Low Disturbance and Limited Access In-situ Soil and Groundwater Bioremediation

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ABSTRACT
Following the recommendations of a Phase I ESA, an intensive Phase II ESA and contaminant delineation investigation program were conducted. The contaminated groundwater and gasoline from a fiberglass UST migrated east, towards the Athabasca River, and underneath an adjacent office building and community hall. Low-level (<1000 mg/L air) VOC fumes were identified inside the office building. In addition, during the Phase II ESA investigation, diesel contaminant was identified in the limited area southeast of the office building. Based on subsequent interviews and air photo reviews, a former forestry operation was detected and determined as a source of diesel contamination. An aggressive soil and groundwater in-situ bioremediation program was designed to prevent further migration of the contaminants towards the Athabasca River and to control the concentration of fugitive VOC inside the office building. In the first phase, the remediation program focused on the extraction of the estimated 35 m^3 of the free gasoline on top of the shallow watertable. The ongoing soil and groundwater in-situ bioremediation program consists of two sets of horizontal air sparging (AS) and soil vapour extraction (SVE) wells installed underneath and east of the office building. The office building, general store, and community hall have been operating without interruption throughout the program execution.

Introduction

The Fort McKay Band Council and McKay Group of Companies Ltd. operated the gas bar in Fort McKay, Alberta since 1991. The gas bar had one fibreglass gasoline underground storage tank (UST). A land transaction between the federal government and the band council initiated a Phase I Environmental Site Assessment (ESA). In the spring of 2000, the Phase I ESA was conducted and consequential groundwater sampling confirmed concentrations of benzene in the groundwater above the Canadian Drinking Water Quality Guidelines (CDWQG) prescribed by Canadian Council of Ministers of the Environmental (CCME).

The Band Council and McKay Group of Companies Ltd. requested that a remediation method be designed and implemented to allow both businesses to operate during the remediation program.

The ongoing in-situ bioremediation program is facing several challenges:

- Severe weather conditions (northern climate);
- Semi remote area with very limited resources (First Nation Reserve)
- Limited access to the free LNAPL and the contaminated soil and groundwater;
- Shallow utilities; and,
- Implementation of health and safety program to protect occupants and visitors of the amenities at the site.

The abovementioned challenges were met by implementing a multi phase approach carefully designed and scheduled to meet the site-specific requirements.

Local Settings

The site of the former Fort McKay Gas Bar is located approximately 70 km north of Fort McMurray, Alberta on the west bank of the Athabasca River (Figure 1).

The legal description of the subject property is River lot 10, 26-94-11 W4M. The gas bar was constructed in 1991, and it was located near the office building, community store and community hall.

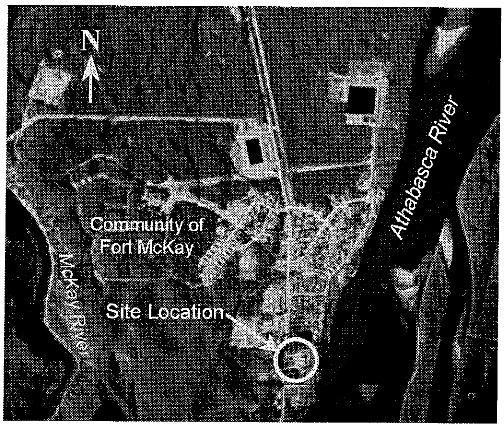

Fig. 1 Site Location Map

Background

The UST was removed on October 2, 2000. At the same time, stained soil in the vicinity of the UST was excavated and stored for further treatment. At the bottom of the excavation a set of Soil Vapour Extraction (SVE) wells were installed to prevent migration of the volatiles into the building. The subsequent Phase II ESA and delineation program detected a free LNAPL (light non-aqueous phase liquid) and groundwater with elevated benzene concentrations east of the gas bar, underneath the adjacent office and community hall buildings, and further east towards the Athabasca River.

Low-level (<1000 mg/L air) VOC fumes were detected inside the office building. During the Phase II ESA investigation, heavier hydrocarbons (diesel) were identified in a limited area southeast of the community hall building (Figure 2). Based on subsequent interviews and review of aerial photographs, a former forestry operation was identified as a potential source of diesel contamination

Following the completion of the delineation program an active and passive hydrocarbon free phase were installed system was installed to prevent further migration of volatile hydrocarbons in the buildings interior. Near the completion of the hydrocarbon free phase extraction a set of air sparging (AS) and (SVE) wells were installed for the groundwater and soil bioremediation.

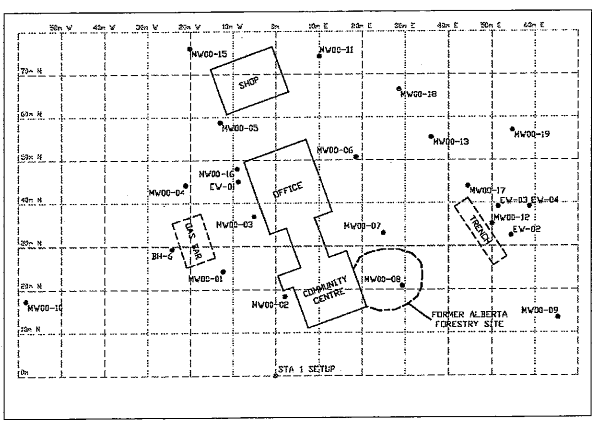

Fig. 2 Site Plan

Local Geology

The surficial geology of the area consists of Quaternary deposits with a loose fine to medium grained light brown silty/sandy till with some tar sand lenses, overlying bedrock. These surficial deposits vary from 1 to 4 metres in thickness. The bedrock is composed of Devonian limestone, which is overlain by a thin (5 – 20 cm) layer of very plastic olive green marine clay. It is believed that the tar sand lenses and the marine clay present a hydraulic barrier for downward (vertical) groundwater migration.

Site Hydrogeology

Water wells in the area are generally completed in Quaternary deposits. The regional groundwater flow direction is estimated to be northeast to north, parallel to surface drainage. The water table at the site is approximately 1.7 to 3.0 m below grade (Figure 3).

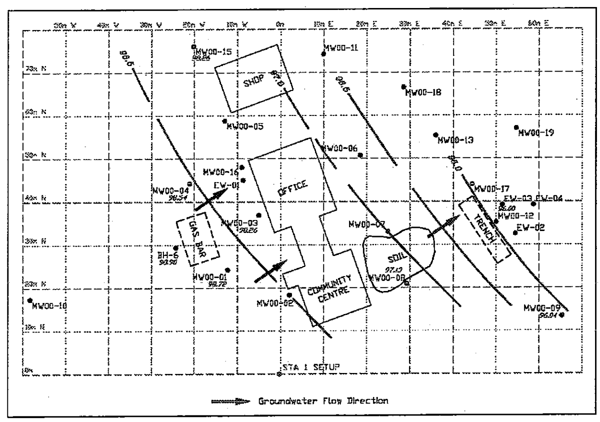

Fig. 3 Groundwater Surface Contour Map

Water well records and information obtained from Alberta Environmental, shows that Township 94 Range 11 W4M contains 11 water wells. These reports do not show any well completion nor water quality data.

Monitoring Well Network

Currently, the groundwater quality monitoring network at the site consists of 20 sampling locations.

The original groundwater monitoring network, installed in June 2000, included seven groundwater quality monitoring wells in the vicinity of the gas bar. During the UST removal, two of these wells were destroyed. Only one of the monitoring wells installed in June of 2000 (BH-6) was found and sampled in the autumn of 2000.

Fifteen additional monitoring wells, MW00-01 to MW00-15, were installed, developed, and sampled in the year 2000 (Phase II ESA). These monitoring wells have a depth range of 3.0 to 3.8 m, similar to the original monitoring well network. These wells intersect a similar stratigraphic profile. At the same time, a set of free phase extraction wells was installed.

In the spring of 2001, an additional monitoring well (MW01-16) was installed at the north-west corner of the office building. During the autumn 2001 groundwater sampling event the groundwater monitoring network was improved by installing three additional monitoring wells east of well MW000-13. Therefore, as of the October 19, 2001, the groundwater monitoring network consisted of twenty groundwater monitoring wells (Figure 2).

All monitoring wells were completed with a 50.8 mm OD threaded, Schedule 40 PVC casing with a 10 slot PVC screen, and sealed above the sand pack with a minimum 0.6 m of bentonite. The annular space around the screen was filled with clean silica sand. The monitoring wells were protected using 175 mm OD monitoring well protectors, cemented in place.

Groundwater Quality (Phase II ESA)

The groundwater quality results, primarily benzene, were compared to maximum allowable concentrations prescribed by CCME Raw Drinking Water Quality Guidelines (DWQG).

Based on laboratory results from collected samples, the benzene concentration distribution map (autumn of 2000) was generated (Figure 6).

The groundwater collected from monitoring well MW00-08 produced significant volumes of heavier (extractable) diesel hydrocarbons.

The free phase was observed in monitoring wells MW00-03, MW00-07 and MW00-08 east of the office building. An approximate free phase distribution map is presented in Figure 4. The estimated volume of the free phase based on a very limited population of measuring points was 35 m^3.

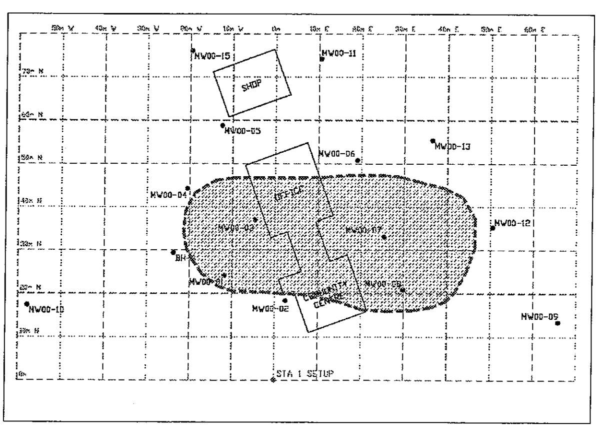

Fig. 4 Free Phase Distribution Map

Site Remediation

The in-situ bioremediation program of contaminated soil and groundwater consisted of:

- Passive hydrocarbon free phase extraction;
- Multi Phase Extraction (MPE) system (hydrocarbons, groundwater and volatiles) installation; and,
- Air (oxygen) injection.

The passive hydrocarbon free extraction was achieved by installing several large diameter (152 mm) vertical extraction wells and by constructing a collection trench ahead of the hydrocarbon plume. The collected hydrocarbons and contaminated groundwater were extracted from the trench on a weekly basis, and temporarily stored for further treatment.

The air sparging wells were installed at the bottom of the impacted groundwater zone to allow adequate air (oxygen) space distribution and time required for the groundwater aeration. The soil vapour extraction wells were installed above the watertable. By forming a local cone of depression (vacuum) they diverted the air volatiles mixture flow direction and prevented unexpected releases of volatiles into the buildings.

The SVE system was operating continuously either by utilizing MPE system or a blower.

Following the completion of the in-situ bioremediation horizontal wells (November 2001) the 20 HP (horse power) MPE system was assembled. Once the extraction of hydrocarbon free phase underneath the buildings was completed the MPE system intake lane was set at different locations utilizing available horizontal and vertical wells. The MPE system intake line was attached to the well heads (vertical and horizontal) at the locations with elevated VOC concentrations.

The completion of horizontal wells consisted of entry and exit wellhead, which allowed the MPE system intake line to be placed at the both ends simultaneously or separately.

The long-term in-situ soil and groundwater bioremediation consists of AS and SVE system installation utilizing pairs of horizontal wells (Figure 5). At the initial stage of the remediation program, the MPE system was utilized at the SVE wells. A 3 HP blower replaced the MPE system when the concentrations of volatiles decreased significantly (80%). An air compressor was utilized for the air (oxygen) injection via AS wells.

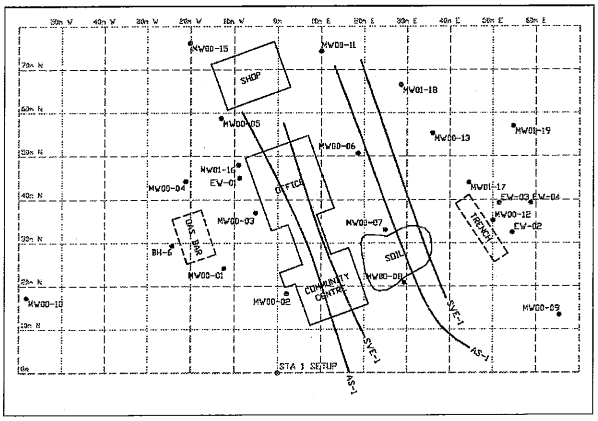

Fig. 5 Horizontal Well Location Map

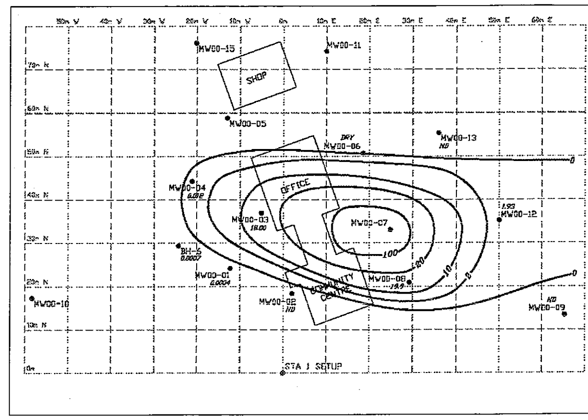

Fig. 6 Benzene Concentration Distribution Map (Autumn 2000)

One set of horizontal wells was completed underneath the buildings intersecting the groundwater flow direction. The second set of horizontal wells, completed in the same fashion, was installed downstream from the buildings.

In-situ Bioremediation Program Results

The in-situ bioremediation program performance is presented in Figures 6, 7, and 8 (Benzene Concentration Distribution Maps). Following the passive hydrocarbon free phase removal completion, in the year 2001, predominantly east of the buildings, the benzene concentrations decreased and the plume area was reduced (Figure 7). The benzene concentrations in the groundwater were reduced by half in less than six months of the simultaneous AS and SVE system operation.

Similar conclusions can be derived from the results of the autumn 2002 groundwater sampling analytical results. A benzene concentration distribution map (Figure 8) in the groundwater shows decreasing concentration by one order of magnitude across the site. The benzene concentrations in MW 00-8A (0.81 mg/L) decreased significantly (~40 times) after only four months of an intensive AS and SVE system operations.

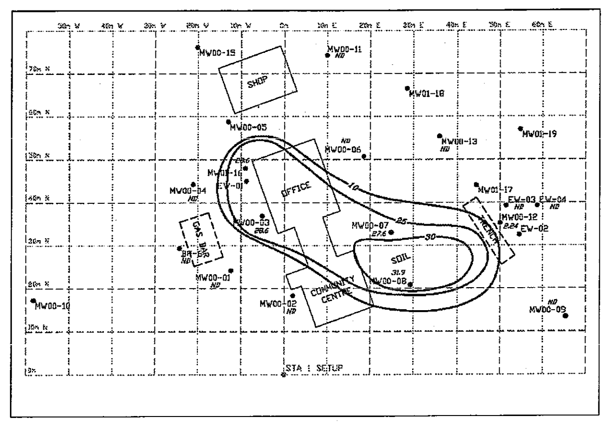

Fig. 7 Benzene Concentration Distribution Map (Autumn 2001)

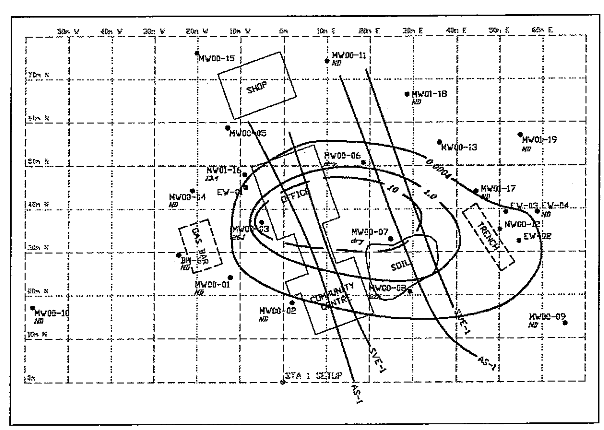

Fig. 8 Benzene Concentration Distribution Map (Autumn 2002)

Conclusions

The Fort McKay gas bar ongoing in-situ bioremediation program met the site-specific challenges and requirements by applying MPE LNAPL removal system and by installing horizontal AS and SVE wells.

The installation of horizontal wells and subsequent bioremediation program rationale successfully competed free LNAPL extraction and achieved significant hydrocarbon removal ratio in soil and groundwater in less than a year of effective operation.

During the remediation program execution there was no interruption of occupants within the business premise. Also, the remediation program system installation was completed with a minimal ground disturbance (two entry and two exit points) and no intrusion through the buildings.

References

Patrick A.D. and Franklin W.S. 1990, Physical and Chemical Hydrogeology, John Wiley and Sons, printed in Canada

Freeze R. A. and Cherry J. A. 1979. Groundwater. Prentice Hall Inc.,

Terracon Geotechnique Ltd. 2001. 2000 groundwater monitoring program and contaminant delineation at Fort McKay gas bar. Calgary, Alberta.

William C. W. 1988. Groundwater pumping tests. Lewis Publishers Inc. Chelsea, Michigan.

Wilson N. 1995.Soil Water and groundwater sampling. CRC Press inc., Lewis Publishers, Florida

The Remediation Course, 2000, Princeton University, Presented in Las Vegas, Nevada.