil environment (ATSDR, 1997).

Exposure to ionizing radiation from radionuclides can lead to many effects, such as skin burns, hair loss, nausea, birth defects, cancer and death (ATSDR, 1997). The severity of radiation toxicity depends on the amount of ionizing radiation received and the exposure duration.

3.2 Sources and Contaminated Areas

Table 3-3 provides a summary of the nature and extent of contaminated source material within the study area. These materials, and the areas in which they occur, are termed “sources” because they may be highly concentrated and therefore have potential to persist at their current location for an extended period. Consequently, they also have potential to act as “sources” for ongoing release of contaminants to potential migration pathways such as: groundwater, surface water, soil vapour, airborne vapours and airborne dust migration. The occurrence of these contaminated source materials in the environment may be due to processes such as:

- Spills or leaks from facilities (past or present) in the study area;
- Past waste disposal practices;
- Diffuse release of contaminants from past or present industrial activities; and
- Accumulation of contamination that migrated from up-gradient source areas.

The objective of Table 3.3 is to provide the reader with an overview of contaminant sources that can be subsequently linked with potential contaminant migration pathways and potential receptors (Sections 3.3 and 3.5, respectively). The degree of certainty associated with each of these components (source, pathway, receptor) is then used to develop a framework for subsequent investigations in the Study Area (Section 5).

Table 3-3 provides a description of source material composition, extent and form. In general, source composition and form are known with a moderate to high degree of certainty, due to past collection and analysis of environmental samples, and also due to background knowledge of the general composition of certain contaminants that are common in the study area (e.g., coal tar). However, in most cases the extent of the source material is known with less certainty: much of the investigative work conducted to date has been aimed at identifying the occurrence, not the extent of highly contaminated areas.

It is noted that additional substantial source materials may occur in the study area that have not been encountered in assessment work conducted to date.

Table 3-3. Summary of Known or Suspected Contaminant Source Materials - Study Area

Source Material Characterization: Composition and Extent	Form of Contaminated Source Material	Relative Degree of Certainty in Source Composition and Extent
<p>S1. Coking distillate wastes and coal tars buried throughout the Coke Ovens site - wastes were reportedly buried in various open excavations that were available around the Coke Ovens site when the waste was generated; excavations filled with this material may be more numerous in the vicinity of the sulphuric acid plant (NDA/JWA, 1990); expected to consist, at least partly of PAHs, MAHs, and HCs.</p>	<p>Unconfirmed; expected to consist at least partly of waste tar that may currently be present as subsurface tar pools (likely DNAPL) tar residual in soil, associated tar compounds dissolved in groundwater and sorbed to soil</p>	<ul style="list-style-type: none"> - High degree of certainty that numerous small pockets of source materials exist, due to knowledge of past disposal practices - Low degree of certainty in the location of individual disposal points - Low degree certainty in the overall composition of the source materials, since they are likely to be highly variable; however, they are expected to consist, at least in part, of waste tar
<p>S2. Used motor oil used for road dust control on the Coke Ovens site - Sprayed throughout the Coke Ovens site during site operation; expected to consist primarily of petroleum hydrocarbons (NDA/JWA, 1990)</p>	<p>Unconfirmed; may currently be present as residual in soil, associated compounds dissolved in groundwater, and sorbed to soil</p>	<ul style="list-style-type: none"> - High degree of certainty that source material (contaminated road surfaces) once existed, due to knowledge of past practices - Low degree of certainty that current or previous road surfaces remain contaminated - High degree of certainty

Source Material Characterization: Composition and Extent	Form of Contaminated Source Material	Relative Degree of Certainty in Source Composition and Extent
		source material consisted primarily of petroleum hydrocarbons; however, it is not known whether other contaminants may have been present in the oil (e.g., metals)
<p>S3. Miscellaneous drain and pipe leaks throughout the Coke Ovens process area - from extensive network of subsurface drains and pipes, above and below ground storage tanks throughout the process area of the Coke Ovens site - may provide numerous point sources of pollution (NDA/JWA, 1990) related to coking products and wastes; composition is unconfirmed, likely to be organic liquids (e.g., tar, oil) comprised at least partly of PAHs, MAHs, and HCs.</p>	<p>Unconfirmed; likely to be organic liquids (e.g., tar, oil); may be in the form of free phase (LNAPL or DNAPL, residual, dissolved and vapour</p>	<p>Low degree of certainty in the current/past location and composition of source material</p>
<p>S4. Dry and wet fallout from steel and coke manufacturing - The Coke Ovens site has picked up considerable air borne dry and wet fallout from steel plant and Coke Ovens air emissions (NDA/JWA, 1990); contamination is likely to be at the ground surface; composition is unconfirmed; could be metals and/or organic compounds</p>	<p>Unconfirmed; may be in the form of particulate matter that has PAH compounds.</p>	<ul style="list-style-type: none"> - High degree of certainty that contamination was generated - Low degree of certainty in current extent and composition
<p>S5. Acid-generating sulphide minerals associated with coal at the Coal Pile Runway - from coal previously stored at the Coal Pile Runway (NDA/JWA, 1990) and possibly from remaining material; also likely to be concentrated in various metals (e.g., arsenic, iron); expected to be at or near the ground surface and throughout the approximate footprint of the previous Coal Pile Runway</p>	<p>Sulphide mineral particles associated with coal</p>	<ul style="list-style-type: none"> - Moderate degree of certainty in extent of source material - High degree of certainty that the source material is comprised, at least partially, of sulphide minerals; likely to also contain heavy metals
<p>S6. Acid-generating sulphide minerals associated with coal at Mullins Coal Bank – from coal previously stored at Mullins Coal Bank (NDA/JWA, 1990) and possibly from remaining material; also likely to be concentrated in various metals (e.g., arsenic, iron); expected to be at or near the ground surface and throughout the approximate footprint of the previous Mullins Coal Bank</p>	<p>Sulphide mineral particles associated with coal</p>	<ul style="list-style-type: none"> - Moderate degree of certainty in extent of source material, although recent coal recovery activities have decreased the extent substantially - High degree of certainty that the source material is comprised, at least partially, of sulphide minerals; likely to also contain heavy metals
<p>S7. Benzol in the vicinity of the Benzol Plant – Benzolized and debenzolized oils produced at the Benzol Plant; ground was saturated with organics (NDA/JWA, 1990) consists, at least in part, of MAHs and PAHs.</p>	<p>Free phase LNAPL (probably benzol) and residual in soil, associated compounds dissolved in groundwater and sorbed to soil</p>	<ul style="list-style-type: none"> - High degree of certainty that source material was previously present - Low degree of certainty in current extent of source materials - High degree of certainty in source material composition

Source Material Characterization: Composition and Extent	Form of Contaminated Source Material	Relative Degree of Certainty in Source Composition and Extent
S8. Slag, municipal wastes and ash - located throughout The Marsh Dump Municipal Solid Waste Disposal Site and the Municipal Ash Landfill (NDA/JWA, 1990).	Buried waste materials including construction debris and tar-like material.	<ul style="list-style-type: none"> - Low degree of certainty in source material extent and composition, high degree of variability is expected - High degree of certainty that contamination was generated.
S9. Organic contamination around the most recent Coke Batteries - Fill around the Coke Battery 2-6 area is heavily stained with organics (Acres, 1985); bedrock in this area is not heavily contaminated (NDA/JWA, 1990); expected to consist, at least partly, of PAHs.	Residual in soil, associated compounds dissolved in groundwater and sorbed to soil	<ul style="list-style-type: none"> - Low degree of certainty in source material extent - Moderate degree of certainty in source composition
S10. Coal tar in Tar Ponds sediment - Coal and coke particles containing coal tar (Acres, 1985) distributed throughout the Tar Ponds; max thickness of 3.53m in southern pond; reduces to 0.3-1.5m toward the upstream end of the pond; max thickness of 4.4m in northern pond; total volume of material in both ponds is estimated at 550,000 m ³ ; consists primarily of PAHs, MAHs, HCs.	Tar residual in sediments, tar compounds dissolved in interstitial water and sorbed to sediments	High degree of certainty in source extent and composition, due to extensive assessment
S11. PCB in Tar Ponds sediments - Eight areas of PCB contamination in excess of 50 mg/kg have been identified in the North and South Ponds (JWEL-IT, 1996); affected material generally within one metre of the sediment surface and approximately 37,000 m ³ were estimated to exceed 50 mg/kg.	Unconfirmed, bulk sediments are described as odoriferous black silt, sand and gravel size particles of coal tar residue, coal, coke and slag (JWEL-IT, 1996); PCB may be present in residual oil, dissolved in interstitial water or sorbed to sediments	Moderate degree of certainty in source extent and composition, due to extensive assessment
S12. Coal tar in Fill throughout the Coke Ovens site - (NDA/JWA, 1990); expected to consist, at least partly, of PAHs, MAHs, HCs.	Residual tar, tar compounds dissolved in groundwater or sorbed to soil	<ul style="list-style-type: none"> - Low degree of certainty in source extent: vertical and horizontal delineation of the fill is well-known due to near-surface nature of the deposits; however extent of coal tar in fill is poorly characterized. - Moderate degree of certainty in source material composition; likely to be highly variable
S13. Coal Tar deposits on the Domtar site - originating from the buried lagoon and tar storage tank farm; free phase DNAPL coal tar was encountered at 88-2B, 88-4B and 85-12 (NDA/JWA, 1990) and pools of tar are present at the surface; composed primarily of PAHs, MAHs, HCs.	Surface and subsurface pools of free phase tar (DNAPL ¹) residual tar in soil, tar compounds dissolved in groundwater and sorbed to soil	<ul style="list-style-type: none"> - Low degree of certainty in source material extent; evaluation of tar distribution (NDA/JWA, 1990) suggests that tar from the lagoon and tank farm have saturated fill material to the top of the underlying till; tar has then migrated laterally towards Coke Oven Brook and, in

¹ Note: DNAPL – Dense Nonaqueous Phase Liquid; a hydrocarbon product that is heavier than water.

Source Material Characterization: Composition and Extent	Form of Contaminated Source Material	Relative Degree of Certainty in Source Composition and Extent
		places, has penetrated the till and underlying Lower Morien sandstone; some data from the source area are supportive the interpretation is largely unconfirmed; - Moderate degree of certainty in source material composition
14. Coal Tar observed along much of the length of Coke Ovens Brook - on the Coke Ovens site (NDA/JWA, 1990) due to past disposal of waste tar directly to the brook; composed primarily of PAHs, MAHs, HCs.	Residual tar in brook sediments, surface and subsurface pools of free phase tar (DNAPL ¹), tar compounds dissolved in brook water and surrounding groundwater and sorbed to soil	- High degree of certainty in extent of source material in recent past, due to NDA/JWA (1990) observations - Low degree of certainty in current extent of source materials - Moderate degree of certainty in source material composition
S15. Coking distillate wastes and coal tars in the vicinity of the older Coke Batteries - these Coke Ovens were located at the then-future location of the Coal Pile Runway (south of Frederick Street) from 1901 to pre-1920 (CBEG, 1998); presence is indicated by black tar-like substance at 85-4; expected to consist, at least partly, of PAHs, MAHs, HCs.	Subsurface free phase tar, residual tar in soil, associated tar compounds dissolved in groundwater and sorbed to soil	- High degree of certainty in existence of source material - Low degree of certainty in extent of source materials - Moderate degree of certainty in source material composition

¹ Note: DNAPL – Dense Nonaqueous Phase Liquid; a hydrocarbon product that is heavier than water.

3.3 Pathways of Contaminant Migration

A summary of known or suspected contaminant migration pathways is provided in Table 3-4. In the context used herein, the term “pathway” denotes a route whereby contamination may migrate away from contaminated source material (see Table 3-3). Such pathways, and the contaminant phases that may migrate through them, include:

- Flow of organic liquid contamination, such as tar, oil or benzol; if these liquids are lighter than water they are known as LNAPLs (Light Nonaqueous Phase Liquids); liquids that are more dense than water are known as DNAPLs;
- Surface water transport of contaminated particles or dissolved contamination;
- Groundwater transport of dissolved contamination and, to a lesser degree, contaminated particles;
- Subsurface transport of gaseous phase contamination in soil vapour; and
- Airborne transport of contaminated dust or gaseous phase contamination.

It is possible for pathways to operate in sequence, in relatively complicated linkages. For example, contamination in soil vapour may partition to groundwater, and then discharge to surface water and then de-gas to the atmosphere. However, potentially complicated linkages such as these are not listed in

Table 3-4: they would be largely speculative, given the quantity of existing site data. Rather, the pathways indicated in the Table can be considered “primary” pathways, in that they either:

- Have been demonstrated to occur in the Study Area on the basis of field observations or sampling; and
- Are considered likely to occur on the basis of site characteristics and the properties of the contaminated source material.

This latter type of interpretation is based on “circumstantial” evidence, which means that the pathway has not been confirmed with site data.

The Table provides a conceptual description of each primary contaminant migration pathway indicated by the above criteria. An evaluation of the degree of certainty in the pathway characterization is also provided. The purpose of this evaluation is to assist in prioritization of pathways as targets of subsequent investigation. Additional evaluation of the potential for contaminant exposure to occur via the identified pathway is provided in the next section.

Table 3-4. Summary of Known or Suspected Contaminant Exposure Pathways - Study Area

Contaminated Source Material	Conceptual Description of Known or Potential Contaminant Exposure Pathway	Relative Degree of Certainty in Pathway Characterization
<p>S1. Coking distillate wastes and coal tars buried throughout the Coke Ovens site</p>	<p>S1.P1. Lateral migration of free phase tar (DNAPL) along a low permeability barrier (e.g., the top surface of the till unit)</p>	<p>Low - The quantity of buried waste material is expected to be relatively small and immobile; free phase tar specifically from this source has not been identified</p>
	<p>S1.P2 Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater</p>	<p>Low - based primarily on circumstantial evaluation since groundwater containing dissolved phase contamination specifically from this source has not been identified; groundwater contamination by dissolved coal tar compounds (e.g., PAHs) was noted to be widespread throughout the Coke Ovens site (Acres, 1985 and NDA/JWA, 1990); this pathway is expected to originate from small sources throughout the Coke Ovens site; the expected direction of migration would be similar to groundwater flow which was generally determined to converge on Coke Ovens Brook; most migration may occur through shallow bedrock, since this was identified as a high permeability zone (NDA/JWA, 1990); service and utility trenches may also provide a preferred pathway for contaminant migration; however, migration may also occur through other units (e.g., fill, till, deeper bedrock), although at a slower rate</p>
	<p>S1.P3 Direct contact with subsurface contaminated material</p>	<p>Low - based primarily on circumstantial evaluation: past disposal activities were identified that would lead to formation of subsurface source(s) (NDA/JWA, 1990); however, source locations are unknown</p>
<p>S2. Used motor oil applied for road dust control on the Coke Ovens site</p>	<p>S2.P1 Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater</p>	<p>Low - same rationale as pathway S1.P2</p>
	<p>S2.P2 Airborne transport of contaminated dust from contaminated source material at the ground surface</p>	<p>Low - based primarily on circumstantial evaluation: source was known to be previously located at surface but current extent is unknown; extent of airborne dust transport from the potential source material is also unknown</p>
	<p>S2.P3 Surface runoff contact with contaminated source material at the ground surface; transport of dissolved phase contamination or contaminated particulate matter in overland runoff</p>	<p>Moderate - based primarily on circumstantial evaluation: source was known to be previously located at surface but current extent is unknown; direction of potential migration in overland runoff would generally follow surface topography to surface water drainage channels; most runoff would leave the Coke Ovens site via Coke Ovens Brook</p>
	<p>S2.P4. Direct contact with contaminated material at the ground surface</p>	<p>Moderate - based primarily on circumstantial evaluation: past practices were identified that would lead to formation of surface source(s) (road surfaces) (NDA/JWA, 1990), but current extent of source is unknown.</p>

Contaminated Source Material	Conceptual Description of Known or Potential Contaminant Exposure Pathway	Relative Degree of Certainty in Pathway Characterization
	S2.P5. Direct contact with subsurface contaminated material	Moderate - based primarily on circumstantial evaluation: past disposal activities were identified that would lead to formation of subsurface source(s) (road subsurfaces) (NDA/JWA, 1990), but current extent of source is unknown
S3. Miscellaneous drain and pipe leaks throughout the Coke Ovens process area	S3.P1. Lateral migration of free phase liquids along a low permeability barrier (e.g., the top surface of the till unit) or along the water table (for LNAPLs)	Low - the volume and location of leaked material is unknown; free phase liquids specifically from this source has not been identified
	S3.P2. Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater	Low - same rationale as S1.P2
	S3.P3. Direct contact with subsurface contaminated material	Low - the volume and location of leaked material is unknown; free phase liquids specifically from this source has not been identified
S4. Dry and wet fallout from steel and coke manufacturing	S4.P1. Airborne transport of contaminated particulate matter	High - generation of source material is likely; direction of transport has been shown through modelling conducted for the current project
S5. Acid-generating sulphide minerals associated with coal at the Coal Pile Runway	S5.P1. Surface runoff contact with source material at the ground surface; dissolution and transport of acidity and metals in overland runoff	Moderate - based primarily on circumstantial evaluation: presence of source material at the surface is probable (NDA/JWA, 1990), and the generation of surface runoff from the source area is probable
	S5.P2. Infiltration of precipitation through source material above the water table or movement of groundwater through source material below the water table; dissolution of contamination (acidity and metals) into the water; migration of dissolved contamination in groundwater	High - based on the detection of acid drainage indicators (metals and sulphate) in groundwater in the source area (NDA/JWA, 1990; CBEG, 1998); two primary directions for migration of contamination away from the source area: a) southwestward toward (and discharging into) Coke Ovens Brook (NDA/JWA, 1990) and b) northward towards the CBDC rail line and Frederick Street (CBEg, 1998)
	S5.P3. Airborne transport of dust	High – fine-grained materials are present at the ground surface.
S6. Acid-generating sulphide minerals associated with coal at Mullins Coal Bank	S6.P1. Surface runoff contact with source material at the ground surface; dissolution and transport of acidity and metals in overland runoff	Moderate - based primarily on circumstantial evaluation: presence of source material at the surface is probable (NDA/JWA, 1990), and the generation of surface runoff from the source area is probable; however, the current extent of source material is not known but is substantially less due to recent removal activities; runoff is expected to generally flow towards drainage channels and finally to Coke Ovens Brook

Contaminated Source Material	Conceptual Description of Known or Potential Contaminant Exposure Pathway	Relative Degree of Certainty in Pathway Characterization
	S6.P2. Infiltration of precipitation through source material above the water table or movement of groundwater through source material below the water table; dissolution of contamination (acidity and metals) into the water; migration of dissolved contamination in groundwater	High - based on the detection of acid drainage indicators (metals and sulphate) in groundwater within, and north of, the source area (NDA/JWA, 1990); groundwater contamination is expected to migrate northwestward away from the source area, towards Coke Ovens Brook (NDA/JWA, 1990)
S7. Benzol and light oils in the vicinity of the Benzol Plant	S7.P1. Migration of free phase LNAPL on the water table	Moderate - mobility was indicated by past detection of free phase LNAPL on groundwater in the vicinity of the source area and the observation of LNAPL in the Benzol Spring and the outlet of Cagney Brook to Coke Ovens Brook (NDA/JWA, 1990); however, the LNAPL source may potentially have been depleted over the past several years, and the current extent and mobility of LNAPL is not known
	S7.P2. Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater	High - based on detection of elevated concentrations of monoaromatics and PAHs in groundwater in the vicinity of the source (NDA/JWA, 1990); groundwater contamination from this source is expected to generally migrate north to northwestward, towards Coke Ovens Brook, and likely to discharge to the brook; most migration may occur through shallow bedrock, since this was identified as a high permeability zone (NDA/JWA, 1990); service and utility trenches may also provide a preferred pathway for contaminant migration; however, migration may also occur through other units (e.g., fill, till, deeper bedrock), although at a slower rate;
	S7.P3. Airborne transport of contaminated dust or vapours from contaminated source material at the ground surface	Moderate - based on past observation of contamination at the ground surface (NDA/JWA, 1990); extent of airborne dust transport from the source material is unknown
	S7.P4. Surface runoff contact with contaminated source material at the ground surface; transport of dissolved phase contamination or contaminated particulate matter in overland runoff	Moderate - based on past observation of contamination at the ground surface in the source area (NDA/JWA, 1990); direction of potential migration in overland runoff away from the source area would generally follow surface topography to surface water drainage channels and Coke Ovens Brook
	S7.P5. Direct contact with contaminated material at the ground surface	Moderate - based on past observation of contamination at the ground surface in the source area (NDA/JWA, 1990);
	S7.P6. Direct contact with subsurface contaminated material	Moderate - based on past evidence of subsurface contamination in the source area (NDA/JWA, 1990);
	S7.P7. Subsurface migration of vapours away from source material	Low – little monitoring of subsurface vapours has been conducted.

Contaminated Source Material	Conceptual Description of Known or Potential Contaminant Exposure Pathway	Relative Degree of Certainty in Pathway Characterization
<p>S9. Organic contamination around the most recent Coke Batteries</p>	<p>S9.P1. Lateral migration of free phase tar (DNAPL) along a low permeability barrier (e.g., the top surface of the till unit)</p>	<p>Low - visible tar-like contamination was encountered in the fill and till in the source area (NDA/JWA, 1990); it was suggested that increasing soil VOCs concentrations with depth in other boreholes indicated the possibility of DNAPL at depth</p>
	<p>S9.P2. Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater</p>	<p>Moderate – dissolved phase contamination was been detected in groundwater monitoring wells in fill, till and bedrock underlying the source area; groundwater contamination from this source is expected to generally migrate north to northwestward, towards Coke Ovens Brook; NDA/JWA (1990) suggest that groundwater from the site may also discharge to the subsurface section Cagney Brook, near the source area</p>
	<p>S9.P3. Surface runoff contact with contaminated source material at the ground surface; transport of dissolved phase contamination or contaminated particulate matter in overland runoff</p>	<p>Moderate - based on past observation of contamination at the ground surface in the source area (Acres, 1985); direction of potential migration in overland runoff away from the source area would generally follow surface topography to surface water drainage channels and Coke Ovens Brook</p>
	<p>S9.P4. Airborne transport of contaminated dust from contaminated source material at the ground surface</p>	<p>Moderate - based on past observation of contamination at the ground surface (NDA/JWA, 1990); extent of airborne dust transport from the source material is unknown</p>
	<p>S9.P5. Direct contact with contaminated material at the ground surface</p>	<p>High - based on past observation of contamination at the ground surface in the source area (NDA/JWA, 1990)</p>
	<p>S9.P6. Direct contact with subsurface contaminated material</p>	<p>High - based on past observation of subsurface contamination in the source area (NDA/JWA, 1990);</p>
<p>S10. Coal tar, coal and coke fines in Muggah Creek sediment</p>	<p>S10.P1. Surface water contact with contaminated source material; transport of dissolved phase contamination or contaminated particulate matter in surface water flow</p>	<p>High - JWEL-IT (1996) identified the potential for this pathway to be active</p>
	<p>S10.P2. Volatilization of contamination or generation of contaminated dust during times when sediment surface is dry; airborne transport of dust or gaseous phase contaminants</p>	<p>High - JWEL-IT (1996) identified the potential for this pathway to be active</p>
	<p>S10.P3. Direct contact with contaminated material at the surface of the sediments</p>	<p>High - JWEL-IT (1996) identified the potential for this pathway to be active</p>
	<p>S10.P4. Direct contact with subsurface contaminated material</p>	<p>High - JWEL-IT (1996) identified the potential for this pathway to be active</p>
<p>S11. PCB in Tar Ponds sediments</p>	<p>S11.P1. Surface water contact with contaminated source material; transport of dissolved phase contamination or contaminated particulate matter in surface water flow</p>	<p>High - Work by JWEL-IT (1996) identified the potential for this pathway to be active for PAHs; PCBs are considered to be analogous to PAHs, in this regard</p>
	<p>S11.P2. Direct contact with contaminated material at the surface of the sediments</p>	<p>High - Work by JWEL-IT (1996) identified the potential for this pathway to be active for PAHs; PCBs are considered to be analogous to PAHs, in this regard</p>

Contaminated Source Material	Conceptual Description of Known or Potential Contaminant Exposure Pathway	Relative Degree of Certainty in Pathway Characterization
	S11.P3. Generation of contaminated dust during times when sediment surface is dry; airborne transport of contaminated dust	High - Work by JWEL-IT (1996) identified the potential for this pathway to be active for PAHs; PCBs are considered to be analogous with respect to dust transport; however, potential for airborne transport of gaseous PCBs is considered negligible, due to the low volatility of these compounds
	S11.P4. Direct contact with subsurface contaminated material	High - Work by JWEL-IT (1996) identified the potential for this pathway to be active for PAHs; PCBs are considered to be analogous
S12. Coal tar and distillate wastes in Fill throughout the Coke Ovens site	S12.P1. Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater	Low - same rationale as pathway S1.P2
	S12.P2. Airborne transport of contaminated dust from contaminated source material at the ground surface	Low - based on past observation of contamination at the ground surface (Acres, 1985; NDA/JWA, 1990); extent of airborne dust transport from the source material is unknown
	S12.P3. Direct contact with contaminated material at the ground surface	High - based on past observation of contamination in shallow fill throughout the Coke Ovens site (NDA/JWA, 1990)
	S12.P4. Direct contact with subsurface contaminated material	High - based on past observation of contamination in shallow fill throughout the Coke Ovens site (NDA/JWA, 1990)
	S12.P5. Surface runoff contact with contaminated source material at the ground surface; transport of dissolved phase contamination or contaminated particulate matter in overland runoff	High – based on past observation of contamination in shallow fill throughout the Coke Ovens site (NDA/JWA, 1990)
S13. Coal Tar and distillate waste deposits on the Domtar site	S13.P1. Lateral migration of free phase tar (DNAPL) along a low permeability barrier (e.g., the top surface of the till unit)	Low - extensive visible tar-like contamination was encountered has been reported in the fill, till and bedrock in the source area (Acres, 1985; NDA/JWA, 1990)
	S13.P2. Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater	Moderate- substantial and extensive dissolved phase contamination was been detected in groundwater monitoring wells in fill, till and bedrock underlying the source area (Acres, 1985; NDA/JWA, 1990); groundwater contamination from this source is expected to generally migrate north to northwestward, towards Coke Ovens Brook
	S13.P3. Airborne transport of contaminated dust from contaminated source material at the ground surface	Low - based on past observation of contamination at the ground surface (Acres, 1985; NDA/JWA, 1990); extent of airborne dust transport from the source material is unknown
	S13.P4. Direct contact with contaminated material at the ground surface	High - based on past observation of contaminated source material at the ground surface in the source area (Acres, 1985; NDA/JWA, 1990)

Contaminated Source Material	Conceptual Description of Known or Potential Contaminant Exposure Pathway	Relative Degree of Certainty in Pathway Characterization
	S13.P5. Direct contact with subsurface contaminated material	High - based on past observation of contaminated subsurface source material in the source area (NDA/JWA, 1990)
	S13.P6. Surface runoff contact with contaminated source material at the ground surface; transport of dissolved phase contamination or contaminated particulate matter in overland runoff	High – based on recent observation of coal tar at the ground surface
S14. Coal Tar observed along much of the length of Coke Ovens Brook	S14.P1. Transport of tar downstream , in surface water flow or along the bottom of the brook	Low - pathway was highly active in the past, due to past disposal of tar directly to the brook; reconnaissance inspection of the brook for the current study indicates that the pathway is now substantially less active, but the long term contaminant loading is unknown
	S14.P2. Migration of tar into sediments underlying the brook	Low - pathway had high potential to be active in the past, due to past disposal of tar directly to the brook; reconnaissance inspection of the brook for the current study indicates that the present potential is much less; however, it is not known whether past migration has caused build-up of tar in sediments underlying the brook
	S14.P3. Dissolution of contamination into Coke Oven Brook; downstream transport of dissolved phase contamination in streamflow	Low - pathway was highly active in the past, due to past disposal of tar directly to the brook; reconnaissance inspection of the brook for the current study indicates that the pathway is now substantially less active, but the long term contaminant loading is unknown
	S14.P4. Direct contact with contaminated material along the bottom of the brook	High - pathway had high potential to be active in the past, due to past disposal of tar directly to the brook; reconnaissance inspection of the brook for the current study indicates that the present potential is substantially less
	S14.P5. Direct contact with subsurface contaminated material underlying the brook	Low - pathway had high potential to be active in the past, due to past disposal of tar directly to the brook; reconnaissance inspection of the brook for the current study indicates that the present potential is much less; however, it is not known whether past migration has caused build-up of tar in sediments underlying the brook
S15. Coking distillate wastes and coal tars in the vicinity of the <i>older</i> Coke Batteries	S15.P1. Lateral migration of free phase tar (DNAPL) along a low permeability barrier (e.g., the top surface of the till unit)	Low - visible tar-like contamination was encountered in fill in the source area (Acres, 1985); however no information exists for large portions of the area

Contaminated Source Material	Conceptual Description of Known or Potential Contaminant Exposure Pathway	Relative Degree of Certainty in Pathway Characterization
	S15.P2. Infiltration of precipitation through contaminated material above the water table or movement of groundwater through contaminated material below the water table; dissolution of contamination into the water; migration of dissolved phase contamination in groundwater	Moderate - substantial and extensive dissolved phase contamination was been detected in groundwater monitoring wells in fill, till and bedrock underlying the source area (Acres, 1985; NDA/JWA, 1990); groundwater contamination from this source is expected to generally migrate north to northwestward, towards Coke Ovens Brook; shallow groundwater may also be intercepted by subsurface structures (the Conveyer Tunnel and the Whitney Brook culvert) which are also expected to direct it southward (NDA/JWA, 1990); recent work by CBEG (1998) indicates that groundwater from the northern edge of the area may move northerly, possibly discharging to Whitney Brook
	S15.P3. Direct contact with subsurface contaminated material	Low - based on past observation of contaminated subsurface source material in the source area (NDA/JWA, 1990)

3.4 Particulate Deposition

Screening modelling of particulate deposition was completed to identify the potential zone of impact of air borne particulate emitted from both the Sydney Steel Plant (SYSCO) and the former Coke facility. The screening particulate deposition modelling also provides an estimate of the impact area of other air contaminants associated with the particulate, including metals and polynuclear aromatic hydrocarbons (PAHs). The time span over which the *worst case* deposition was expected to have occurred was from the 1950s through to 1975 during which time the two facilities were known to be operating at their maximum capacities. The annual deposition modelling presented herein is representative of this worst case time period.

However, it should be noted that the screening deposition results are only estimates of the worst case as detailed source specific emission rates were not readily available. For this screening evaluation, the deposition modelling was also simplified by grouping major sources together, neglecting building wake effects and using representative meteorological data.

The screening emissions and dispersion modelling of particulate emissions from the facilities involved the following tasks:

- Estimate emissions from each major particulate emission source at the SYSCO and Coke facilities representative of the 1950s to 1970s time period;
- Conduct dispersion modelling of particulate to calculate the estimated annual deposition rate in grams per square metre per year ($\text{g}/\text{m}^2/\text{yr}$) and define the approximate impact areas using deposition contours; and
- Evaluate the results of the worst case emissions and dispersion modelling with respect to historical operations at the facilities and the potential for particulate, metals, and PAHs impact.

3.4.1 Particulate Emissions Estimates

Emissions were estimated based on the United States Environmental Protection Agency (USEPA) document, "AP-42 Stationary Source Emission Factors, Chapter 12, Section 2, Coke Production and Section 5, Iron and Steel Production", dated January 1995.

To determine the sources of particulate emissions operated at the SYSCO and Coke Ovens facilities during the period from the 1950s to the 1970s, CBCL/CRA conducted personal interviews with former SYSCO and Coke Ovens staff who were familiar with past operations the facilities. The information gained included facility sources, throughputs, and operational times for use, in conjunction with the AP-42 emission factors.

Tables 3-5 through 3-7 summarize the emission estimates for the two facilities, based on the AP-42 emission factors and the site specific information. These would represent maximum rated production for these units. Actual production rates were considerably less according to SYSCO officials.

Table 3-8 provides a summary of the particle size distribution for all of the sources at the two facilities. The particle size distributions were estimated based on information provided by AP-42 documents. It is noted that where particulate distributions were not available they were estimated. For the #6 battery stacks through #5 coking cycle, the particulate distribution has been estimated based on the distribution for a boiler, as no published data was available for these sources.

Emission estimates for the two facilities in the 1970s were provided by Environment Canada (EC) in the following reports:

- Environment Canada. 1974. "Air Pollution Assessment of Sydney Steel's Present and Future Coke-Making Operations, Sydney, Nova Scotia". Air Pollution Control Directorate, December 1974; and
- Environment Canada. 1973. "Air Pollution Assessment of Sydney Steel's Present and Future Steel-Making Operations, Sydney, Nova Scotia", Mining, Mineral and Metallurgical Division Abatement and Compliance Branch, Air Pollution Control Directorate, August 1973.

In some cases the EC emission estimates were based on AP-42 emission factors and facility operational information available at the time of report preparation (1970s). EC did not detail the sources or methodologies for some of the emission estimates.

Table 3-9 summarizes the source parameters (source type, airflow rate, temperature, stack height, stack diameter, and source dimensions) for both facilities as well as the AP-42 and EC emissions rate estimates for each source.

Table 3-9 shows that the EC emission rates and the AP-42 emission rates calculated by CBCL/CRA are comparable. For modelling purposes it was assumed that where there were emission estimates from both AP-42 (Tables 3-5 to 3-8) and EC (Table 3-9), the data presented by EC provided the most accurate estimate of the emission rates for the source in question. For emission sources that were known to be in operation at the facilities, but were not discussed in EC reports, emission estimates were based on the

AP-42 calculations (Tables 3-5 to 3-8). It is noted that both the AP-42 and EC data for all sources has been provided for reference only, the majority of modelling was completed based on EC estimates.

As shown in Table 3-9, there were approximately 49 particulate emitting sources at the two facilities. Included in the sources were point sources such as the blast furnace stacks, volume sources such as the low-level emissions from the Coke facility batteries and area sources such as the stockpiles of raw materials.

Based on local information, the emission estimates completed by EC in 1972 and the supplemental AP-42 emission estimates are considered to be representative of the *worst case* operational conditions for both the SYSCO and Coke facilities. During this time there were emission controls on the blast furnaces consisting of dust collectors and a scrubber. The gas from the blast furnaces had a high Btu value and after cleaning was used as a fuel for the boilers. As previously noted, the "worst-case" emissions are presented in this report. The nature and efficiency of the emission controls are not known and therefore not accounted for in the AP-42 emission estimates. The majority of the modelling was completed based on EC emission estimates. Since the EC work was completed at the time of operation, it is possible that these emission controls were accounted for in the estimates, however, documentation confirming this was not available. Table 3-10 provides a historical summary of the facility operations based on available information. Table 3-10 shows that the facilities were operating at peak levels in the 1950s to 1970s.

3.4.2 Dispersion Model Inputs

The USEPA Industrial Source Complex 3 (ISC3) model was chosen to complete the deposition modelling of the emissions from the two facilities. This model is recognized both in Canada and the United States as an accurate model for use in dispersion and deposition modelling of air contaminants. The model has the ability to manage multiple sources. As well, the model allows for input of complex terrain and detailed meteorological data. For the purposes of modelling the two facilities, the following information was used as input into the ISC3 model:

3.4.2.1 Meteorological Data

Meteorological Data for Sydney, Nova Scotia was obtained for the years 1987, 1988, 1989, 1990, and 1991. Meteorological data for the years prior to 1987 is known to exist, however it was not readily available in the format required as input to the ISC3 model. It was assumed that the five years of data represented by 1987 to 1991 would be sufficient to establish the general meteorological conditions that prevail in Sydney.

3.4.2.2 Complex Terrain Data and Receptor Grid

Digital mapping of Sydney for the area surrounding the two facilities was obtained. The metric 1:10,000 scale digital Universal Transverse Meridian (UTM) mapping was prepared from 1992 aerial photography by the Province of Nova Scotia. The mapping included information regarding roadways, land formations, hydrography and topography. Complex terrain information was extracted using AutoCAD to develop an x, y, and z receptor grid. The digital terrain information was used as input for the receptor grid in ISC3. A 10 k by 8 k receptor grid, consisting of 2,000 receptors surrounding the facilities on a 200 m grid spacing was used as shown on Figure 3-1.

3.4.2.3 Emission Source Parameters for SYSCO Steel and Coke Facility

With a large number of sources and receptors, the modelling of particulate deposition requires extensive computer processing time. As shown in Table 3-9, there were approximately 49 separate emission sources during the worst case operating period of 1950s to 1970s. With the best available computer hardware, running all 49 sources with 2,000 receptors and five years of hourly meteorological data would have required up to several months of computer run time. To reduce the computer run time to a manageable time, the 49 emission sources were reviewed and simplified to six sources. The sources were reduced by grouping the most significant sources of particulate emissions. For the Coke Ovens Facility, the Coal Crushing operation was considered to be one source. The operation of the batteries occurred in one long building, therefore, all sources of particulate from the batteries was considered to be produced from one volume source, and all particulate emissions associated with the operation of the batteries were added together. Both of the battery stacks were 76.2 m in height, therefore emissions from the two stacks were assumed to occur from one stack with the combined particulate emission of both the #5 and #6 Battery Stack. The combustion stack was a lower height than the battery stacks and was therefore included as a separate point source. A review of the emissions from the Steel Facility identifies that the particulate emissions from the Blast furnace bleeders and the Open Hearth Furnaces are significantly larger than any other emission sources from the facility and would therefore be the primary source of off property emissions. As a result, the emissions from the Steel Facility were grouped into two point sources. Simplified Source 5 represents the combined particulate emissions from the No. 1 and No. 3 Blast Furnace Bleeders. Simplified Source 6 represents the combined particulate emissions from the Open Hearth furnaces. The six simplified emission sources created for the two facilities are summarized in Table 3-11. The particulate distributions for the simplified sources are summarized in Table 3-12.

The emission rates for the simplified sources were grouped as follows:

Coke Ovens Facility		
Simplified Source	Description	Emission Rate (g/s)
Source 1	Coal Crushing	9.52
Source 2	Batteries;	
	Oven Charging	9.06
	Oven Door Leaks	4.67
	Oven Pushing	3.62
	#5 Battery Coking Cycle	0.03
	#6 Battery Coking Cycle	0.03
	Quenching	<u>5.43</u>
	Total Source 2	22.80
Source 3	#5 Battery Stack	3.79
	#6 Battery Stack	<u>4.35</u>
	Total Source 3	8.14
Source 4	Combustion Stack	2.94

SYSCO Steel Facility

Simplified Source	Description	Emission Rate (g/s)
Source 5	Blast Furnace bleeder No. 1	113.4
	Blast Furnace bleeder No. 3	<u>113.4</u>
	Total Source 5	226.8
Source 6	Open Hearth Furnace No. 1	137
	Open Hearth Furnace No. 2	137
	Open Hearth Furnace No. 3	164
	Open Hearth Furnace No. 4	137
	Open Hearth Furnace No. 5	274
	Open Hearth Furnace No. 6	<u>164</u>
	Total Source 6	1013

The simplified source parameters (stack height, stack diameter, airflow rate, temperature, dimensions) are an average of the individual sources used to make up the simplified source. For example, a total emission rate of 1,013 g/s was assumed to be emitted from one open hearth furnace, with an average stack height of 61 m, an average exit temperature of 3003 degrees Kelvin, an average exit velocity of 20 m/s, and an average stack diameter of 2 m (see Table 11). The location of the simplified source was assumed to be in the centre of the individual sources.

A review of Table 3-9 shows that several sources were not included in the simplified sources. Some sources were not included in a simplified source because their emission rates were insignificant (less than 1 gram per second). The sintering emissions and the cast house emissions were not included in a simplified source for the steel facility because these emissions sources did not coexist with all six of the large open hearth furnaces sources. The sintering and cast house emissions that were left out of the modelling were balanced by including all six open hearth furnaces in the model runs even though open hearth furnace 2 was not operated at all times during the 1950s to the 1970s.

UTM coordinates for the simplified sources were established by CBCL/CRA based on available information and an aerial photograph of the two facilities.

3.4.2.4 Emission Source Parameters Coke Facility PAH Emissions

Polynuclear Aromatic Hydrocarbons (PAHs) are emitted primarily from the coking operation rather than the steel making process. PAHs have been identified as a contaminant of concern in the area surrounding the former Coke facility. Therefore, a separate air dispersion model was completed to establish a potential zone of impact for particulate deposition from the air emissions generated by the Coke facility.

Based on the Environment Canada (1984) report ambient PAHs were reported as being associated with particle sizes with a diameter less than 7 micrometres (μm). The study reports that less than 1 percent of PAHs were found on particulate with a diameter greater than 7 μm . Based on this information, the simplified emission estimates (Table 3-11) for the former Coke facility were redistributed to include only

emissions of particulate up to and including 7 µm. Table 3-13 provides a summary of the simplified emission estimates for the former Coke facility for particle sizes up to 7 µm.

3.4.3 Dispersion Modelling Results

The following two scenarios were considered for the SYSCO and Coke facility deposition modelling:

- Total Particulate and Metals Impacts: The combined particulate emissions from both the SYSCO and Coke facilities, assuming that they are operating simultaneously, for all particle sizes; and
- PAH Impacts: The impact of the Coke facility only, for particle size diameters of 7 µm or less.

For both scenarios the ISC3 model provides the results of an average annual particulate deposition over a five-year meteorological time span.

Figure 3-2 provides the results of the average annual worst case particulate deposition modelling for the combined particulate emissions from both facilities, for all particle sizes. Based on the model output, the maximum, average annual, off-property particulate deposition rate is estimated to be 386.84 grams per square metre per year ($\text{g}/\text{m}^2/\text{yr}$). The total particulate deposition from the two facilities is representative of a potential worst case annual impact for particulate and metals contained in the particulate.

Figure 3-3 provides the results of the average annual worst case particulate deposition modelling for particles sizes of 7µm or less emitted from the Coke Ovens facilities only. Based on the model output, the maximum, average annual, off-property particulate deposition rate is estimated to be 10.11 $\text{g}/\text{m}^2/\text{yr}$. The total particulate deposition from the Coke Ovens facilities for particle sizes of 7 µm or less is considered representative of a potential worst case annual impact for PAH compounds contained in the particulate.

Figure 3-2 identifies that the maximum off-property concentrations of particulate deposition occur to the Northeast of the SYSCO facility. Figure 3-3 identifies that the maximum off-property concentrations of particulate deposition are occurring to the south of the Coke Ovens facilities. Based on a comparison of the two Figures and the magnitude of the emission rates from both the SYSCO and Coke Ovens facilities, it is concluded that the majority of particulate deposition occurs as a result of the SYSCO open hearth steel making process.

As previously discussed in Section 2.1.6, dustfall air monitoring was initiated by Nova Scotia Department of Public Health in 1958. In 1982, Environment Canada reported that dustfall levels ranged from 5.1 to 353.4 $\text{g}/\text{m}^2/\text{month}$ depending on the distance of the monitoring station from the facilities, and the year of sampling. Decreases in dustfall levels reported between 1972 and 1982 are likely related to the decrease in SYSCO's production levels during this time.

By comparing the EC dustfall monitoring results (1972 to 1980) at all monitoring stations to the total particulate deposition estimates on Figure 3-2, the following observations are made:

- There is an excellent correlation between the maximum concentration locations predicted by the model and those monitored by EC. The model contours are consistent with the trends of particulate deposition as monitored by EC;

- The model under predicted particulate deposition by a factor of two to three when compared to the EC monitoring stations at locations over 500m from the facilities; and
- The model under predicted particulate deposition by a factor of 2 to 20 when compared to the EC monitoring stations at locations within 500m from the facility.

The model under predicted particulate deposition compared with the EC monitoring data due to several factors:

- Low level fugitive emissions that were not included in the dispersion model can add to the deposition levels on the site property and very close to the facilities;
- The dispersion modelling did not include building wake effects which can substantially increase ground level deposition near the facilities;
- The screening deposition modelling used a typical worst case emission rate scenario for the period 1950's to 1970's, however there may have been specific years that had higher emission rates than those modelled; and
- Particulate emissions from other sources in Sydney such as coal mining and handling operations, Nova Scotia Power Corporation facilities, various other industrial sources, and residential coal-fired furnaces were not included in the modelling.

If more accurate modelling results are required, then a more comprehensive understanding of the particulate emission sources (both on and off-site), and more detailed modelling and sensitivity analysis needs to be undertaken. As well, it may be useful to calibrate to the measured points, and back calculate emission levels for the major sources, to help provide a more accurate picture.

3.4.3.1 Contaminant Concentrations in Particulate

Information regarding the percent composition of the particulate emissions was provided in the 1973 Air Pollution Control Directorate report discussing the SYSCO operations (Environment Canada, 1982). The information is summarized in Table 3-14. The percent composition numbers as shown in Table 3-14, can be directly applied to the deposition contours to provide an estimate of the annual compound-specific deposition in g/m^2 . For example, the percent composition of copper in the particulate emitted from the open-hearth furnaces is estimated to range from 0.11 percent to 0.16 percent. Assuming that copper is emitted at the same percentage from other sources it can be estimated that the maximum concentration of deposition is equal to $386.84 \text{ g}/\text{m}^2/\text{yr}$ multiplied by 0.16 percent copper or $0.619 \text{ g}/\text{m}^2/\text{year}$ copper.

As previously noted, the primary contaminants of concern from the Coke facility are PAHs. In the EC, (June 1984) report the following information was provided: "The USEPA has estimated that Coke Ovens are responsible for 19% of nationwide emissions of BaP (155 tonnes per year using a crude emission factor of 2.7 g per tonne of coal processed)". By comparing the 2.7 g/tonne of coal processed emission factor to the average AP-42 emission factors for particulate from the emission sources at the Coke Facility (see Table 3-5) and accounting for only those particles with a diameter less than $7 \mu\text{m}$, a percentage of BaP in the particulate was estimated as 1.2 percent:

Coke Facility Source	AP-42 Emission Factor (kg/Mg of Coke produced)	Percent Particle Size <7 microns
Oven Door Leaks	0.27	43.3
Oven Pushing	0.58	43.3
Quenching	0.57	30.1
Combustion Stack	<u>0.234</u>	<u>95.9</u>
Average	0.41	53.15

$$\text{Percent BaP in Particulate} = \frac{2.7 \text{ g BaP}}{\text{Tonne of Coke Produced}} \times \frac{\text{tonne of Coke Produced}}{410 \text{ g}} \times \frac{1}{.5315 \text{ (less than } 7\mu)} \times 100 = 1.2\%$$

This percent composition of BaP in the particulate deposition, can be directly applied to the deposition contours illustrated on Figure 3-3 to provide an estimate of the annual BaP deposition in g/m² at a particular contour interval. Therefore it is estimated that the maximum concentration of BaP deposition is equal to 10.11 g/m²/yr multiplied by 1.2 percent BaP or 0.121 g/m²/year BaP.

As discussed previously, if particulate contaminants of concern need to be better understood from a depositional point of view, then more comprehensive evaluation and modelling is required.

3.4.4 Summary

Screening particulate deposition modelling was completed to identify the potential zone of impact of particulate emissions from the SYSCO and Coke facilities, including metals and PAHs contained in the particulate. As further described below, it is noted that the model is to be used as a screening tool only. Due to the limited scope of work involved with this report, detailed calibration of the model was not completed.

Particulate emission estimates from EC studies in the 1970's were used. These emission estimates were supplemented by emissions estimates using USEPA AP-42 emission factors for steel and coke operations with estimated operating data. The source emission rates were representative of the peak operations that occurred from the 1950's to 1970's.

The major sources were grouped into six sources to simplify the screening dispersion modelling. A five-year set of meteorological data (1987 to 1991) for Sydney was used to establish general meteorological conditions. A 10 k by 8 k receptor grid with 200m spacing and digital ground elevation mapping was used.

The deposition modelling for total particulate emissions from both facilities resulted in a maximum deposition rate of 386.84 g/m²/yr and a deposition zone as shown on Figure 3-2. The total particulate deposition rates may be multiplied by the metals concentrations in Table 3-14 to obtain estimated metals deposition rates.

PAH deposition is associated with emissions from the Coke Ovens facility for particle sizes up to 7 µm. The maximum deposition rate for the 7 µm particle sizes was 10.11 g/m²/yr with a deposition zone as

shown on Figure 3-3. The 7 µm deposition rates may be multiplied by an estimated BaP concentration in particulate of 1.2% to obtain estimated BaP deposition rates.

The screening deposition zone patterns correlated well with the locations of maximum deposition rates monitored by EC from 1972 to 1980. The screening deposition modelling under predicted the EC monitoring results by factors of two to three for monitoring stations located more than 500 m from the facilities and by factors of 2 to 20 for monitoring stations located less than 500 m from the facilities.

The screening deposition modelling may have under predicted the EC monitoring results for several reasons, including:

- Low-level fugitive emissions that were not included in the dispersion model can add to the deposition levels on the site property and very close to the facilities;
- The screening dispersion modelling did not include building wake effects which can substantially increase ground level deposition near the facilities;
- The screening deposition modelling used a typical worst case emission rate scenario for the period 1950's to 1970's, however there may have been specific years that had higher emission rates than those modelled; and
- Particulate emissions from other sources in Sydney such as coal mining and handling operations, Nova Scotia Power Corporation, various industrial sources and residential coal-fired furnaces were not included in the modelling.

The deposition estimates provided in Figures 3-2 and 3-3 cannot be used as the basis for past or future health impact evaluations. The scope of this screening modelling was to define the potential zone of impact of particulate, metals and PAHs deposition, however accurate quantification of deposition rates or concentrations would require further work.

More accurate deposition modelling can be conducted to provide better estimates of deposition rates of particulate, metals and PAHs in units of grams per square metre per year as presented in Figures 3-2 and 3-3. Improvements can be made in the model predictions by the following:

- Incorporate building wake effects from facility structures;
- Use accurate emission estimates for individual sources on a year-by-year basis over the lifetime of the facility operations (rather than worst case);
- Incorporate particulate emission rate estimates for off-site sources;
- Evaluate the impact of individual major and minor sources on deposition rates using sensitivity analyses;
- Conduct deposition runs for each year of operation and meteorological data; and
- Run deposition model without grouping sources.

The model predictions can also be “calibrated” using actual sampling data. The particulate deposition data previously collected by EC can be used to adjust the model predictions for the actual measured

deposition rates. The EC monitoring data can also be used to back-calculate emission rates from major sources to evaluate the accuracy of emission estimates.

The deposition predictions of the model can also be ground proofed using existing and future soil sampling data. Ground proofing would verify the pattern of particulate, metals and PAHs deposition predicted by the model. This ground-proofing would also allow a correlation to be made between the model contours and probable ground concentrations in areas not sampled.

The modelling can be readily modified to provide estimates of concentrations in air of particulate, metals and PAHs that can then be used for health impact evaluations for the inhalation exposure scenarios of past years of operation. The modelling contours shown in Figures 3-2 and 3-3 could be modified to provide annual exposure concentrations in air in units of micrograms per cubic metre ($\mu\text{g}/\text{m}^3$) for this purpose.

3.5 Potential Exposure Locations

A list of the general human and ecological groups that could potentially be exposed to contamination originating from contaminated materials in the study area is provided in Table 3-15. This list is intended to provide a list of groups where the potential for exposure is the highest, rather than a list of all humans and ecological groups that may be exposed.

In Table 3-16, these groups are ranked according to an evaluation of the potential for contaminant exposure via each of the contaminated source material / exposure pathway combinations that were identified previously. The purpose of presenting the information in this manner is to illustrate the potential linkages between:

- Contaminated source materials;
- Contaminant exposure pathways; and
- Human and ecological groups that may potentially be exposed to contamination.

This exposure is termed *potential* because additional information would generally be required to determine the occurrence and significance of contaminant exposure. The types of additional information that may be required include:

- Confirmation of the presence of receptors (i.e., people or ecological components) at the potential exposure location;
- Measurement of environmental concentrations of the contaminant at the potential exposure location; and
- Evaluation of the quantity, nature and effects of direct contact with the contamination.

3.6 Inputs and Outputs

The inputs and outputs to and from the Site Area are defined within the memorandum of understanding (MOU). This section addresses the potential contaminants entering the Site Area (input), and leaving the

Site Area (output) based on the information available as presented in Sections 2 and 3. An input represents groundwater, surface water, or air that moves onto the Site Area and that has a potential contamination. An example of inputs are the various brooks that flow onto the Coke Ovens Site and join with Coke Ovens Brook. An output is groundwater, surface water or air that flows out of the Site Area. The inputs and outputs represent potential contaminant sources that either impact the Site Area or the areas adjacent to the Site Area. The inputs may not be significant in nature, but indicate areas that need to be characterized and assessed during Phase 2/3. The inputs to the Site Area, a description of the input and the potential contaminants are summarized in Table 3.17, while the outputs from the Site Area are summarized in Table 3.18. A graphical representation of this information is provided in Figure 3-4. The Site Area has ubiquitous contamination related to principally to PAHs. As such, groundwater that crosses the Site boundary has the potential to be impacted and could be considered a global output. Table 3.18 highlights the main groundwater potential locations.

Table 3-15 Potential Receptors in the Vicinity of the Study Area

Potential Receptors: Humans(H) or Ecological(E)	Description
H1	Residents located adjacent to the north side of the Study Area – on Frederick Street and Curry’s Lane
H2	Residents located adjacent to the west side of the Study Area – on Victoria Road
H3	Residents located adjacent to the south side of the Study Area – on Vulcan Avenue, Beech Street, Birch Street and Ash Street
H4	Workers on the Coke Ovens Site
H5	Persons gaining unauthorized access to the Coke Ovens site
H6	Residents in areas adjacent to the Tar Ponds
H7	Workers in areas adjacent to the Tar Ponds
H8	Residents located within the Air Dispersion Plume
E1	Ecological receptors on the Coke Ovens site (Plant and animal communities resident on the site, wildlife that use the site as a staging, resting, or feeding area; and human visitors to the site.
E2	Ecological receptors in Coke Ovens Brook (Plant and animal communities resident in the Brook and/or those that move seasonally between the Harbour and Tar Ponds to the Brook.
E3	Ecological receptors in the Tar Ponds (Plant and animal communities resident in the Brook and/or those that move seasonally between the Harbour and Tar Ponds to the Brook.
E4	Ecological receptors in the South Arm of Sydney Harbour Plant and animal communities resident in the Harbour, wildlife that uses the Harbour as a breeding, resting or feeding and/or staging area, and human users of the Harbour.
E5	Ecological receptors in the Air Dispersion Plume (Plant and animal communities resident in/on lands or waters within the air dispersion plume, animals that use these areas for feeding, breeding, resting and/or staging and human users/residents of these areas.

Table 3.17: Summary of Inputs to the Site Area

Inputs to Site Area	Physical Description	Potential Contaminant
I-1 Coke Ovens Brook	Originates east of Site Area, enters Site Area along the east side of the Coke Ovens Site. Radar and Incinerator Brooks joins prior to the Site Area. Watershed is mainly industrial or vacant land. Municipal Landfill surface water enters the Brook prior to Site Area.	Landfill leachate from Municipal and Marsh Landfills (general chemistry parameters, metals, VOCs, PAHs) Urban/industrial contaminants Depositional particulate fallout (dissolvable and erosionable)
I-2 Whitney Pier Brook (Frederick Street Brook)	Originates north of Site Area, enters Site Area along the north side of the Coke Ovens Site. Frederick Street Brook joins prior to Site Area. Watershed is industrial (rail line), urban and vacant land.	Urban/industrial contaminants Depositional particulate fallout (dissolvable and erosionable) Contamination associated with recent seep (arsenic, lead, PAHs), surface water indicates iron and aluminum exceedances
I-3 DOMTAR Brook	Originates north of Site Area, enters Site Area along the north side of the Coke Ovens Site.	Urban/industrial contaminants (PAH contaminants noted in Brook) Depositional particulate fallout (dissolvable and erosionable)
I-4 Cagney Brook	Originates south of Site Area, enters Site Area along the south side of Coke Ovens Site (Mullin's Bank). Cossitt Lake is headwaters. Watershed is mainly urban/industrial.	Urban/industrial contaminants Depositional particulate fallout (dissolvable and erosionable)
I-5 Wash Brook	Originates south of Site Area. Enters Site Area at the south end of Muggah Creek. Watershed is mainly urban/industrial.	Urban/industrial contaminants Depositional particulate fallout (dissolvable and erosionable) Municipal sewage (4 sanitary outfalls)
I-6 and I-7 Sanitary Outfalls	Sanitary/storm sewers. Enter Site Area along south side of the Coke Ovens Brook Connection.	Municipal sewage Urban/industrial contaminants Depositional particulate fallout (dissolvable and erosionable)
I-8, I-9, I-10, I-11, I-12, I-13, and I-14 Sanitary Sewer Outfalls	Sanitary/storm sewers. Enter Site Area along east and west sides of Muggah Creek.	Municipal sewage Urban/industrial contaminants Depositional particulate fallout (dissolvable and erosionable)
I-15 Sysco Cooling Pond	SYSCO plant effluent/cooling water. Enters Site Area along north side of Coke Ovens Brook Connection.	Formerly received industrial effluent (SYSCO) (metals, hydrocarbons)
I-16 Sysco Boom Mill Scale Pit	Effluent from Boom Mill Scale Pit (operational in 1980). Enters Site Area along the east side of Muggah Creek.	Industrial effluent related to Boom Mill Scale Pit operation
I-17 Marsh Landfill and Regional Landfill	Groundwater from landfills that enter the Site Area along the east side of the Coke Ovens Site. Studies currently being conducted to define impacts	Industrial and municipal landfill leachate (general chemistry, metals, VOCs, PAHs)

I-18 Frederick Street/Devco Rail Line	Groundwater from fill materials that enter the Site Area along the north side of the Coke Ovens Site. Groundwater may also be an output in this area.	Leachates from soils used for fill and free products (CBEG, 1998) (metals, PAHs)
I-19 SYSCO Slag Pile and High Dump	Area source, shallow groundwater flow. Enters Site Area along the east side of Muggah Creek.	industrial waste leachate (dependent on type of waste placed) coal tar (buried under slag), PAHs
I-20 Muggah Creek Fill Materials	Area source, shallow groundwater flow. Enters Site Area along the southeast side of Muggah Creek.	Contaminants associated with fill material coal tar (buried under slag), PAHs
I-21 Rail Yard	Area source, shallow groundwater flow. Enters Site Area along the west side of Muggah Creek.	petroleum hydrocarbons
I-22 Cement Plant and Petroleum Bulk Storage Area	Area source, shallow groundwater flow. Enters Site Area along the west side of Muggah Creek.	petroleum hydrocarbons

Table 3.18: Summary of Outputs from the Site Area

Outputs from Site Area	Physical Description	Potential Contaminant
O-1 Muggah Creek Estuary	Mouth of Muggah Creek Estuary to Sydney Harbour. Surface water discharge, plus tidal influences.	PAH compounds, coal tar, municipal sewage, coal and coke particulate
O-2 DOMTAR Lagoon	Seepage along west side of former lagoon storage areas. Coke Ovens Site.	Coal tar and PAHs
O-3 Air	Dust and vapour releases due to remediation activities and current conditions and historical releases.	Contaminants dependent on remedial work being conducted (PAHs, VOCs, dust)
O-4 Frederick Street/DEVCO Rail Line	Groundwater discharge. Groundwater flow in this area is not definitive. Groundwater may also be an input in this area.	Potential flow movement of groundwater (PAHs, metals, and coal tars) to move north in this area due to local brook influences.
O-5 Groundwater	Groundwater discharge	Potential flow movement of groundwater (PAHs, metals and coal tars) not defined at the present time. Cross property movement potential may occur along the north and west property boundaries of the Coke Ovens Site (see O-2 and O-4).

3.7 Summary - Conceptual Model of Contamination and Exposure

In Chapters 2 and 3 of this report, considerable detail has been provided on historical practices that occurred at the Site as well as summarizing and interpreting as best as possible various investigations that have been undertaken over the years. The results of this work have allowed the conceptualization of possible/probable contamination sources, migration pathways and receptors/exposure. This summary constitutes a Conceptual Model of contamination and exposure in the study area. By the nature of a Phase 1 study (non-intrusive and historical) and the dated nature of some of data, this work should be considered as potential issues/receptors, which need to be addressed in detail in subsequent phases of work (i.e. Phases 2 and 3). In an attempt to summarize this wide array of information, and provide guidance for the Phase 2 and 3 work programs that need to be undertaken, the results have been summarized and categorized in tabular form for ease of reference.

In Table 3-19, contaminated source materials have been categorized to place them in the context of an overall conceptual model. Table 3-20 provides a summary of the primary pathways whereby exposure to contamination from these sources could occur. A conceptual representation of contaminated source materials, migration pathways and potential receptors in the vicinity of the site is shown in Figure 3-5. A summary of contaminant sources and inputs in the Site and Investigation Areas is provided in Figure 3-6. The exposure pathways and potential receptors for each contaminant source on the study site are illustrated in Figures 3-7 to 3-20.

3.7.1 Widely Dispersed Sources - Solid and Liquid Coking Wastes

Five of the identified sources have been described as widely dispersed and four of these are located throughout the Coke Ovens site (S1, S2, S3 and S12 as detailed on Table 3-19). Their presence is due either to past disposal practices of coking distillate waste materials (S1, S3 and S12) or site dust control practices (S2). Contamination from all four sources is expected to be primarily organic: derived from either coal tar or petroleum hydrocarbons.

Table 3-19: Summary of Contaminated Source Materials According to Category - Study Area

Contaminated Source Material ¹	Source Category P - Probable, C - Confirmed			
	Widely Dispersed	Discrete Location	Shallow (<1m)	Deep (>1m)
S1. Coking distillate wastes and coal tars buried throughout the Coke Ovens site	P		P	P
S2. Used motor oil applied for road dust control on the Coke Ovens site	P		P	
S3. Miscellaneous drain and pipe leaks throughout the Coke Ovens process area	P		P	P
S4. Dry and wet fallout from steel and coke manufacturing	P		P	
S5. Acid-generating sulphide minerals associated with coal at the Coal Pile Runway		C	C	C
S6. Acid-generating sulphide minerals associated with coal at Mullins Coal Bank		C	C	C
S7. Benzol in the vicinity of the Benzol Plant		C	C	C
S8. Contaminated materials within slag, municipal wastes and ash ²				
S9. Organic contamination around the most recent Coke Batteries		C	C	C
S10. Coal tar in Tar Ponds sediment		C	C	C
S11. PCB in Tar Ponds sediments		C	C	C
S12. Coal tar in Fill throughout the Coke Ovens site	C		C	C
S13. Coal Tar deposits on the Domtar site		C	C	C
S14. Coal Tar observed along much of the length of Coke Ovens Brook		P	P	P
S15. Coking distillate wastes and coal tars in the vicinity of the <i>older</i> Coke Batteries		C	C	P

In terms of exposure, organic liquid migration is identified as a potential pathway for three of these four sources (S1, S3 and S12). For this pathway, it is expected that the organic liquid is coal tar-based and can reasonably be expected to be a DNAPL. Given the generally shallow nature of these sources, it is expected that any excess DNAPL would migrate to the bottom of the fill unit and would then spread laterally along the dip of the underlying till unit, which is expected to be less permeable. However, the amount of lateral DNAPL migration from these sources is unknown, but would not be expected to be significant since there is no evidence of high volume DNAPL releases.

Given the relatively small expected DNAPL volume, the highest potential for exposure to mobile DNAPL is considered to exist for on-site receptors (human and ecological; H4, H5, E1 and E2). However, exposure potential is also considered to be relatively high for residents adjacent to the north side of the site (H1), since the surface of the till unit may slope off-site in that direction in some areas (CBEG, 1998). The presence of DNAPL from these sources has not been confirmed in this area of the site.

¹ See Table 3-3 for additional source information

² Within the framework of this study, this source is considered outside the site area; see Table 3.17 for additional description (Inputs I-17 and I-19).

The direction in which dissolved phase contamination migrates away from these sources in groundwater is expected to be variable, depending on the location in the groundwater flow system. Groundwater movement on the Coke Ovens site has been shown to generally converge on Coke Ovens Brook from both sides (e.g., NDA/JWA, 1990). However, recent work by CBEG (1998) has indicated some potential for off-site flow of groundwater on the north side of the site, towards Frederick Street. This flow direction may be particularly active for shallow groundwater (e.g., in the fill unit).

In the vertical dimension, it has been suggested (NDA/JWA, 1990) that shallow bedrock underlying the Coke Ovens site is more highly fractured than deeper bedrock. Consequently, it has been further suggested that this zone may provide a preferential pathway for groundwater (and contaminant) movement.

Surface water transport of contamination from these widely dispersed sources is expected to converge on Coke Ovens Brook due to the topographic gradients across the site; however, local drainage pathways may vary somewhat.

3.7.2 Acid Generating Source Materials

Sulphide-bearing coal materials associated with the Coal Pile Runway and Mullins Coal Bank (Sources S5 and S6, respectively) have been identified as acid-generating, on the basis of groundwater monitoring data. These materials are generally expected to correspond with the respective footprints of these facilities when they were operating, although there is likely to be substantial further spreading beyond the previous boundaries. In the case of S6, coal recovery activities have been carried out that may have decreased the vertical and horizontal extent of the source materials.

Oxidation of these source materials may result in the introduction of acidity and metals to groundwater and surface water in the source areas. Human and ecological receptors on the Coke Ovens Site (H4, H5, E1 and E2) have been identified as having high potential for exposure to contamination via these pathways. From S5, the contaminant transport in both surface runoff and groundwater is expected to occur southwards, towards and into Coke Ovens Brook. However, the component of northward groundwater flow identified earlier (CBEG, 1998) at the north edge of the site also has the potential to move contamination off-site in a northward direction. As a result, residents immediately north of the site on Frederick Street (H1) have been identified as having a relatively high potential for exposure due to this source/pathway combination (S5.P2).

Transport of acidity and metals away for S6 in groundwater and surface water is expected to be generally northward due to an apparently strong hydraulic gradient and topographic gradient in this direction. Most contamination migrating from the source via both these pathways is expected to drain to Coke Ovens Brook, although they may be first intercepted by drainage ditches or tributary brooks. However, only small amount of groundwater data is available in the vicinity of the southern edge of the Coke Ovens site. Consequently, migration of acidity and/or metals contamination from Mullins Coal Bank in surface water and groundwater (source/pathway combinations S6.P1 and S6.P2, respectively) is still considered to present a relatively high potential for exposure for residents immediately south of the Coke Ovens site (H3).

3.7.3 Contaminated Source Materials at Previous Coking and Distillation Sites

Sources S7, S9, S13, and S15 have originated at locations of previous process buildings used in the coking and distillation process. At all locations, the migration of coal-derived liquids is considered possible and, given the large quantity of these liquids generated at these locations, substantial migration is possible. At S9, S13 and S15, the organic liquids are expected to be primarily DNAPLs (although LNAPLs may occur). Given the density of these liquids, they may penetrate below the water table and may then migrate laterally on top of the till unit or, in places where the till is thin or has been excavated, may penetrate through to bedrock. NDA/JWA (1990) hypothesized that at the Domtar site (S13) DNAPLs may have penetrated to bedrock and may have migrated along the Canso-Morien contact which is relatively shallow in this area, and dips eastward.

At the northern extent of both the Domtar Site and the *older* Coke Batteries, there is considered to be potential for off-site migration of DNAPLs in a northward direction towards Frederick Street (H1). Otherwise, the highest relative potential for exposure due to organic liquids migration is considered to related to on-site receptors (H4, H5, E1 and E2).

Migration of dissolved phase contamination away from these source materials, in both surface water and groundwater, is again expected to generally converge on Coke Ovens Brook. However, as discussed previously, the potential exists for northward groundwater flow near the northern site boundary. This leads to a relatively high exposure potential for residents immediately north of the Coke Ovens site (H1), with respect to groundwater transport from the Domtar site and the *older* Coke Batteries (source/pathway combinations S13.P2 and S15.P2, respectively [refer to table 3-4]).

3.7.4 Coal Tar in Coke Ovens Brook

Previous disposal practices at the Coke Ovens site involved direct discharge of waste tar to Coke Ovens Brook, where it would gradually move downstream and into the Tar Ponds. During earlier assessment work (NDA/JWA, 1990) it was noted that much of the brook remained coated with tar. This source has been identified as having high potential to lead to contaminant exposure for Coke Ovens site receptors (H4, H5, E1 and E2), as well as ecological receptors in the Tar Ponds and the South Branch of Sydney Harbour. Identified exposure pathways are via downstream tar migration, dissolved phase migration in stream water, and migration of tar into sediments underlying the brook.

It is apparent that this source and the associated pathways were highly active in the past, as indicated by the accumulation of tar in the Tar Ponds. However, inspection of the brook conducted through the current investigation indicated that the quantity of source contamination and contaminant migration along associated pathways may have decreased substantially.

It is also noted that Coke Ovens Brook is considered to receive and transmit body surface water and groundwater contaminant migration pathways from most of the sources identified on the Coke Ovens site.

Due to unrestricted access to portions of Coke Ovens Brook, the residents of Victoria Street have been added as a potential exposure group, although this could be eliminated by measures such as additional fencing.

3.7.5 Tar Ponds Sediments

Muggah Creek has accumulated contamination from upstream sources for so many years that the creek sediments must now be considered a contaminant source (S10 and S11). Acres (1985) conducted substantial evaluation of the distribution and fate of these sediments, and this body of work was added to by JWEL-IT (1996). This work indicates that migration of sediment occurs from Muggah Creek to the South Arm of Sydney Harbour and that ecological receptors in both these water bodies are exposed to contamination.

Ongoing contaminant loading to the Tar Ponds sediments from the remainder of the Area of Investigation is likely to be occurring, although the rate is not known. Coke Ovens Brook is still considered to be the primary transport pathway for the majority of the contamination.

3.7.6 Atmospheric Transport - Dry and Wet Fallout; Dust from Contaminated Source Materials

Screening particulate deposition modelling was completed to identify the potential zone of impact of particulate emissions from the SYSCO and Coke facilities, including metals and PAHs contained in the particulate. The deposition estimates provided in this report cannot be used as the basis for past or future health impact evaluations. The scope of this screening modelling was to define the potential zone of impact of particulate, metals and PAHs deposition, however accurate quantification of deposition rates or concentrations would require further work.

The source emission rate estimates were representative of the peak operations that occurred from the 1950's to 1970's. A 10-kilometre by 8-kilometre receptor grid with 2000 receptors and digital ground elevation mapping was used. A five-year set of meteorological data (1987 to 1991) for Sydney was used to establish general meteorological conditions. The deposition modelling for total particulate emissions from both facilities resulted in a maximum deposition rate of 386.84g/m²/yr and a deposition zone as shown on Figure 3-2. PAH deposition is associated with emissions from the Coke Ovens facility for particle sizes up to 7 microns (µm). The maximum deposition rate for the 7 µm particle sizes was 10.11 g/m²/yr with a deposition zone as shown on Figure 3-3.

Table 3.20: Summary of Potentially Active Contaminant Exposure Pathways - Study Area

Contaminated Source Material ¹	Primary Contaminant Exposure Pathway Identified as Potentially Active ^{2 3}				
	Organic Liquid Migration	Dissolved Phase in Groundwater	Dissolved and/or Particulate in Surface Water	Atmospheric Transport of Gaseous and/or Particulate	Direct Contact
S1. Coking distillate wastes and coal tars buried throughout the Coke Ovens site	S1.P1 (H1, 4, 5) (E1, 2)	S1.P2 (H1, 4, 5) (E1, 2)			S1.P3 (H4, 5) (E1, 2)
S2. Used motor oil applied for road dust control on the Coke Ovens site		S2.P1 (H1, 4) (E1, 2)	S2.P3 (H1, 2 ⁴ , 4, 5) (E1, 2)	S2.P2 (H8) (E5)	S2.P4/P5 (H4, 5) (E1, 2)
S3. Miscellaneous drain and pipe leaks throughout the Coke Ovens process area	S3.P1 (H1, 4, 5) (E1, 2)	S3.P2 (H1, 4) (E1, 2)			S3.P3 (H4) (E1, 2)
S4. Dry and wet fallout from steel and coke manufacturing				S4.P1 (H8) (E5)	
S5. Acid-generating sulphide minerals associated with coal at the Coal Pile Runway		S5.P2 (H1, 4) (E1, 2)	S5.P1 (H2 ⁴ , 4, 5) (E1, 2)	S5.P3 (H8)	
S6. Acid-generating sulphide minerals associated with coal at Mullins Coal Bank		S6.P2 (H3, 4) (E1, 2)	S6.P1 (H2 ⁴ , 4, 5) (E1, 2)		
S7. Benzol in the vicinity of the Benzol Plant	S7.P1 (H4) (E1, 2)	S7.P2 (H2, 4) (E1, 2)	S7.P4 (H2 ⁴ , 4, 5) (E1, 2)	S7.P3/P7 (H2 ⁵ , 4, 8) (E5)	S7.P5/P6 (H4, 5) (E1, 2)
S9. Organic contamination around the most recent Coke Batteries	S9.P1 (H4, 5) (E1, 2)	S9.P2 (H4) (E1, 2)	S9.P3 (H2 ⁴ , 4, 5) (E1, 2)	S9.P4 (H8) (E5)	S9.P5/P6 (H4, 5) (E1, 2)
S10. Coal tar in Tar Ponds sediment			S10.P1 (H6, 7) (E3, 4)	S10.P2 (H8) (E5)	S10.P3/P4 (H6, 7) (E3)
S11. PCB in Tar Ponds sediments			S11.P1 (H6, 7) (E3, 4)	S11.P3 (H8) (E5)	S11.P2/P4 (H6, 7) (E3)
S12. Coal tar in Fill throughout the Coke Ovens site		S12.P1 (H1, 4) (E1, 2)	S12.P5 (H 1, 2 ⁴ , 4, 5) (E 1, 2)	S12.P2 (H8) (E5)	S12.P3/P4 (H4, 5) (E1, 2)
S13. Coal Tar deposits on the Domtar site	S13.P1 (H1, 4, 5) (E1, 2)	S13.P2 (H1, 4) (E1, 2)	S13.P6 (H1, 2 ⁴ , 4, 5) (E1, 2)	S13.P3 (H8) (E5)	S13.P4/P5 (H1, 4, 5) (E1, 2)
S14. Coal Tar observed along much of the length of Coke Ovens Brook	S14.P1/P2 (H2 ⁴ , 4, 5) (E1, 2, 3, 4)		S14.P3 (H2 ⁴ , 4, 5) (E1, 2, 3, 4)		S14.P4/P5 (H2 ⁴ , 4, 5) (E1, 2)
S15. Coking distillate wastes and coal tars in the vicinity of the <i>older</i> Coke Batteries	S15.P1 (H1, 4, 5) (E1, 2)	S15.P2 (H1, 4) (E1, 2)			S15.P3 (H4) (E1, 2)

¹ See Table 3-3 for additional source description

² Pathway headers in this table are intended to be generic; see Table 3-4 for additional description of specific pathways

³ Potential human (H) and ecological (E) receptors are indicated; descriptions of receptors are provided in Table 3-15

⁴ Residents on Victoria Road (H2) indicated due to potential exposure to Coke Oven Brook

⁵ In this case, the potential exposure pathway is “subsurface transport of gaseous phase contamination”; see pathway S7.P7.

CHAPTER 4 RECOMMENDED INTERIM MEASURES

4.1 Interim Measures

Often as a result of a Phase 1 Environmental Site Assessment, a number of situations are noted that do not require additional data collection prior to initiating effective and appropriate corrective actions. In the Muggah Creek Phase I Environmental Site Assessment, the Team has addressed these situations in the context of *Recommended Interim Measures*. All of the Interim Measures recommended below can be at least initiated, if not completed, prior to the receipt of data from future investigations. Interim measures can not be considered as permanent solutions to contaminated areas, but have value as temporary measures that improve safety and reduce the potential for human contact and the spread of contamination.

It should be noted that, at the time of the writing of this report, there was no documented evidence of situations within the scope of this Study that represent a short term risk to human health. In this context, these interim measures are recommended as actions that CAN be taken immediately as opposed to actions that MUST be taken immediately.

It should also be noted that some of these recommendations have been begun in projects commissioned by JAG or are in the planning stages.

It is also important that public consultation be continued and expanded through the JAG process. This will require implementation of a comprehensive communications strategy.

4.2 Exposed Coal Tar - Coke Oven Site

Coal tar in a free phase form was observed during the Site tour of the Coke Ovens Site on July 14, 1998. The amount of free phase coal tar material present varied from small seepage areas to pools of coal tar approximately 0.15 metres deep and 0.5 metres to 1 square metres in area. In addition, material that resembles a solidified coal tar /soil mixture is also present in the vicinity of the free phase tar material.

The major concerns associated with free phase coal tar at the ground surface relate to potential human exposure and animal exposure. Potential human exposure pathways are dermal and incidental ingestion as a result of human contact; inhalation as a result of work within the area, and potential movement/migration of coal tar into public access areas via 'tracking'. Potential ecological concerns relate to precipitation runoff and direct contact with aquatic and land based animals.

The following locations were noted to have free phase tar material:

- Various locations throughout the former DOMTAR facility lands;
- Northwest area of the Coke Ovens Site, more particularly the lands north of Coke Oven Brook, west of Whitney Pier Brook and south of the former DOMTAR facility;
- Several locations within Coke Oven Brook, and
- Several small areas southeast of the former by-products plant.

Recommended Interim Measures:

- *Conduct a detailed visual inspection of the northwest corner of the Coke Ovens Site and the Site Area associated with coal tar production, use and disposal, as well as associated areas in the Investigation Area. Map each occurrence of visible coal tar at ground surface;*
- *Install an interim surface covering over all coal tar locations noted during the detailed inspection. The covering should consist of at least 0.15 to 0.30 metres of soil. For areas where a pool of coal tar is present, the tar should be removed (for proper off-site disposal) and the area covered. Use of a non-woven geotextile should be considered to help prevent the tar from seeping into the cover material.*
- *Identify areas where coal tar has been noted and note them within the Site Health and Safety Plan to ensure that all persons entering the area are made aware of the potential for direct contact with coal tar.*
- *Conduct regular inspections of the Site to determine if any additional seep areas are present, and if encountered these should be dealt with as above;*
- *Conduct a detailed annual inspection of the areas of known coal tar deposits, document existing conditions, and undertake such maintenance as required.*

4.3 Former DOMTAR Storage Tank

The Coke Oven Site contains an open tank that was formerly used by DOMTAR to store coal tar and/or other by-products. During the 1988 demolition work, tank bottom sludges and other waste materials from the other tanks were placed in the remaining tank. Currently the tank overflows as a result of precipitation events. There is a potential for human exposure through dermal contact with materials released as a result of tank overflows and/or possible rupture, as well as the potential for release of contaminants to soils, groundwater and surface water.

Recommended Interim Measures::

- *Undertake any additional testing required to characterize the tank contents for safe disposal;*
- *Remove and dispose of the tank contents (liquids and sludges) in accordance with the appropriate environmental regulations and codes of practice; and*
- *Demolish and dispose of the tank; test the area for contamination; as appropriate, regrade the site to provide an interim cover for any exposed free tar (as per Section 4.2) and vegetate the area.*

4.4 Removal of Above Ground Structures and General Site Cleanup

The Coke Ovens Site contains a number of above ground structures that are abandoned and/or partially demolished. At the time of the CBCL/CRA Site tour, the most recent demolition program had been halted. All remaining structures must be removed to provide access to the soils beneath the buildings for investigation, assessment, and remediation. The existing structures may or may not contain contaminants of concern. Potential human exposure pathways should be assessed for each structure individually. There are also general safety concerns related to the structural stability of partially demolished structures and the miscellaneous site debris.

The main structures at the Coke Ovens Site that need to be addressed are the By-Products (ammonium sulphate) plant, the Coke Ovens battery stacks, the miscellaneous steel materials and building foundations.

Recommended Interim Measures:

- *Conduct a detailed inventory (including precise location) and assessment of remaining on-site structures and miscellaneous steel and building foundations (providing this has not been done as part of the ongoing demolition program).*
- *Develop a detailed demolition work plan based on human health and safety, environmental, structural and disposal requirements, including the specific method of rehabilitation for each structure and/or area*
- *Demolish and dispose of structures and implement at least temporary rehabilitation of the affected area, including detailed documentation of the work conducted.*
- *Identify and document the location and condition of any below grade structures (pipes, tanks, etc.) or voids encountered during the execution of the work.*

4.5 Surface Water Drainage

Several brooks, namely Coke Ovens Brook; Whitney Pier Brook; and Cagney Brook, bisect the Coke Ovens Site. During the period of operation of the Coke Ovens, Cagney Brook was diverted across the site via an underground culvert that eventually emptied into Coke Ovens Brook. During recent remedial work to improve surface drainage on the site, a section of the Cagney Brook culvert was removed and a ditched channel was constructed, allowing the waters of Cagney Brook to once again drain overland across the Coke Ovens site.

Recommended Interim Measures:

- *Develop and implement a surface water drainage plan for the Coke Ovens Site. The Plan should have as its primary objectives the routing of surface water away from areas of heavy contamination, and the prevention of ponding of water on the Site (i.e. discouraging infiltration of surface water and water from precipitation events to Site soils and groundwater).*

4.6 Filling of the Muggah Creek (Tar Ponds)

The dumping of Steel Plant wastes, other industrial wastes and other materials into the Muggah Creek Estuary has been an on-going practice for the last century. The resultant infill has greatly changed the topography of both the Estuary and Sydney Harbour.

Recommended Interim Measure:

- *Allow no further infilling of the Muggah Creek Estuary, especially within the boundaries of the Site Area, to allow for ready access for investigation and remediation.*

4.7 Dust Control Measures

The Coke Ovens Site is a disturbed landscape that consists of bare ground and some sparsely vegetated areas. Bare ground areas have resulted from recent disturbance or overall poor conditions for plant growth. Within the bare ground areas there is an increased potential that disturbance of the soils during

remedial works, or ordinary wind conditions will disperse contaminated materials through dusts and grit blown to other Site and off Site areas.

Recommended Interim Measures:

- *Undertake a botanical assessment of existing vegetation and soil conditions at the Site (species, condition etc.)*
- *Identify areas that would benefit from revegetation.*
- *Develop seed mixtures appropriate to the conditions at the Site, taking into account the use of native species where appropriate and acceptable.*
- *Re-vegetate existing bare ground areas, as well as all areas disturbed during de-commissioning, monitoring and remedial works.*
- *Implement appropriate dust control programs during remedial operations, including construction and maintenance of Site roads.*
- *Develop a revegetated perimeter area along the Site boundary to assist in separation of the Site from neighbouring land use. Consideration should be given to grading and plantings that would assist in wind and dust control.*

4.8 Site Area Security

Throughout the Site Area, neighbouring land use ranges from residential to heavy industrial, and the Area itself is traversed by rail lines, public roads and public pathways. Currently, a security fence secures key areas of the Coke Ovens Site, but other areas are not so well restricted. All lands and waters that comprise the Site Area must be considered as contaminated and as such, should be restricted to access by authorized personnel only.

Recommended Interim Measures:

- *Inspect the perimeter of the Site Area to identify any existing points of access, permitted or incidental.*
- *Document the location, condition and usefulness of all security fences and signage.*
- *Tar Ponds –Install security fencing and signage along the boundary or at the top of bank of the Tar Ponds in the areas where the public has unrestricted access. Based on CBCL/CRA tours, this area would be mainly in the south Tar Pond area around Dodd Street, Prince Street and Terminal Road. On all adjacent industrial land, the property owners should be notified of the potential hazards and postings placed as appropriate.*
- *Coke Ovens Site –Extend security fences in the northwest corner to restrict/prevent access in the Victoria Street overpass area.*
- *Coke Oven Brook Connection – Install security fence along the southern top of bank to restrict access to the area and portions of the north bank where the public would have access (fencing to be co-ordinated with SYSCO security needs).*
- *Conduct regular inspections and maintenance of the security fencing.*
- *Implement a Site Area access control program to ensure only authorized access and to enforce proper Health and Safety Protocols.*

4.9 Separation Zones

The Site Area encompasses the main locations for coke production, related industrial activities, and those areas where significant contamination is known to exist (e.g. Tar Ponds). The Site Area is referred to in the MOU and elsewhere as “Canada’s worst hazardous waste site” (Memorandum of Understanding, 1998). This reference to the worst hazardous waste site is a reflection of the “national environmental and health issues with serious implications” that are present.

Hazardous waste sites that are under remediation, as well as sites that routinely handle hazardous materials, are typically surrounded by an area of land that separates or buffers these sites from neighbouring land uses. **These separation zones are intended to ensure that adjacent land use is compatible with remedial works undertaken at the hazardous waste site.** Residential land use is not considered a compatible land use adjacent to hazardous waste sites. Generally compatible land use for lands adjacent to hazardous sites consists of open space areas, industrial uses and/or commercial uses.

The criteria used to establish appropriate separation zones include the following:

- **Proximity;** what is the distance from the location of the remedial work to a receptor;
- **Science;** what are the existing and/or potential human health and environmental issues associated with existing conditions at the hazardous site, and the proposed site remediation (dust, vapour and odour generation, groundwater and surface water quality, etc.);
- **On and off-site monitoring programs;** what is the need for unrestricted access to adjacent lands for monitoring of air, groundwater, surface water and soil, before, during and after remediation;
- **Safety;** what potentially unsafe conditions (e.g. blasting etc.) might exist at the site;
- **Contingency measures;** what adjacent areas of the Site may be required for implementation of contingency plans to be used during remediation; and
- **Social issues;** what are the concerns of residents in adjacent areas regarding operations and conditions at the Site and their real and/or perceived effects on them and their families.

Establishment of a separation zone is a detailed process based on health risk assessment and scientific data as well as the criteria outlined above.

Criteria used to establish these zones must be sufficiently flexible as to allow re-examination of the boundaries and locations as new data become available. The development of a separation zone should also be considered as a temporary measure, effected during the life of the remedial works program, but no longer required when the site has been fully remediated and the lands returned to an acceptable end land use. Parameters that are used to further define the locations and extent of separation zones include:

- Locations of contaminated materials that require or will likely require remediation;
- Locations of structures that will require demolition and disposal;
- Locations of contaminated groundwater zones and contaminated surface watercourses;
- Neighbouring land use and public service systems (water, sewer, roads, etc.);
- Current and foreseeable remedial measures to be conducted at the facility;
- Social acceptability; and

- Practicality and enforcement.

A significant portion of the lands and waters of the Site Area (Coke Ovens Site, Muggah Creek Tar Ponds and the Coke Ovens Brook Connection) is heavily contaminated. In the upcoming years, comprehensive invasive investigations will be undertaken to more fully define the extent of contamination in this Area (Phases 2 and 3), and considerable remedial works are being planned. These investigations and remedial works will take place throughout the Site Area, coming up to, and in some areas, potentially going beyond, existing Site Area boundaries. At some locations, residential properties directly abut or are in close proximity to the Site location that is to be remediated.

The following summary of the Site Area boundaries, current land use, need for remediation and general areas where separation zones are recommended given the state of knowledge at the present time. It should be noted that the identification of streets does not necessarily indicate that these streets would be included in a separation zone. The streets are identified as examples of the adjacent land use and to better describe the location.

COKE OVEN SITE – EAST SIDE

- *Adjacent land use:* industrial/municipal (municipal landfill site)
- *Site Area use:* former Mullins Bank Coal storage, residual coal has been removed and bulk of area graded, the area is currently sparsely vegetated
- ***Interim Recommended Measure:*** *No additional separation zones are needed based on adjacent land use, former Site use and stage of remediation*

COKE OVEN SITE – SOUTH SIDE

- *Adjacent land use:* industrial (former rail lines, west end of Vulcan Avenue) and residential (Vulcan Avenue, Elm Street, Birch Street, Ash Street and Forest Street)
- *Site Area use -* former Mullins Bank Coal storage, residual coal has been removed and bulk of area remediated, the area is currently sparsely vegetated
- ***Interim Recommended Measure:*** *No additional separation zones are needed based on former Site use and the stage of remedial works. If further remediation is required for the former Mullins Coal Bank, the issue of separation zones in this area should be reconsidered.*

COKE OVEN SITE – NORTH SIDE

- *Adjacent land use:* industrial (CBDC DEVCO rail line) and residential (Frederick Street, Currys Lane and Tupper Street)
- *Site Area use:* former DOMTAR plant, Coke Oven Battery No. 1, and coal and coke storage areas located adjacent to CBDC (DEVCO) rail lines
- ***Interim Recommended Measure:*** *Initiate the process to develop and evaluate criteria and information necessary to define an appropriate separation zone and establish a zone to distance residential land use from anticipated investigation and remediation activities related to the former DOMTAR plant, Coke Oven Battery No. 1 and the coal and coke storage areas. Data from recent studies on conditions on/near Frederick Street should be incorporated into the criteria used to define the Separation Zone in this area.*

COKE OVEN SITE – WEST SIDE – VICTORIA STREET (INCLUDES UNDERPASS AREA)

- *Adjacent land use:* industrial at north end (Victoria Street underpass lands and SYSCO) and residential at south end (Victoria Street)
- *Site Area use:* former DOMTAR plant, benzol tanks, Mullins Bank Coal storage (south end)
- ***Interim Recommended Measure:*** *Establish separation zones to distance residential land use and public access areas from anticipated investigation and remediation activities related to the former benzol tank area and the former DOMTAR plant (beneath the overpass).*

COKE OVEN BROOK CONNECTION

- *Adjacent land use:* industrial (SYSCO to the north), municipal road way to the south (Cape Breton Street) and industrial lands
- *Site Area use:* Coke Ovens Brook was used as a repository for coal tars, coke, coal and other waste materials, which were washed downstream to the Muggah Creek Estuary (Tar Ponds)
- ***Interim Recommended Measure:*** *No separation zone required due to adjacent land use*

TAR PONDS

- *Adjacent land use:* east side land use is industrial (SYSCO); south side land use is commercial (car dealership, bus terminal, professional building) and municipal (Prince Street Depot); west side land use is industrial (rail line, railway repair shop, petroleum storage)
- *Site Area use:* the Tar Ponds are the principal location where waste products(e.g. coal tar, coal and coke fines, etc.) from long term releases by the Coke Ovens and other associated industries have accumulated
- ***Interim Recommended Measure:*** *No separation zone is required at this time. The establishment of a separation zone should be reconsidered as part of the process for development of a remediation plan for the Tar Ponds.*

At some locations in the Site Area, in addition to or in lieu of separation zones, additional site access controls are recommended (Section 4.8).

4.10 Site Health and Safety Plan

Based on the background data provided in Chapters 2 and 3, the Site Area and selected locations in the Investigation Area will require a significant amount of investigation, assessment and remedial work to be completed over an extended time period. Any work conducted on the Site Area should be completed in accordance with a Site Specific Health and Safety Plan. Two methods that can be used to address health and safety issues at contaminated sites include:

- Each contractor develops a health and safety plan specific to the tasks they are to conduct; or
- A site-specific health and safety plan is developed and each contractor is required to review and act in compliance with the plan.

As different work tasks may occur throughout the life of a project, the site specific health and safety plan would need to be augmented/revised to meet the needs of specific work tasks.

Recommended Interim Measures:

- *A Site Specific Health and Safety Plan be developed and implemented for the complete Site Area. The Site Specific Health and Safety plan should be modelled after the United States Occupational Health and Safety (OSHA) requirements, and conform to Federal and Provincial requirements for health and safety plans.*
- *The Site Specific Health and Safety Plan should address all activities at the Site Area including, but not limited to, the interim measures noted in this section; regular Site Area security and inspection; and all investigations and monitoring programs to be undertaken as part of Phases 2 and 3.*
- *Each contractor commissioned to work on the Site Area must conform with the Plan, as well as identify additional requirements or amendments to the Plan that are needed to address the specific tasks being conducted. More detailed Health and Safety plans need to be developed when actual remediation of the Site is to be undertaken.*

4.11 Existing Monitoring Wells

A large number of monitoring wells have been installed in the previous investigations performed related to the Tar Ponds Clean-up project and the various investigations of the Coke Ovens Site and adjoining areas. These have been identified with their locations on plans and figures in this report. These monitoring wells represent a considerable investment and will be valuable tools for future investigations and monitoring required for this project. It is important that as many of these wells as possible are preserved for future use.

Recommended Interim Measures:

- *A program should be initiated to locate each monitoring well and assess its condition.*
- *Serviceable wells should be repaired and protected with steel casings grouted in place and with locks to restrict access. All locks should be keyed the same to facilitate access for future JAG projects.*
- *Any wells that are no longer serviceable should be properly decommissioned to prevent the well acting as a contamination migration pathway.*

4.12 Municipal Ash Incinerator Disposal (MAID) Site

The Landfill Leachate Study by CBEG determined that surface water discharges from the disposal area have contaminated Coke Oven Brook. The study determined that in the groundwater a large number of the parameters analysed exceeded background levels but only three parameters, ammonia, iron and selenium exceeded fresh water aquatic guidelines. The groundwater also exceeded some of the drinking water guidelines for aesthetic objectives.

Recommended Interim Measures:

- *The surface drainage system at the MAID site should be mapped and measures installed to prevent discharge of contaminated water to surface water courses.*
- *Monitoring of the groundwater at the site should be continued, to determine any trends in the levels of the measured parameters. Additional wells within the MAID site should be added to determine the effects from different areas of the MAID site.*
- *Additional investigation should be performed to better characterize the geology and hydrogeology of the strata underlying the MAID site to assist in analyses.*

CHAPTER 5 FRAMEWORK FOR SUBSEQUENT INVESTIGATIONS

The evaluation of contaminated source materials, contaminant migrations pathways and potential exposure to contamination by humans and ecological receptors presented in Section 3 has been used to derive an overall framework for future investigations in the Study Area, provided in Table 5-1. These investigations (Phase 2/3) will provide the factual basis for the evaluation of the need for additional characterization and assist in defining appropriate remedial requirements/objectives (Phase 4). In total, this framework represents an outline of a field program intended to increase the degree of certainty in key contaminant transport and exposure issues, including:

- The hydraulic properties of the main hydrogeologic units in the study area (Section 2.1.4)
- The groundwater and surface water flow systems (Section 2.1.4)
- The extent of contaminated source materials (Section 3.2)
- The direction and extent of contaminant migration in groundwater and surface water (Section 3.3).
- The presence and nature of receptors at potential exposure locations (Section 3.5).

For each of these four issues, the degree of certainty in the current understanding has been qualitatively evaluated. These evaluations are provided in the indicated sections of this report. Where the current understanding has been evaluated as having “low” to “moderate” degrees of certainty and there is a need for better definition, the respective component has been targeted for additional investigation and has been incorporated into the framework.

The framework design has also considered the potential for humans or ecological components to be exposed to contamination. This potential for exposure is qualitatively evaluated in Section 3.5 of this report, on the basis of combinations of contaminated source materials and contaminant migration pathways. In cases where the potential for exposure was evaluated as “high” to “moderate”, the source/pathway combination was included in the framework for additional investigation.

The approach described above is useful in that it provides a basis for selecting targets for additional investigation. However, the study area is large, the contaminant issues are complicated and the investigations conducted to date can be considered limited and dated. Consequently, a relatively high degree of uncertainty exists for most hydrogeological parameters, contaminant distributions and contaminant exposure scenarios. The great majority of these will therefore require additional investigation to provide an acceptable level of understanding with which to move forward.

The types of additional information specified in this framework are of the following general categories:

- Additional delineation of “widely dispersed” sources of contaminated materials.
- Additional delineation of contaminated source materials at “discrete locations”, such as the previous Benzol Plant and the former Coke Ovens.
- Characterization of site hydrogeology and hydrology on reconnaissance-scale, across the entire study area.
- Characterization of site hydrogeology and hydrology on a localized scale, to be focussed in the vicinity of individual “discrete location” sources, and associated migration pathways

- Delineation of contaminant distributions related to contaminant migration pathways from “widely dispersed” sources of contaminated materials
- Delineation of contaminant distributions related to migration pathways from contaminated source materials at “discrete locations”.
- Quantification of contaminant fluxes entering and leaving the study area.

Implicit in this framework is the recognition that widely dispersed source of contaminated materials will require a broader, less detailed investigative approach than a source that generally remains within an isolated area. However, it is expected that these two scales of investigation will complement each other and lead to a more thorough understanding of contaminant migration in the study area.

Any existing information that relates to the specific objectives in Table 5-1 should be considered in the final design of the data collection program, and in the interpretation of any new data.

Table 5-1. Overall and Specific Objectives for Subsequent Investigations in the Site Area and Vicinity

Overall Objective	Collect Additional Data to Address the Following Specific Objectives:
1. Additional characterization to evaluate the distribution of “widely dispersed” contaminated source materials on the Coke Ovens site	A. Locate pits of buried waste on the Coke Ovens site (Source S1) B. Evaluate Current hydrocarbon and metals content of road surfaces on the Coke Ovens site (S2) C. Locate small drain and pipe leaks on the Coke Ovens site (S3) D. Delineate contaminated Fill throughout the Coke Ovens site (S12) Note: Planned geophysical surveys will contribute to objectives A, C and D.
2. Additional site-wide characterization of contaminant migration from “widely dispersed” contaminated source materials (S1, S2, S3, S4 and S12) on and off (output) the Coke Ovens site	For potential surface water, groundwater and organic liquid (e.g., DNAPL and LNAPL) pathways: A. Delineate the horizontal and vertical extent of main till units B. Evaluate the range and distribution of hydraulic conductivity for all hydrogeologic units C. Delineate groundwater recharge and discharge areas D. Characterize groundwater / surface water interaction E. Characterize vertical groundwater interaction between hydrogeologic units F. Delineate groundwater flow directions and groundwater divides G. Determine surface water flows into, out of, and within the site area H. Determine dissolved and particulate contaminant concentrations in surface water flowing into, out of, and within the on the Coke Ovens site I. Determine dissolved contaminant concentrations in groundwater on the Coke Ovens site J. Evaluate for the presence of mobile DNAPL and LNAPL at reconnaissance-scale on the Coke Ovens site K. Evaluate the role of underground site facilities and services in groundwater flow and contaminant migration.

Overall Objective	Collect Additional Data to Address the Following Specific Objectives:
3. Additional characterization of contaminated source materials at “discrete locations” on the Coke Ovens site	<p>For each of S5, S6, S7, S9, S13, S15:</p> <ul style="list-style-type: none"> A. Delineate the horizontal and vertical extent and distribution contaminated source materials B. Evaluate for the presence and extent of mobile organic liquids such as tar and benzol (for sources S7, S9, S13, S15) C. Determine the range of composition of contaminated source materials
4. Additional characterization of contaminant migration in potential exposure pathways from contaminated source materials at “discrete locations” on and off the Coke Ovens site	<p>For surface water, groundwater and organic liquid (e.g., DNAPL and LNAPL) pathways associated with each of S5, S6, S7, S9, S13, S15:</p> <ul style="list-style-type: none"> A. Delineate the horizontal and vertical extent of main hydrogeologic units B. Determine the range and distribution of hydraulic conductivity for all hydrogeologic units C. Characterize groundwater / surface water interaction D. Characterize vertical groundwater interaction between hydrogeologic units E. Delineate groundwater flow directions F. Determine surface water flows into, out of, and within the contaminated source area I. Determine contaminant concentrations in surface water G. Delineate horizontal and vertical distribution of contaminants in groundwater, from the source area to the downgradient extent of the pathway H. Delineate the horizontal and vertical extent of free phase organic liquid extending away from the source area (for sources S7, S9, S13, S15)
5. Additional characterization of contaminated source material and migration pathways associated with Coke Ovens Brook on the Coke Ovens Site and Coke Ovens Brook Connection	<ul style="list-style-type: none"> A. Delineate contaminated source materials along the bottom of the Brook and cooling pond B. Delineate contaminated source materials underlying the bed of the brook, at a reconnaissance scale C. Evaluate brook flow rate under various flow conditions D. Evaluate dissolved phase and particulate contamination/loadings in Brook water under a range of flow conditions and at various locations
6. Additional characterization of contaminant loadings entering (input) the study area through the east side of the Coke Ovens site	<ul style="list-style-type: none"> A. Delineate the horizontal and vertical extent of main hydrogeologic units along the east side of the Coke Ovens site B. Characterize the distribution of hydraulic conductivity for all hydrogeologic units C. Characterize groundwater / surface water interaction D. Characterize vertical groundwater interaction between hydrogeologic units E. Delineate groundwater flow directions F. Determine surface water flows (primarily Coke Ovens Brook) into the east side of the study area I. Determine contaminant concentrations in surface water G. Determine the horizontal and vertical distribution of contaminants in groundwater, from the entry point to the downgradient extent of the groundwater pathway <p>Note: JAG expects that work currently being conducted by CBEG will contribute substantially to achieving these objectives.</p>
7. Additional characterization of contaminant loadings (input) to Muggah Creek Estuary via surface water or pipe effluents	<ul style="list-style-type: none"> A. Identify all channelized surface water inputs to Muggah Creek Estuary B. Identify all pipe effluents to Muggah Creek Estuary C. Determine the flow in all surface water channels and pipes discharging to Muggah Creek Estuary D. Evaluate dissolved phase and particulate contamination discharging to Muggah Creek Estuary via surface water channels and pipes <p>Note: Investigations contributing to the above objectives are either planned or in progress; any such efforts should be coordinated to ensure that the objectives are addressed effectively, and without duplication of effort.</p>

Overall Objective	Collect Additional Data to Address the Following Specific Objectives:
8. Additional characterization of contaminant loadings (input) to Muggah Creek Estuary via groundwater	<ul style="list-style-type: none"> A. Determine the horizontal and vertical extent of main hydrogeologic units in the vicinity of Muggah Creek Estuary B. Characterize the Distribution of hydraulic conductivity for all hydrogeologic units C. Characterize any groundwater / surface water interactions D. Characterize vertical groundwater interaction between hydrogeologic units E. Delineate groundwater flow directions G. Determine the vertical distribution of contaminants in groundwater around the periphery of Muggah Creek Estuary
9. Additional characterization of contaminant output from the study area via Muggah Creek Estuary outflow	<ul style="list-style-type: none"> A. Evaluate Muggah Creek Estuary outflow rate under various flow conditions B. Evaluate dissolved phase and particulate contamination in outflow water under various flow conditions
10. Additional characterization of contaminant source and loadings (inputs) to the Site Area from particulate deposition	<ul style="list-style-type: none"> A. Evaluate and characterize the distribution and extent of dry and wet fallout from steel and coke manufacturing (S4) B. Characterize dissolved phase and particulate migration of this fallout in surface water into the Site Area from all surface water inputs

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the information collected and reviewed for this Phase 1 Site Assessment of the Muggah Creek Watershed, the following conclusions are provided:

- 1) Contamination within the Site Area exists as ubiquitous contamination and point source contamination. Principal contaminants within the Site Area are PAH compounds (i.e. coal tar material), VOCs (i.e. benzene, toluene, xylene), hetrocyclic (HC) compounds, acidity, sulphur, metals, and PCBs. Ubiquitous contamination within the Site Area relates to the coal and coke storage areas and is mainly associated with the PAHs, acidity and metal compounds. The point source contamination areas relate to specific buildings, facilities or services. The main point source contamination areas and the principal chemical constituents are as follows:
 - Coke Ovens facility:
 - Benzol Plant and tank storage location – VOCs (benzene, toluene, xylene);
 - Sulphuric Acid Plant – sulphur and acidity; and
 - Coke Oven Batteries – PAH compounds, HC compounds, coal tar.
 - Former DOMTAR facility– PAH compounds, free phase HC compounds, coal tar;
 - Coke Ovens Brook – PAH compounds, HC compounds, free phase coal tar, landfill leachate (metals dissolved solids, nutrients, dioxins/furans and radionuclides); and
 - Tar Ponds – PAH compounds, HC compounds, free phase coal tar, PCBs, coal dust, and municipal sewage.
- 2) The environmental investigations, assessments and remedial measures conducted in the Site Area to date have been principally focussed to a specific area or objective, and not to the overall issues associated with the JAG mandate, that being the remediation of historical contamination within the Muggah Creek Watershed. The JAG mandate is broader than previous studies and as such the previous investigation/assessment conclusions and recommendations may not be consistent with the JAG mandate. A comprehensive overall assessment is required to understand the Site Area impacts (Phase 2/3)
- 3) The environmental reports obtained and reviewed indicate that only a few environmental investigations have been conducted outside of the Site Area. The environmental investigations conducted outside of the Site Area have been focussed to a specific objective such as a spill or tank release, concerns with a school or playground area and more recently the Regional landfill and the Lower Frederick Street Area. These studies provide environmental data related to the specific item, and do not necessarily address issues and concerns related to off-site contamination related to the Site issues and are not necessarily tied to the Site Area.
- 4) A comprehensive assessment of the contamination within the Site Area does not exist. The implications of the contamination (coal tar, PAHs, VOCs, and metals) within the Site Area are not fully understood as to the extent of contamination or the relationships between groundwater, surface

water or soil, nor the off-Site movement of contamination through the various media along the Site Area boundaries.

- 5) The technical data such as analytical data and geologic data are reported in a diverse number of reports and formats. There is no one database (electronic or hard copy) that has compiled all of the important technical information related to environmental and other aspects of the Site Area. Consequently, a significant amount of technical information is not readily useable.
- 6) The technical data available for the Site Area were principally collected during the late 1980's and the early 1990's. The ground and surface water data may not be representative of the current time period. These data although useful to provide assistance during site characterization assessments, must be confirmed through more current investigations.
- 7) The particulate modelling conducted as part of this Phase 1 Site Assessment indicates that areas within the vicinity of the Coke Ovens facility and SYSCO the maximum average annual off-Site deposition rates was 386 g/m²/yr. It should be noted that this figure is based on the assumptions outlined, however the deposition model indicates that contamination consistent with the air discharges will be present throughout portions of Muggah Creek watershed and beyond. The modelling input parameters need to be refined to reflect the historical discharges to achieve more accurate deposition rates.
- 8) Interim measures, as outlined in Section 4.0, should be assessed in detail and implemented as appropriate.
- 9) Phase 2 and Phase 3 (CCME Guidelines) investigation and assessment should be conducted. Section 5.0 provides an outline for the Phase 2 and 3 investigation and assessment work.

The Site Area is not fully characterized which is the intent of the further Phase 2/3 investigation. Therefore a comprehensive risk assessment can not be completed at this time. Any risk assessment for the Site Area should address the complete site.

6.2 Recommendations

Based on the information collected and reviewed for this Phase 1 Site Assessment of the Muggah Creek Watershed, the following recommendations are provided:

- 1) Additional Site characterization and assessment work is required for the Site Area to define inputs and outputs from the Site Area, and to characterize and delineate the environmental issues at the Site Area and as noted herein. **The investigation and characterization work should be conducted in accordance with the requirements of Phase 2 and 3 of the CCME guidelines regarding site decommissioning activities. An outline of the investigation and characterization work required is presented in Section 5 of this report.**
- 2) The technical information for the Site Area is contained in a number of reports. Usage of the technical information is difficult in the present format and key components of the technical data may be unintentionally excluded as a result during future assessments. **Comprehensive technical and information databases should be developed using GIS and maintained for the Site Area to**

- ensure efficient and comprehensive usage of the technical data.** The databases should document report, maps, plans, analytical data, and borehole/monitoring well data.
- 3) A long-term management approach for the technical investigations/remediation for the Site Area needs to be developed. The long term management approach should address the following:
- Development of a long term investigative and remedial strategy;
 - Development of a long-term education program that deals with such items as the JAG process, investigations, assessments, remediation programs. The educational approach should use the electronic media where possible;
 - Consideration of long term technical support to JAG to provide peer review, guidance and strategic advice; and
 - Development of investigations focussed towards understanding the contaminant issues and needed remedial actions for the Site Area.
- 4) Interim remedial measures have been recommended in Section 4. The recommended interim measures should be assessed in detail and implemented as appropriate.