

RISK MANAGEMENT OF A FORMER SALT STORAGE YARD

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Abstract

A risk management plan was developed by Matrix Solutions Inc. (Matrix) and implemented by The City of Calgary (City) to address salt impacts at a former road salt storage yard facility (the facility).

The facility was located at the south edge of the City on an Alberta Infrastructure highway right-of-way. The facility was constructed in the mid 1980s and decommissioned in 2003. Currently, the site is bounded by residential land use to the north, and the highway right-of-way to the west, east and south. A permanent pond and wetland area is located south of Highway 22X, approximately 180 m south of the site.

Environmental investigations conducted from 2001 to 2005 confirmed the presence of sodium chloride (NaCl) salt impacts to the soil, groundwater and surface water both onsite and offsite. Chloride (Cl) concentrations were greater than ten times background over an area of 4.7 hectares (ha), including 2.43 ha onsite and 2.27 ha offsite. The chloride-impacted soil extended from surface to depths from 2 to 4.5 m below ground surface.

The volume of “severely” impacted soil, where the electrical conductivity (EC) on a saturated paste extract exceeded 10 dS/m and the chloride concentration exceeded 100 meq/L, was estimated at 20,000 m³, mostly onsite. The extent of salt-impacted groundwater corresponded closely to the extent of salt impacted soil and appeared to be spreading at a slow rate. Salt impacts are believed to have migrated offsite via surface water runoff from the site within a ditch to at least 230 m east and downgradient of the site. In addition, salt impact had reached the permanent pond 180 m south of the site.

The purpose of the risk management plan was to minimize offsite salt impacts and to temporarily reclaim the site. The risk management plan included regular monitoring of groundwater and surface water and installation of an impermeable clay cover as a source isolation measure. The key components of the clay cover design included a 30 cm thick layer of compacted clay covered by 30 cm of subsoil and 15 cm of topsoil.

The clay cover was installed in November 2006. A total of 3,500 m³ of compacted clay, 7,600 m³ of subsoil, and 2,870 m³ of topsoil was placed. The entire 2.45 ha site area was seeded in October 2007. Groundwater and surface water monitoring are conducted on a semi-annual basis.

When future development of the site is determined a soil management plan will be prepared to address potential environmental issues with the handling and disposal of the salt impacted soil that remains at the site.

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BACKGROUND INFORMATION

1.1 Site Setting and History

The site is located on the north side of the westbound lane along Highway 22X between 6th Street and 14th Street S.W. at the southern limits of the City of Calgary.

The former road maintenance facility was located on a property leased to the City by Alberta Infrastructure. One of the purposes of this facility was to store sodium chloride road salt and pickled sand (sand mixed with road salt) for maintenance of city roads. The facility was constructed in the mid 1980s and former facilities included an office trailer, a maintenance shed, a salt storage tent, an earthen dugout for collection of surface water, a maintenance shed, a salt storage tent, an earthen dugout for collection of surface water, an equipment storage area, and stockpiles of calcium treated sand and gravel, pickled sand and road gravel as shown on Figure 1.



Figure 1: 1998 aerial photograph of the site showing the site facilities as well as the westbound (top) and eastbound (bottom) lanes of Highway 22X, an intermittent pond within the median and a permanent pond south of the highway.

Most of these facilities were decommissioned in 2003, except for remnants of former facilities that included the metal framing and concrete foundations for the salt storage tent and the dugout for capturing surface water.

1.2 Land Use and Topography

Surrounding land use includes a residential development (Somerglen Common SW) to the north of the site, the highway right-of-way covered by grasses to the east and west of the site, and Highway 22X Westbound to the south of the site. A pasture and intermittent pond area are present within the median area separating the westbound and eastbound lanes of the highway. To the south of Highway 22X Eastbound lies a permanent pond and wetland surrounded by agricultural land.

The surface of the site is flat and slopes gently from the west to the east. A slope rises approximately 3 m above the site to the residential back yards along the north boundary. An intermittent pond is located south of the site within the median of the divided highway. A permanent pond is located to the south of Highway 22X Eastbound, approximately 180 m south of the site.

Prior to installation of the clay cover, surface drainage from the former maintenance facility was to the east and south across the site following the topography. Surface water from the site generally flowed southeast and collected in an onsite dugout. When full, the water in this dugout discharged into the ditch that extends along the north side of, and parallel to, Highway 22X Westbound. A portion of this discharged water flowed eastward along the ditch and the remainder flowed south through a series of culverts and ditches to the permanent pond located south of Highway 22X Eastbound.

2.0 ENVIRONMENTAL ASSESSMENT

2.1 Environmental Investigations

Environmental investigations conducted by Matrix and others at the site are listed below. The borehole and monitoring well locations are shown on Figure 2.

- Phase I Environmental Site Assessment (ESA) conducted in 2001.
- A Phase II ESA was conducted in 2002. The scope of work for this assessment included drilling a total of 13 boreholes and installing 10 groundwater monitoring wells. The wells were installed to depths ranging from 4.6 to 9.4 m below ground surface (bgs) and were completed within till.
- A soil and groundwater investigation was conducted in 2004. The scope of work for this assessment included conducting horizontal and vertical electromagnetic (EM) surveys, drilling 11 probeholes as part of the vertical EM survey and installing 15 groundwater monitoring wells both onsite and offsite. These wells were installed to depths ranging from 3 to 7.6 m bgs and were completed within till.
- A supplemental investigation was conducted in 2005. The scope of work included installing six monitoring wells to delineate offsite impacts. These wells were installed at depths ranging from 6.1 to 9.6 m bgs and were completed within till. One well was installed to a depth of 13 m bgs and was screened within bedrock.

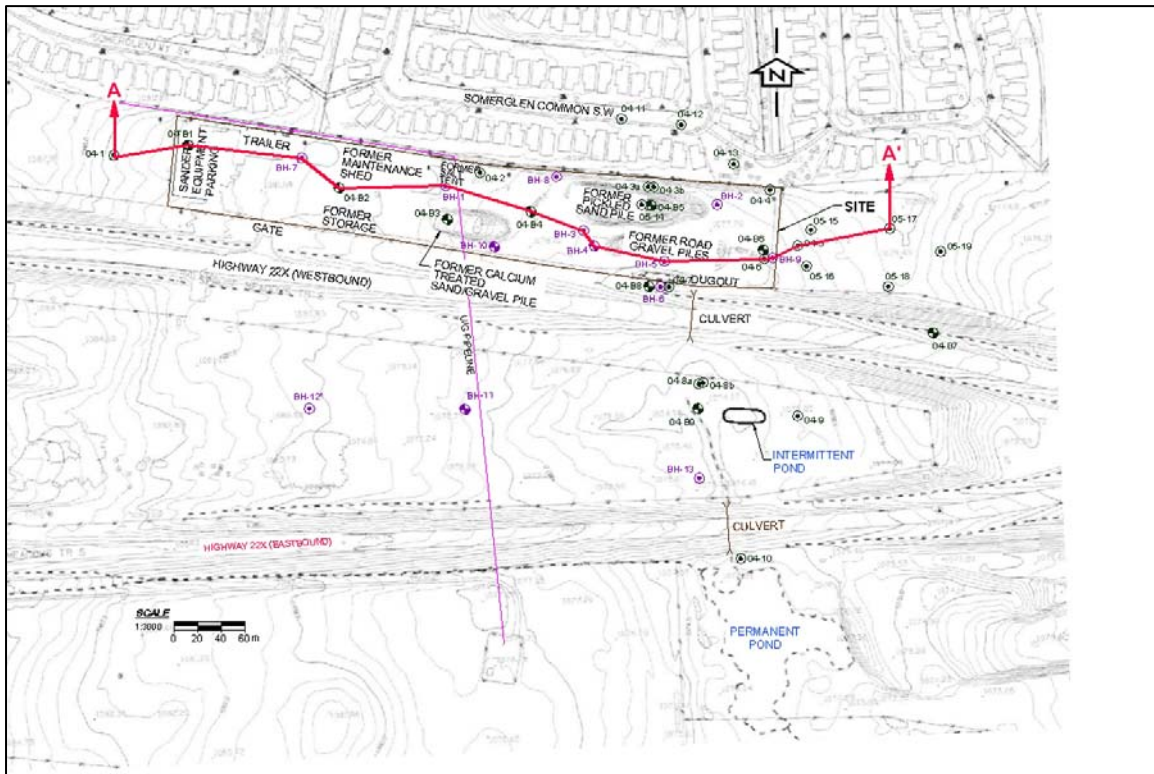


Figure 2: Site plan showing borehole and monitoring well locations as well as the geological cross section line.

2.2 Site Geology

The site is generally underlain by approximately 0.4 to 0.7 m of gravel fill overlying a 2.5 to 9.0 m thick sequence of silty clay glacial till sediments which in turn overlie bedrock. The stratigraphy is illustrated on the geological cross section shown on Figure 3. Discontinuous sand and/or gravel lenses, up to 1.0 m thick, were encountered in several boreholes across the site.

To the south of the site, within the median of the divided highway and south of Highway 22X Eastbound, a 2 m thick deposit of silt was encountered overlying the silty clay till. To the east of the site, a gravel bed is located between the silty clay and bedrock.

Bedrock was encountered in several boreholes beneath the glacial till at depths ranging between 2.5 and 9.1 m bgs. Based on the borehole data, the bedrock surface appears to rise and fall abruptly to the east of the site. The bedrock was generally comprised of dry, weathered, siltstone that was white to light orange in colour.

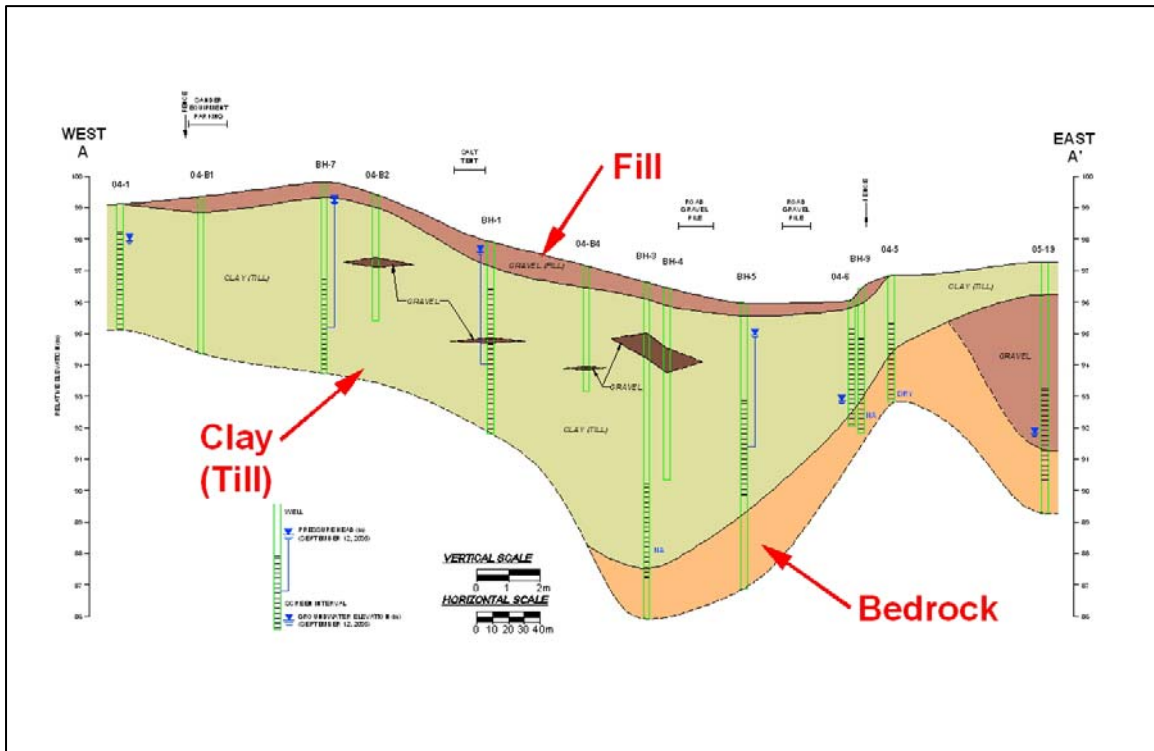


Figure 3: A west–east geological cross section illustrating the stratigraphy across the site.

2.3 Site Hydrogeology

The horizontal groundwater flow is directed to the southeast following the topography. The vertical groundwater flow is indicated to be downward at three nested well locations. The depth to groundwater ranges in the till between 0.16 and 3.88 m bgs. The calculated hydraulic conductivity values for the silty clay till ranged between 7×10^{-10} and 5×10^{-8} m/s. The depth to groundwater in the bedrock was approximately 6 m lower than in the overlying till.

2.4 Groundwater Use

There is no identified use for the shallow groundwater underlying the site. The low permeability silty clay with a hydraulic conductivity of less than 10^{-8} m/s underlying the site would not be suitable for use as a domestic use aquifer. The closest water wells were located approximately 0.9 km south of the site and were screened in bedrock at depths of 30.5 m bgs. Considering the thickness of low permeability clay underlying the site, it is unlikely that groundwater from the site is hydraulically connected to a domestic use aquifer.

2.5 Identified Environmental Impacts

The results of these investigations indicated that, in general, salt impacts occurred in the soil and groundwater across the site, with the most severe impacts measured in the east-

central portion of the site and offsite to the south within the Highway 22X median. These severe impact areas were delineated with the horizontal EM survey and are shown on Figure 4. Salt impacts resulting in “poor” to “unsuitable” soil ratings with respect to the Alberta Environment Salt Contamination Assessment and Remediation Guidelines (AENV, 2001) extended to depths generally up to 2.0 m bgs and locally up to 4.5 m bgs. The maximum soil EC was 51 dS/m and the maximum chloride concentration was 623 meq/L (12,100 mg/kg) in a saturated paste extract from soil obtained from a borehole located at the former pickled sand pile.

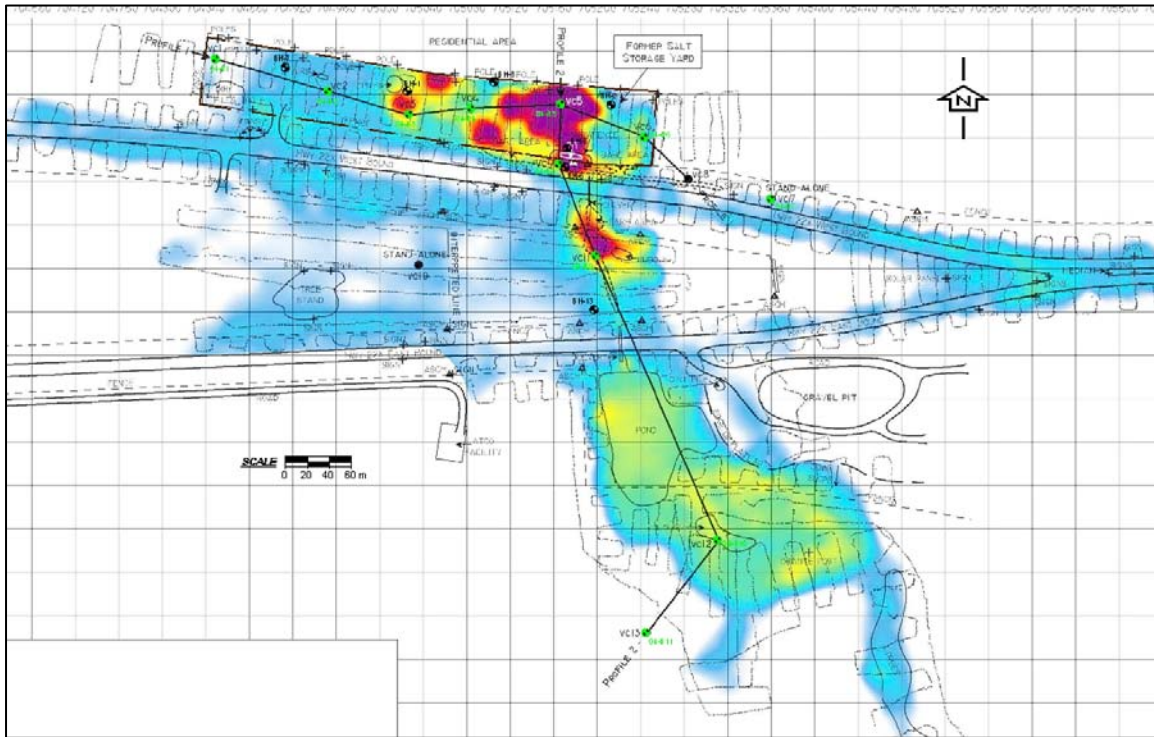


Figure 4: Results of the horizontal EM38 survey showing the areas of high apparent soil conductivity in red and purple. Within the site, these areas correspond to the locations of former stockpiles and the dugout.

Chloride impacted soil, where chloride concentrations were greater than 10 times those measured in the soil samples collected from a background borehole, was interpreted to cover a total area of approximately 47,000 m², of which approximately 24,000 m² was within the fenced site area, and 23,000 m² was within the surrounding offsite area. The chloride impacted soil extended from depths generally less than 2 m bgs up to 4.5 m bgs beneath the former pickled sand pile. The volume of the “severely” impacted soil, where the EM conductivities exceeded 200 mS/m, the EC in soil exceeded 10 dS/m and the chloride concentration in soil exceeded 100 meq/L, was estimated to total approximately 20,000 m³, of which 18,300 m³ was located within the fenced site area, and 1,700 m³ was located within the highway median.

The groundwater monitoring and sampling data indicated that the lateral extent of dissolved sodium chloride salts corresponded closely to the extent of impacted soil. The maximum EC in groundwater was 84,500 $\mu\text{S}/\text{cm}$ and the maximum chloride concentration was 42,500 mg/L in a sample collected from a monitoring well located adjacent to the former dugout. The dissolved salt impact in groundwater appears to be spreading at a slow rate.

Salt impacts are believed to have migrated offsite via surface water runoff from the site dugout, primarily through a series of culverts that transect the divided highway to the south of the site. The maximum EC was 13,800 $\mu\text{S}/\text{cm}$ and the maximum chloride concentration was 5,500 mg/L in a sample collected from the intermittent pond in the highway median. The salt impacts to surface water occurred within the east-flowing ditch to at least 230 m east of the site. In addition, salt impacted surface water had been collect from surface water flowing into the permanent pond approximately 180 m south of the site.

3.0 DEVELOPMENT OF RISK MANAGEMENT PLAN

3.1 Approach To Risk Management

Due to the uncertain future land use at the site and the possibility of constructing a highway through the site, the City chose to manage the existing identified environmental risks in the short term. This approach involved ensuring that offsite risks were minimized and that the site was reclaimed. The three key aspects addressed in the risk management plan are the contaminant type, pathways and receptors. Management of the environmental risk involved removing at least one of those factors.

- Type – sodium and chloride can be toxic to plants and aquatic life, and can be toxic to humans and animals.
- Pathways – the migration pathway for the salt impact is in groundwater, which is slow, and surface water, which is fast. Groundwater monitoring has confirmed that salt has not reached a potential bedrock aquifer below the site.
- Receptors – the nearest receptors are the permanent pond south of Highway 22X and the ditch along the north side of the highway. The nearest human receptors are two drinking water wells located approximately 0.9 km south of the site.

3.2 Source Isolation Options

Based on consideration of the contaminant type, pathways, receptors and future land use, two source isolation options to remove the surface water pathway were considered. One was excavation and removal of the “severely” impacted soil. The other was covering the “severely” impacted soil with either an impermeable membrane or a compacted clay cover.

Each option was evaluated considering factors including cost, effective longevity, future land use and re-vegetation. Based on the evaluation, the City selected installation of a compacted clay cover over the “severely” impacted soil.

The key technical advantages to the source isolation option are: i) the salt concentration in surface water migrating offsite is reduced; ii) the clay cover would provide an effective barrier for at least five to ten years, which is the expected time frame before redevelopment; and iii) the infiltration of surface water through the salt-impacted soil into the underlying groundwater is minimized.

The key technical disadvantages to the source isolation option are: i) the major source of salt impact remains; and ii) the clay cover will not permanently isolate the salt impacts because it will become less competent due to root penetration and the possible upward migration of salts.

4.0 RISK MANAGEMENT PLAN

4.1 Compacted Clay Cover Design

The key design features of the compacted clay cover included:

- 30 cm of compacted clay over the “severely” impacted area (11,700 m²). The clay specification was 65% clay and silt fraction (75 µm screen) with compaction to 98% Standard Proctor maximum dry density.
- 30 cm of subsoil over the entire site (24,500 m²). This material was “C” horizon soil that was placed, but not compacted.
- 15 cm of topsoil over the entire site (24,500 m²). This material was placed, but not compacted.
- Re-vegetation with grasses over the entire site (2.45 ha). The specification for the seed mixture was The City of Calgary Urban A mix, which consists of Kentucky Blue Grass (20%), Creeping Red Fescue (35%), Annual Rye (30%) and Perennial Rye Grass (15%) applied at the rate of 300 kg/ha.

In addition, other unique activities that were considered in the design included: i) replacement of the “flush-mounted” protective covers over the monitoring wells with “stick-up” protectors to enable continued use of the wells; ii) excavation and removal of asphalt from the former parking area; iii) excavation and removal of “soft” soil at the dugout; iv) removal of the former Salt Tent foundations; v) removal of the chainlink fence; and vi) construction of ditches to direct surface water flow around the clay cover.

4.2 Monitoring

Regular semi-annual monitoring of the groundwater and surface water was implemented in 2005 (pre-cap) and will continue for at least the next two years (post cap). This involves measuring groundwater levels at all monitoring wells to monitor groundwater

flow conditions. In addition, groundwater samples will be collected from all monitoring wells to identify trends, if any, in the salt concentrations.

Surface water samples will be collected from locations established upgradient, at the site and downgradient of the site. These locations include the permanent pond and the ditch beside Highway 22X Westbound.

4.3 Risk Management Triggers

The risk management triggers are conditions that indicate that a potential risk to offsite receptors may be present. The purpose of the triggers is to provide an early warning so that other remediation options can be evaluated and implemented to mitigate offsite impacts. The triggers include limits for groundwater and surface water quality.

When the groundwater in offsite monitoring wells has a consistent and persistent trend of increasing chloride concentrations, and the chloride concentrations reach 800 mg/L, which is less than the maximum concentration guideline of 860 mg/L developed by the US EPA and recommended by Alberta Environment for surface water (AENV, 1999), the trigger condition is assumed to have been met. This condition assumes that the shallow groundwater discharges directly to surface water and that no dilution occurs, a conservative assumption.

Another trigger condition exists when the groundwater in the deep monitoring well completed in bedrock has a consistent and persistent chloride concentration of at least 200 mg/L, which is less than the aesthetic objective of 250 mg/L for drinking water (Health Canada, 2006). This assumes that the groundwater in this well is in contact with a domestic use aquifer.

When the surface water leaving the site has a consistent and persistent chloride concentration of at least 800 mg/L, which is less than the maximum concentration guideline of 860 mg/L developed by the US EPA and recommended by Alberta Environment for surface water (AENV, 1999).

5.0 IMPLEMENTATION OF RISK MANAGEMENT PLAN

5.1 Installation of Compacted Clay Cover

The monitoring wells were extended in September 2006. After preparation and awarding of the contract, the majority of the earthworks for the clay cover installation were completed in November 2006. The top soil, sub soil and clay materials were obtained from an agricultural property being re-developed immediately east of Calgary city limits. Materials were tested to ensure they met the physical and chemical requirements.

The quantities of key materials included 3,500 m³ of compacted clay, 7,600 m³ of subsoil and 2,790 m³ of topsoil. In addition 4,500 m² of asphalt were removed, 840 m of chainlink fence were removed and re-used elsewhere, and 2.45 ha of topsoil were seeded. The location of the clay cover relative to the EM anomalies is shown in Figure 5.

Other unique activities that came up during construction were removal of power poles that had been used when the facility operated, and placement of a geosynthetic bentonite liner over the natural gas line as an alternative to placing compacted clay.

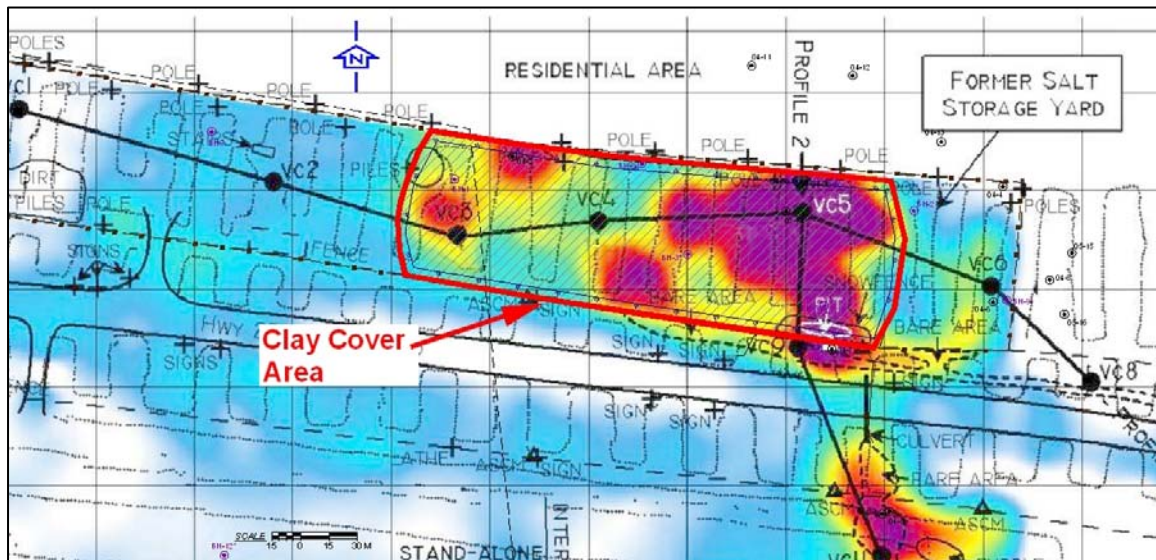


Figure 5: The location of the compacted clay cover relative to the area of high apparent soil conductivity identified by the horizontal EM survey.

5.2 Monitoring Program

The monitoring program began in 2005. The groundwater monitoring network consists a total of 30 monitoring wells, including three nested pairs. The wells are located onsite, and offsite upgradient, cross-gradient and downgradient. Groundwater monitoring includes measuring water levels and collecting samples for laboratory analyses semi-annually in the spring and fall. The samples are analyzed for routine parameters.

Surface water monitoring consists of collected samples from seven locations, including upgradient and downgradient of the site. The samples are collected in the spring and submitted for laboratory analyses of routine parameters.

6.0 CONCLUSIONS

The storage and handling of road salt at a former road maintenance yard resulted in sodium chloride salt impacts to shallow soil and groundwater, as well as to surface water flowing from the site. The extent of salt impact in soil, where the chloride concentration is greater than ten times background, covers a total area of approximately 47,000 m², both onsite and offsite. Within this area, an estimated 20,000 m³ of “severely” impacted soil has an EC greater than 10 dS/cm and chloride concentrations greater than 100 meq/L. The majority of this “severely” impacted soil is within the site.

Although shallow groundwater has also been impacted by salt, the flow velocity is indicated to be very slow and there is no nearby receptor. The salt impact does not extend into groundwater within the underlying bedrock.

Salt has migrated offsite in surface water. Elevated sodium and chloride concentrations have been measured in surface water that discharges to a permanent pond located approximately 180 m south of the site.

A risk management plan of source isolation and monitoring was developed and implemented at the site. The plan included installation of a compacted clay cover over the “severely” impacted soil and regular monitoring of groundwater and surface water. This was considered to be the best option based on the contaminant type, pathways, receptors and future land use. This plan is intended to address the salt impact to offsite receptors in the near term until the final land use has been determined.

The key features that make this site well suited for this risk management plan are: i) very slow migration of salt through the soils; ii) no impact to a potential domestic use aquifer; iii) no human exposure; and iv) re-development of the land in the future.

7.0 REFERENCES

- Alberta Environment (AENV), 1994. “Alberta Tier I Criteria for Contaminated Soil Assessment and Remediation.” Soil Protection Branch, Chemicals Assessment and Management Division, Edmonton, Alberta, March 1994.
- Alberta Environment (AENV), 1999. “Surface Water Quality Guidelines for Use in Alberta.” Environmental Sciences Division, Edmonton, Alberta, November 1999.
- Alberta Environment (AENV), 2001. “Salt Contamination Assessment and Remediation Guidelines.” Environmental Sciences Division, Edmonton, Alberta, Publication No. T/606, May 2001.
- Canadian Council of Ministers of the Environment (CCME), 1992. National Classification System for Contaminated Sites. National Contaminated Sites Remediation Program report CCME EPC-CS39E. Winnipeg, Manitoba, March 1992.
- Health Canada, 2006. “Guidelines for Canadian Drinking Water Quality.” Summary Table. Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment, March 2006.
- United States Environmental Protection Agency (USEPA), 1999. “National Recommended Water Quality Criteria – Correction.” EPA 822-Z-99-001.