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Case Study of a Transformer Repair Facility, Soil and Groundwater Remediation, Richmond, BC

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Abstract

The focus of this paper is to provide a case study outlining the remediation of a former transformer repair facility in Richmond, BC. The remediation work included several different areas across the Site where soil was impacted with PCBs and metals, and groundwater was impacted with chlorobenzene, petroleum hydrocarbons and dissolved metals.

Remediation at the Site was carried out using ex-situ techniques for soil, which included excavation, segregation, transportation and disposal of impacted material and in-situ techniques for groundwater, which included the installation of a Multi-Phase Extraction and Air Stripping System for treatment of contaminants prior to discharge into the sanitary sewer system.

The nature of the contaminants, along with the cost associated with their treatment and disposal, background groundwater concentrations exceeding regulatory disposal criteria to municipal services and the close proximity of the Site to the Fraser River , presented substantial challenges for the remediation of this Site. It should also be noted that PCB contamination and remediation is far less common in Western Canada than in Northern and Eastern Canada. This presentation will include the remedial options reviewed, the technical aspects of the chosen remediation activities and an economic analysis of the recommended techniques.

1.0 Background

1.1 PCBs History

Polychlorinated biphenyls (PCBs) are synthetic chemical compounds consisting of chlorine, carbon and hydrogen.

PCBs are very stable, fire resistant compounds which do not conduct electricity and have low volatility at normal temperatures. These and other properties made them desirable components in a wide range of industrial and consumer products. Some of these same properties make PCBs environmentally hazardous, especially their extreme resistance to chemical and biological breakdown by natural processes in the environment.

Commercial production of PCBs began in the United States in 1929 in response to the electrical industry's need for a safer cooling and insulating fluid for industrial transformers and capacitors. Even though Canada never produced PCBs, they were widely used in a variety of products.

PCBs stopped being manufactured in North America in 1977 and their use as a constituent in new products manufactured in or imported into Canada was prohibited by regulations between 1977 and 1980.

In 1985, the federal and provincial governments implemented more stringent regulations to ensure the safe handling and transportation of PCBs.

Typical chemicals associated with the presence of PCB oils are chlorobenzene, lead, xylene, and petroleum hydrocarbons. The presence of high levels of chlorobenzene in groundwater usually indicate serious and widespread contamination by transformer oil.

1.2 Previous Site Uses

The Site was owned by Canadian Westinghouse Co Ltd. from 1968 until 1998, when it was sold to Siemens Canada Limited. During that period of time, it operated as a repair facility of PCB-containing transformers. The transformers were serviced, cleaned and stripped inside the building, repaired in a varsol dip tank (concrete pit) and washed in a pressure washing area inside the shop. Drums of chemicals containing PCBs and solvents were stored outside the building in different locations.

The property was sold by Siemens in 2004 and, as part of the purchasing agreement, a Certificate of Compliance (CofC) from the BC Ministry of Environment (BC MOE) was required. Delineation work to determine the nature and extent of contaminants and remediation work needed to be conducted.

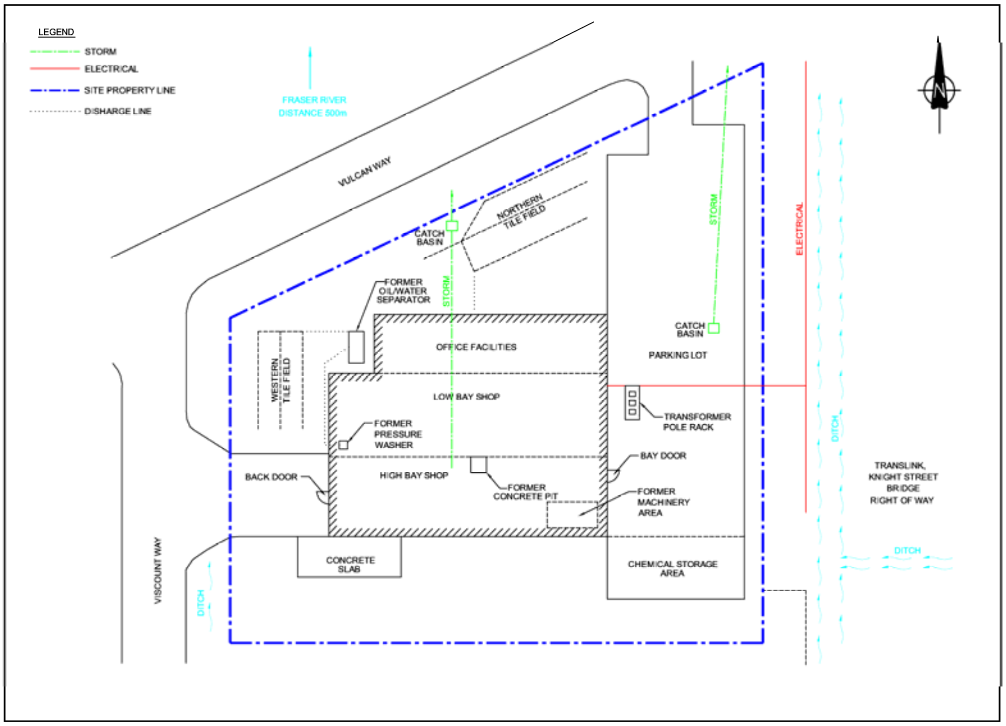
1.3 Previous environmental work

Previous environmental studies, conducted in 1992, reported higher levels of PCB contamination in the soil than were found in the initial reassessment. It is presumed that remediation to 1992 standards was successfully completed. Current standards dictate that further action was required to remediate the Site to obtain a CofC.

2.0 Site Description

The Site is a 5000 m^2 light industrial property located in the City of Richmond, BC, 500 m south of the Fraser River.

A plan with the main features of the Site is presented below:



2.1 Site Stratigraphy and Hydrogeology

The soil conditions encountered consisted of the following stratigraphic sequence: fill materials or top soil over clayey silt underlain by silty sand to sand. The presence of silt and clay loams and the underlying interbedded silt and fine sand deposits acted as barriers limiting the downwards vertical migration of dissolved contaminants at this Site, as such vertical migration of contaminants was contained at relatively shallow depths (2-5m).

Additionally, as the Site is considered to remain for commercial use, the Commercial Land Use (CSR CL) standards for soil were determined to be applicable to the Site.

Based on the close proximity to the Fraser River, groundwater in this area is tidally influenced due to hydraulic connectivity with the river. However, the presence of a dyke along the Fraser River functions as a hydraulic barrier to lateral movement of perched waters. The ditch at the east side of the Site is connected to the City of Richmond dyke drainage system which discharges to the Fraser River.

Migration times from the ditch to the Fraser River are considered to be a matter of hours to days, as such, the Aquatic Life Marine/Estuarine Standards for groundwater were applied to the Site.

2.2 Delineation program

The delineation program for the Site took approximately 3 ½ years to complete (from May 2002 until November 2005) and consisted of advancing 116 boreholes and 43 groundwater monitoring wells to fully identified the different contaminants at the Site and the extent of impacts to provide a Remediation Plan to propose alternatives to remediate the areas and obtain the required CofC.

3.0 Zones of Contamination and Contaminants of Concern

The delineation program identified PCBs, metals, petroleum hydrocarbons and chlorobenzene as contaminants of concern in three different mediums at the Site.

3.1 Soil

Soil contamination was identified in six different areas at the Site, including the Translink Knight Street Bridge Right-of-Way (ROW) adjacent to the Site. The contaminants of concern and the maximum concentrations identified are presented in the Table below:

Contaminant	CSR CL Applicable Standard (ppm)	Maximum Concentration Detected above Standard (ppm)
PCBs	15 (HWR: 50)	32,000
Arsenic	25	32.3
Cadmium	2	7.4
Chromium	60	256
Copper	250	1420
Lead	1000	1160
Zinc	300	364

Notes

CSR CL – Contaminated Sites Regulation Commercial Land Use standard
HWR – Hazardous Waste Regulation
ppm – parts per million (mg/kg)

3.2 Groundwater

Contamination in the groundwater was identified in two different areas at the Site. The contaminants identified included chlorobenzene and petroleum hydrocarbons. The contaminants of concern and the maximum concentrations identified are presented below:

Contaminant	CSR AWM Applicable Standard (ppb)	Maximum Concentration Detected above Standard (ppb)
Chlorobenzene	120	490
$EPHw_{10-19}$	5000	6400
LEPHw	500	6400

Notes

- ppb – parts per billion (mg/L)
- CSR AW – Contaminated Sites Regulation – Aquatic Life Marine/Estuarine standard
- $EPHw_{(C10-19)}$ - Light extractable petroleum hydrocarbon in groundwater without correcting for regulated PAHw concentrations
- LEPHw – light extractable petroleum hydrocarbons in groundwater corrected for regulated PAH concentrations

3.3 Concrete

PCBs were also identified within the concrete slab inside the building. As there are no current standards applicable to concrete, soil standards were used for comparison only.

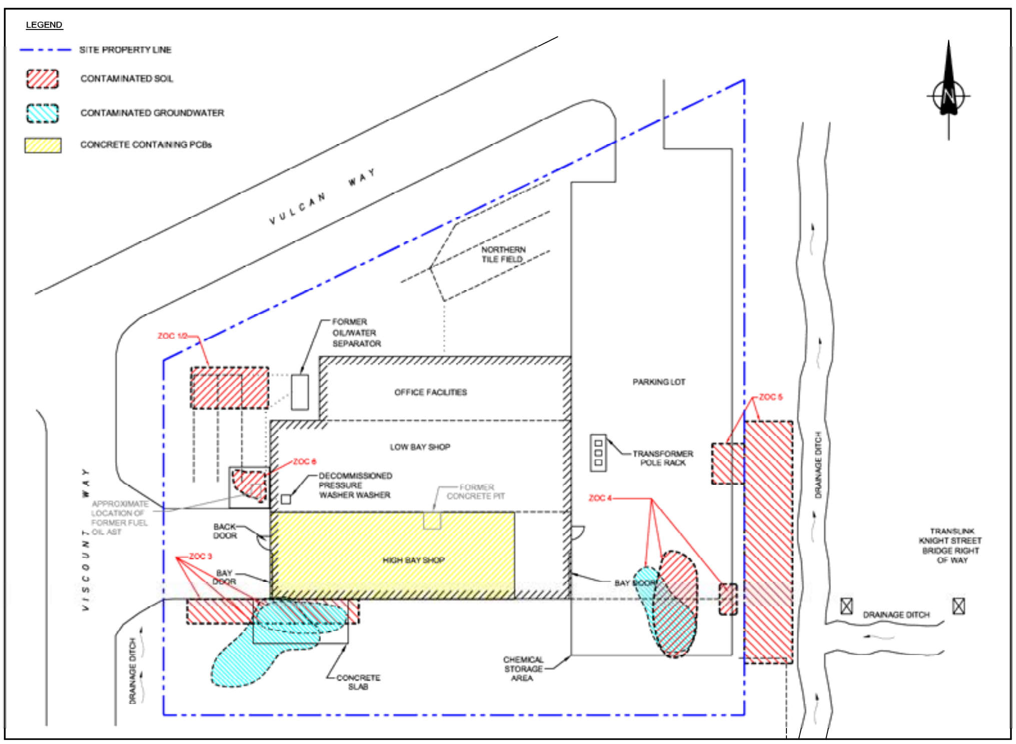
Based on the results from the delineation conducted at the Site, the PCBs had not migrated into the soil beneath the concrete. The contaminant of concern and the maximum concentrations identified are presented in the Table below:

Contaminant	CSR CL Standard used for comparison (ppm)	Maximum Concentration Detected (ppm)
PCBs	15 (HWR: 50)	480

Notes

CSR CL – Contaminated Sites Regulation Commercial Land Use standard
HWR – Hazardous Waste Regulation
ppm – parts per million (mg/kg)

The identified zones of contamination (ZOC) are presented below:



4.0 Remediation Options Evaluated

Several factors must be evaluated in selecting a remediation option as outlined in Part 4, Section 56 in the Environmental Management Act (EMA). This section of the EMA indicates that preference must be given to remediation alternatives that provide permanent solutions to the maximum extent practicable, taking into account the following factors:

- any potential for adverse effects on human health or for pollution of the environment;
- the technical feasibility and risks associated with alternative remediation options;
- remediation costs associated with alternative remediation options and the potential economic benefits, costs and effects of the remediation options; and,
- other prescribed factors.

A number of remedial options were reviewed to address the different impacts at the Site. The following remedial options were considered based on the contaminants characteristics and the economical analysis:

Soil

- Risk Assessment;
- In-situ treatment of the soil impacts; and,
- Soil removal (excavation) and off-site treatment and disposal.

Groundwater

- Groundwater removal and off-site treatment and disposal; and,
- In-situ treatment of the groundwater impacts.

5.0 Remedial Option Selected

5.1 Soil

Risk assessments are typically considered the most cost effective remedial strategy. However, PCBs do not qualify for risk assessment under MOE guidelines, as such, this option was not viable.

An in-situ treatment option using chemical oxidation by Fenton's Reagent (hydrogen peroxide (H_2O_2) and a ferrous salt) was evaluated. Several factors determined that this option was not feasible for the Site. These factors were:

- The elevated concentration of contaminants would have required large quantities of H_2O_2 to remediate the Site to meet standards, making it not economically feasible;
- Permits required to inject chemical into the ground are costly and difficult to obtain;
- Based on the acidic pH required for this treatment to work (from 2-4), and due to the fact that the impacted soil was in contact with the groundwater table, there was a potential for introducing acidic groundwater into the adjacent Fraser River.

The best, most widely used and proven technology for destroying PCBs is high temperature incineration (greater than 1200° C for two seconds dwell time). Properly done, this has been shown to destroy PCBs at an efficiency of 99.9999 percent.

Based on the high efficiencies proven by this technology and the short term disturbances to the Site, the selected remediation option was:

- Excavation and transport of impacted soils with PCBs for off-site incineration; and,
- Excavation of impacted soils with metals for off-site disposal.

5.1.1 Economic Analysis

Different disposal facilities for soil with PCBs concentrations exceeding HWR were evaluated in order to minimize remediation costs.

- Transport of contaminated soil by rail to Saint-Ambroise, Quebec. The unit rate for excavation, transport and disposal was $1080/tonne.
- Transport of contaminated soil by truck to Alberta. Unit rate for transport and disposal was $1200/tonne.

Based on estimated amount of PCB contaminated soil exceeding HWR (525 tonnes), savings of $63,000 plus excavation costs would be achieved by transporting the impacted soil by rail to Saint-Ambroise, Quebec.

5.2 Groundwater

Two options for remediating the groundwater impacted plumes were evaluated: Off-site treatment and disposal and In-situ treatment.

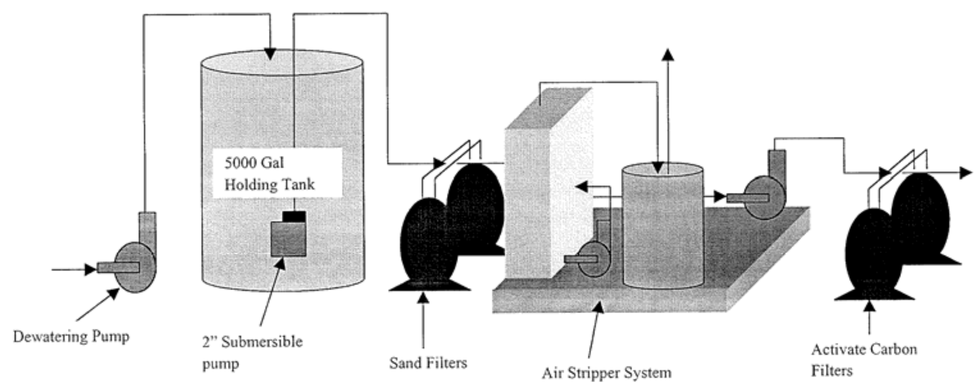
An economic analysis was conducted to determine the best remediation option. The following are the numbers provided by the selected contractor:

- Off-site treatment and disposal of chlorbenzene impacted water: \$250/m^3
- In-Situ equipment rental and operation (on a monthly basis): $15,000

Based on an estimated impacted volume of 535 m^3 and an estimated timeframe to complete the remediation of 2 months, the savings from using the in-situ treatment versus off-site disposal were estimated to be over $100,000.

As such, the in-situ remediation option using a Multi-Phase Extraction and Air Stripping system was selected to remediate the chlorobenzene and petroleum hydrocarbon impacts in the groundwater.

A schematic diagram of the in-situ treatment system is presented below:



Water Treatment System
Capacity 45-60 GPM

5.3 Concrete

As the impacted concrete remains in use at the Site it is considered a hazardous material. The Hazardous Waste Regulations do not apply until as the concrete is removed from use becoming a hazardous waste.

The Richmond Health Authority and the Workers Compensation Board (WCB) were contacted and they indicated that the concrete does not pose a concern from a public health standpoint. Additionally, Section 3 of the Canadian Environmental Protection Act (CEPA), states that as the concrete is continually occupied it is not covered under the Storage of PCB Material Regulations.

Based on these considerations, it was determined that the concrete could be left on-Site. However, future demolition of the floor or renovations requiring removal of portions of the floor will generate a PCB waste material that will require appropriate handling, transportation and disposal

6.0 Implementation of Remedial Option

Soil

The soil remediation was conducted in a staged approach due to the high cost related to the final disposal of the material. This approach consisted of excavating the ZOCs to the minimum areas determined by the delineation activities, sampling the walls and base of the excavation and submitting them for laboratory analysis to verify if clean limits had been achieved.

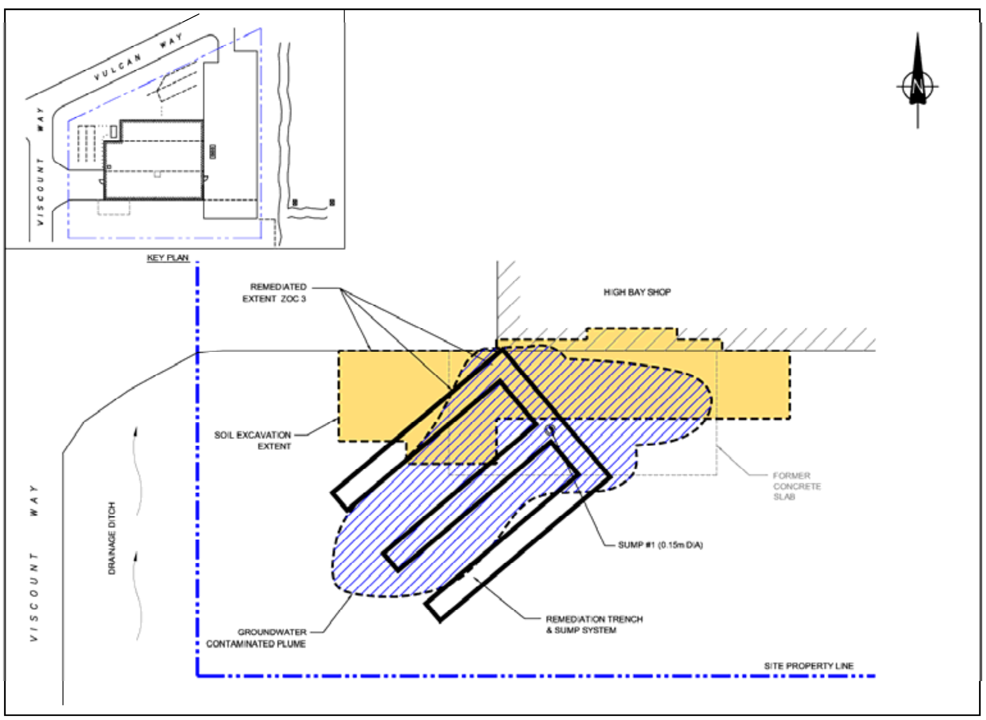
Due to the conservative excavating technique being used, finding clean limits for the excavations was proving to be very challenging. As the turn around time for analysis of PCBs in BC is 7 working days, a means of expediting the remediation process was required to reduce the costs being incurred by dewatering the open excavations. Pre-screening of soil samples by way of a field testing kit allowed for more timely and efficient assessments of excavation limits. Once clean soil samples were obtained in the field, samples were submitted to the laboratory to confirm the results.

Groundwater

Dissolved contaminants at the Site were remediated using a Multi-Phase Extraction and Air Stripping System to extract and treat groundwater prior to discharge into the City of Richmond sanitary sewer.

Two groundwater extraction sumps were installed for ZOC3 and ZOC4. The sumps consisted of a 0.3 m diameter slotted polyvinyl chloride (PVC) pipe as the vertical extraction point located at the centre of a main trench approximately 8.5 m long by 1 m wide at a depth of 5 mbg; three additional trenches, 7 m long were then oriented in the direction of the impacted plumes. All the trenches were backfilled with coarse grained soils below the water to facilitate collection and extraction of impacted groundwater.

The design of one of the sumps is presented in the diagram below:



After the installation of the sumps was completed, the treatment system was installed. The treatment system was operated using two submersible pumps in a batch mode, whereby groundwater was pumped from one of the sumps to a holding tank and then from the holding tank to the treatment system. When groundwater from one holding tank was being treated, and discharged into the sanitary system, groundwater from the second sump was pumped to a second holding tank. This batch process facilitated remedial progress monitoring of each of the two groundwater contaminated areas as separate waste streams.

Groundwater remediation from ZOC3 was achieved after one month of running the in-situ treatment system; at that point, the system operated on a continuous basis, without the use of the holding tanks, treating only groundwater from ZOC 4.

Remediation work for the contaminated plume in ZOC4 took 10 months to complete due to residual PCB contamination, later identified, in the soil in that area.

6.1 Remediation Permits Required

Soil

As the PCB soil contamination had extended to the adjacent Translink Right of Way, off-Site excavation permits needed to be obtained from the affected party and off-site migration documentation needed to be provided to the MOE.

One of the conditions from Translink prior to issuing the permit to remediate the off-site contamination was for the soil to be remediated to CSR Soil Relocation Standards (CSR SRS). The SRS standard for PCBs is 5 mg/kg. As the SRS standard is more stringent than the CL standards applicable to the Site, additional soil needed to be excavated in order to meet the requirements of the permit.

Groundwater

Part of the in-situ treatment remediation option required that the treated groundwater be discharged into the City of Richmond sanitary system, as such, a discharge permit from the Greater Vancouver Regional District (GVRD) was required.

Prior to issuing the discharge permit, the GVRD required system design details and operation maintenance, which included designing a model to predict treated water discharge volumes per day and discharge concentrations of chlorobenzene and petroleum hydrocarbons and calculations to predict activated carbon breakthrough.

Once the permit was obtained, periodic sampling of the system discharge needed to be conducted to ensure permitted discharge concentrations for various parameters were being met.

7.0 Challenges

As previously mentioned, the GVRD permit required periodic sampling for different parameters of the discharge water. One of the required parameters was iron.

The permit specified a maximum discharge limit for total iron of 10 mg/L, however, background groundwater concentrations of iron in the City of Richmond vary between 16 mg/L to over 130 mg/L, as such, discharge limits for this parameter were being exceeded during the continuous discharge of treated water. Based on these exceedances, the GVRD issued a non-compliance letter.

Even though iron was not a contaminant of concern at the site, modifications to the treatment system were required to ensure that the discharged water would meet the GVRD requirements.

The modifications to the system included re-installing one holding tank before the treatment system to allow for any suspended solids present in the groundwater to sediment at the bottom of the tank, two 1 micron cloth filters were connected in series after the holding tank to capture any solids that had not settled, after the cloth filters, the groundwater would be passed through the original sand filters, the air stripper system and activated carbon filters prior to discharge into the sanitary system.

Once the modifications were completed, the discharge water to the sanitary system met the requirements of the GVRD and the non-compliance letter was withdrawn.

Another challenge encountered during remediation activities was that chlorobenzene concentrations in ZOC 4 were not attenuating as quickly as those in ZOC 3. It was considered then, that impacts might still be present in the soil in zone ZOC 4. As a consequence, groundwater being drawn to the sump was getting impacted with the remaining contaminants. Based on this consideration, additional soil delineation and remediation for that area had to be undertaken.

8.0 Conclusions

The remediation at the Site took almost 4 years to complete and several challenges were encountered during the process. Some of these included:

- obtaining the required permits for off-site remediation and water discharge to the municipal sanitary system;
- the difficulty of identifying and obtaining clean soil samples during excavation activities that extended the remediation process; and,
- the extended period of time and additional costs associated with the groundwater plume remediation in ZOC 4.

Once remediation activities were completed for the Site, a Certificate of Compliance from the MOE was issued on August 30, 2006.

A summary of the remediated quantities for soil and groundwater is presented below.

8.1 Soil

Soil remediation activities at the Site were conducted during the period from July 2002 until April 2006.

A summary of the excavated soil quantities and the remediated contaminants of concern is presented below:

Summary of Excavated Soil Quantities

ZOC	COCs	Date of Excavation	Waste Characterization		
			> HWR	**CSR CL+**	**CSR SRS+**
ZOC1/2	PCBs, Cd	September 2003	271.8	198.21	---
ZOC 3	PCBs,		130		
ZOC 5	PCBs		63.25		
ZOC 4	PCBs	May-June 2004	76.96	124.52	---
ZOC 6	As, Cd, Cr, Cu, Pb, Zn	April 2006	---	21.65	---
Translink ROW	PCBs	July 2002	---	---	259.7
Total Soil Tonnage remediated by Excavation			542	344.38	259.7
Notes					
---	no soil characterized at this waste level				

Notes
Quantities are presened in tonnes
CSR CL+ – Greater than CSR Commercial Land use standards
> HWR – Greater than CSR HW, TDG HW and/or HW 41.1 standards
CSR SRS+ - greater than CSR Soil relocation agreement

The difference in volume from the one originally estimated of 525 tonnes was relatively marginal, however, savings of $65,000 were achieved by transporting the impacted soil with PCBs to Saint-Ambroise, Quebec.

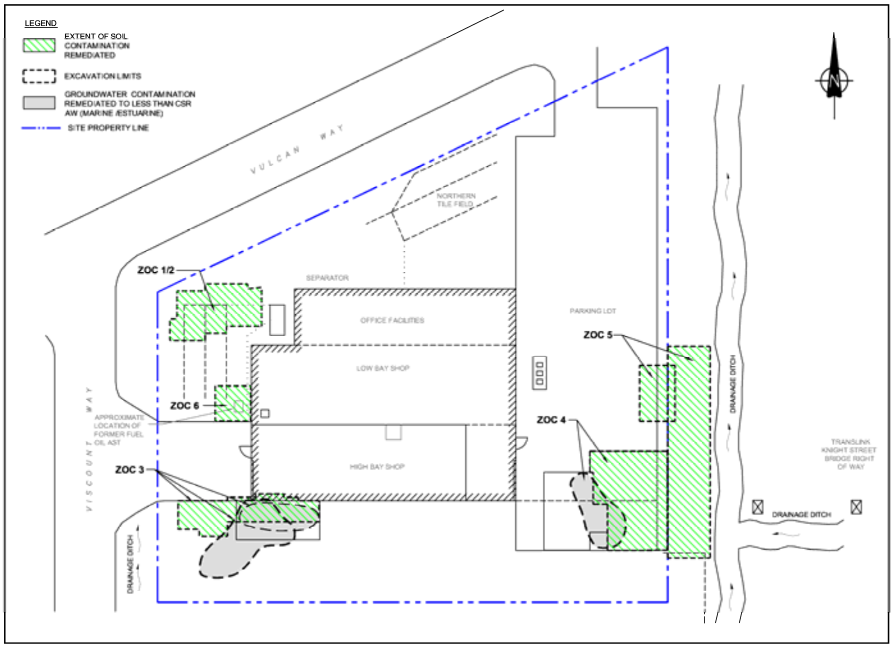
8.2 Groundwater

Groundwater remediation activities at the Site took 10 months to complete, compared to the two months previously anticipated, and were conducted between October 2003 and July 2004.

A total of volume of 1,180 m^3 of groundwater were treated and discharged into the Richmond sanitary system, compared to the 535 m^3 initially estimated.

Based on the total volume of water remediated from the Site, and the time it took to complete the groundwater remediation, a total of $145,000 in saving were achieved by selecting the in-situ treatment option versus the off-site transport and disposal.

The final extents of the remediation activities conducted at the Site from the period of July 2002 until April 2006 are presented below:



LEGEND
EXTENT OF SOIL CONTAMINATION REMEDIATED
EXCAVATION LIMITS
GROUNDWATER CONTAMINATION REMEDIATED TO LESS THAN CSR AW (MARINE /ESTUARINE)
SITE PROPERTY LINE
VULCAN WAY
NORTHERN TILE FIELD
ZOC 1/2
SEPARATOR
OFFICE FACILITIES
LOW BAY SHOP
HIGH BAY SHOP
PARKING LOT
ZOC 5
ZOC 6
APPROXIMATE LOCATION OF FORMER FUEL OIL AST
ZOC 4
ZOC 3
VISCOUNT WAY
DRAINAGE DITCH
DRAINAGE DITCH
TRANSLINK KNIGHT STREET BRIDGE RIGHT OF WAY
DRAINAGE DITCH

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