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THE ENVIRONMENTAL REMEDIATION OF CLARK ISLAND A FORMER ALLIEDSIGNAL INC. SITE

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ABSTRACT

Clark Island is a 63 ha island located in Lake St-Francis, part of the St-Lawrence River, Québec, Canada. Since the early 40s the island has been used for the production of mineral acids by its former owner, Allied Chemicals Limited. Acidic wastes were placed over large portions of the island. The presence of these waste materials together with contaminated soils was identified as a potential threat to the nearby river water quality as well as to the underlying bedrock groundwater quality. A major remedial investigation and feasibility study was initiated in 1987. The approved scope of the remediation project included the construction of one 60,000 m^3 single lined cell for the placement of contaminated soils, and one 130,000 m^3 double lined cell for the placement of acidic wastes. The remediation project was implemented during the 1991-1993 period. In order to assess the efficiency of the remediation, a detailed environmental monitoring program was implemented during the works and in the following years. The general conclusion of this major project is that confining acidic wastes in lined cells provide a safe and economical way to avoid detrimental consequences to the environment.

KEYWORDS

Environmental remediation, environmental monitoring, acidic wastes, pyrite cinders, water quality, confinement cells

INTRODUCTION

Clark Island is located in Lake St-Francis, near Valleyfield, Québec, Canada, as illustrated on Figure 1. Lake St-Francis is part of the St-Lawrence River system and is situated about 50 km upstream of Montréal. Most of the 63 ha island is presently owned by General Chemical Canada Limited (GCCL) which operates bauxite grinding and alum production facilities.

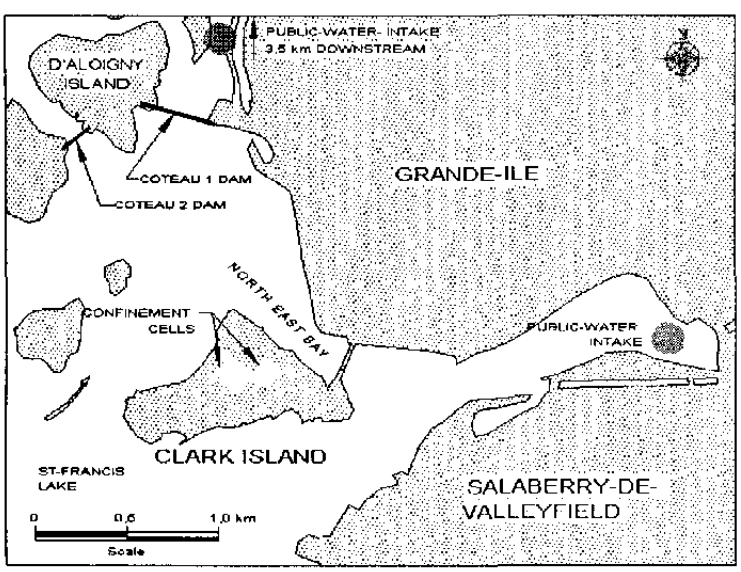

Figure 1 - GENERAL LOCATION

The former owner of the site, Allied Chemicals Limited, has been using Clark Island for the production of mineral acids since the early 40s. Sulphuric acid, hydrofluoric acid, reagent grade chemicals and hydrated aluminum sulphates were produced. In 1983, most of the production facilities were decommissioned as the site was sold to its present owner.

In 1984, Clark Island was identified by the Québec regulatory authorities as one of the priority hazardous sites within the province. A request for detailed environmental investigation was issued in 1986 by the Québec Ministry of the Environment (QME). AlliedSignal Inc. then decided to proceed with a remedial investigation and feasibility study of the site.

OVERVIEW OF PLANT HISTORY

Industrial operations began on Clark Island in 1941 with the construction of a sulphuric acid plant. Until 1963, this plant used pyrite (iron sulphide ore) as the raw material, resulting in the accumulation of about 300,000 metric tons of pyrite cinders. This waste was sluiced and pumped into various settling ponds on the island. From 1963, zinc sulphide was used to replace pyrite as the raw material. The produced zinc calcine was sold to a nearby zinc refinery leaving no waste for on-island disposal.

Alum production commenced on the island in 1946 and continues to the present. As alum muds were produced, they were washed and pumped into settling ponds.

The production of hydrogen fluoride began in 1956 with fluorspar as the raw material. An estimated amount of 400,000 metric tons of gypsum wastes were produced until 1982 in this process. These wastes were pumped along with alum muds into settling ponds on the island.

During the 1983-1986 period, a series of decommissioning activities took place at the Clark Island site. However, concerns were raised with respect to the efficiency of these measures.

REMEDIAL INVESTIGATION

In January 1987, AlliedSignal Inc. hired Tecsult Inc., an environmental consulting firm of Montréal, to develop a remedial investigation plan with the objectives of (1) answering the agency's concerns, (2) assessing potential human health risks and (3) obtaining an adequate database for the selection of a remedial action. The proposed investigation plan was approved in the summer of 1987 and implemented during the 1987-1988 period. The actual investigation works included:

- a survey of the nearby river water and groundwater users;
- a detailed characterization of the waste materials;
- a detailed characterization of the surface soils;
- an in-depth study of the nearby river water quality;
- the preparation of the hydrogeologic model of the site.

The main findings of these investigations are summarized below.

Water Users

A total of 67 private water users and 4 public water intakes were identified in the immediate vicinity of Clark Island. About one third of the private water users operate groundwater wells with Iron, Zinc and Fluorides typically detected in above background concentrations. Four municipalities operate surface water intakes with more than 43,000 people drinking this water. The water was found to comply with drinking water standards for the compounds of interest.

Waste Characterization

A series of test pits and boreholes were put down throughout the island to assess waste thickness and collect waste samples for laboratory identification.

Pyrite cinders waste is a dark red to brown uniformly graded silt-sized material. It is essentially composed of iron oxides with traces of several heavy metals. The waste is typically found in thin layers either beneath the gypsum/alum waste deposit or at the surface. The pyrite cinders are, in general, classified as a hazardous waste given the potential for release of cadmium, selenium, zinc and fluorides in the leachate test. A total of more than 120,000 m^3 of such wastes were identified.

Gypsum/alum waste mixture is a grey material typically found at the surface. The main constituent of the waste is calcium sulphates with lead as the only leachable metal. The gypsum/alum waste did not, in general, classify as a hazardous waste.

Alum waste produced since the closure of the hydrofluoric acid facility was disposed separately in an excavated portion of the gypsum/alum ponds. It is a whitish to light grey soft to very soft material composed of the non soluble portion of the bauxite ore. It classifies as a solid waste.

Surface Soil Characterization

A series of soil samples were collected from areas outside the waste ponds on the island. The metal concentrations were measured in these samples and compared with existing soil contamination criteria established by the QME. Heavy metals commonly found to exceed these criteria include cadmium, copper, lead, selenium and zinc. The areas where contaminated soils were found measure about 27,000 m^2 representing nearly 60,000 m^3.

River Water Characterization

Four river water sampling events occured in 1988 from 17 stations around Clark Island. The only area where the river water quality was found to be impaired by compounds originating from Clark Island is a narrow stretch along the northwest shoreline. In this zone, occasional exceedances of the Canadian Maximum Permissible Concentration (MPC) in drinking water for iron, zinc and fluorides were noted.

Hydrogeologic Model

A total of 47 monitoring wells were installed at strategic locations around the island in order to assess subsoil stratigraphy, measure hydrogeologic parameters and collect groundwater samples. The island stratigraphy is typical of the St-Lawrence Lowlands. A thin layer of alluvial deposit is found immediately beneath the waste ponds. It is underlain by a 6-7 m thick very dense glacial till deposit of low permeability. The underlying bedrock is found at about 8.5 m below the river water level and is composed of dolomitic limestone.

Two separate groundwater levels were identified. The upper water level is established in the surficial waste ponds and alluvial deposits. In this level, groundwater flows horizontally towards the island shorelines. The lower water level is located in the underlying dolomitic bedrock. In this level, groundwater flows in the northeast direction. Both water levels are separated by the till layer which acts as an aquitard. The groundwater flow regime is presented schematically on Figure 2.

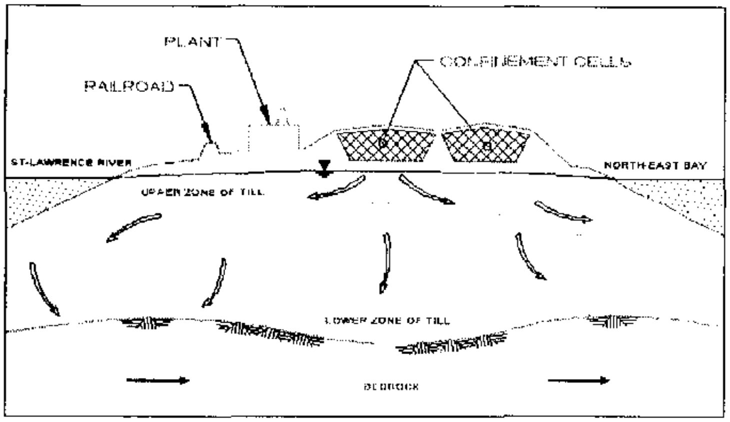

Figure 2 - SCHEMATIC GEOLOGICAL AND HYDROSTRATIGRAPHIC CROSS-SECTION OF CLARK ISLAND

In 1987, the quality of the upper groundwater level was found to be contaminated by heavy metals. Cadmium, iron, lead, zinc and fluorides concentrations typically exceeded the contamination criteria for groundwater quality established by the QME. Heavy metals may leave the island with the groundwater flow. The calculated yearly amounts of metals leaving the island in this way include 4 kg of cadmium, 10 kg of lead and 18,000 kg of zinc.

The groundwater quality in the till aquitard is characterized by a rapid reduction of metal concentrations with depth.

Groundwater contamination is limited to the upper part of the till layer. Sulphates and iron concentrations of up to 2,400 mg/l and 24 mg/l respectively were measured in 1987. Based on the hydrogeologic parameters of the till ($i_v = 0.20$, $k_h = 2 \times 10^{-7}$ cm/s, $n_e = 0.05$), it was calculated that the time required for heavy metals such as zinc and cadmium to travel through the till is in the order of several decades. However, ferrous iron and sulphates were found to travel much faster.

In 1987, the groundwater quality in the lower water level is not contaminated since no exceedances of the groundwater quality criteria were noted. However, the presence of iron and sulphates in above background concentrations is typically observed in the downgradient wells. Iron concentrations of up to 7.2 mg/l and sulphates concentrations of up to 800 mg/l were measured in bedrock groundwater. Such high concentrations of iron and sulphates are associated with the presence of large quantities of iron oxide and calcium sulphate wastes on top of the island.

BASELINE HEALTH RISK ASSESSMENT

A quantitative baseline health risk assessment was prepared together with the remedial investigation. This assessment was focused on three receptor populations, namely the on-site workers, the unauthorized recreational users of the site and the residential receptors. These receptors are exposed to a list of 8 chemicals (As, Cd, Cu, Hg, Pb, Se, Zn and F) potentially associated with former Clark Island activities through a variety of exposure pathways. These exposure pathways include (1) dermal contact with surface wastes, surface soils and surface water, (2) incidental ingestion of the surface wastes and surface soils, (3) drinking water and (4) fish consumption.

The study quantified, through a series of analytical steps, the carcinogenic lifetime risks and the noncarcinogenic hazard indices. It concluded that the carcinogenic risks potentially associated with the site are low and that the hazard indices are below one for all receptors indicating safe conditions.

REMEDIATION OBJECTIVES

The overall goal of AlliedSignal was to clean-up Clark Island and its immediate neighborhood to levels protective of the various components of the environment. The GCCL employees and nearby residents were considered as the most valuable components of the environment. The protection of their health and welfare was at the center of the proposed remediation project.

Specific remediation objectives were also formulated by the QME. They stand as follows:

- protect the present and future users of the site;
- allow the safe use of the site;
- stop the contamination of Lake St-Francis;
- stop the contamination of the groundwater and of the surface water.

FEASIBILITY STUDY

In 1990, Tecsult prepared a feasibility study for the remediation of Clark Island. A series of eight remediation scenarios were developed. The scenarios considered ranged from simple capping to complete removal of wastes for off-site disposal. The scenario addressed to the major environmental concerns associated with Clark Island which were:

- the presence of waste basins and contaminated soils;
- the potential impact on river water quality;
- the potential long term impairment of bedrock groundwater quality.

The eight remediation scenarios were submitted to a selection process using a number of criteria (technical, economical, environmental). All scenarios were designed to comply with the existing regulations and to provide a significant reduction in human health exposure. The retained scenario included:

- connection of nearby residents to the municipal water system;
- excavation and placement of contaminated soils in a single lined cell (HDPE) of 60,000 m^3 capacity;
- excavation and placement of acidic wastes in a double lined cell (HDPE) of 130,000 m^3 capacity;
- capping of the remaining gypsum/alum waste with a HDPE liner;
- continuous monitoring of the groundwater quality and of the integrity of the confinement cells

WORK IMPLEMENTATION

The scope of the remediation works was authorized by the QME in July 1991. The remediation contract was awarded in August 1991. The remediation of Clark Island was carried out from September 1991 to July 1993.

During the first year, all alum muds and about 50 % of the gypsum/alum wastes located outside the main pond were excavated. Both wastes were mixed and spread in the northern part of the main waste bed. The gypsum/alum wastes were partly excavated and used for the construction of the cells' dykes. Geosynthetics (geotextiles and geomembranes) were used for the construction of the single lined contaminated soils cell. Excavation areas, located outside the main waste bed, were backfilled with a natural till material.

In 1992, both confining cells were completed and the excavated soils and pyrite cinders were placed in the confinement cells. The water pumped during dewatering operations in the excavations was treated on-site. The treated water meeting the discharge criteria was directed to the river. The capping of both cells as well as of the rest of the main pond was realized by the end of 1992. The cap structure also includes a HDPE geomembrane.

The complete Clark Island remediation works including the construction of the waterline amounted to more than 12 M $ (US).

ENVIRONMENTAL MONITORING

A series of environmental monitoring activities were implemented during the remediation of Clark Island. Some of these activities are to be continued until the year 2000 in order to quantify the long term effects of the Clark Island remediation on the environment and to assess its efficiency. The main activities include the monitoring of the river water quality from two nearby public water intakes and from 10 stations located in the river around Clark Island as well as the monitoring of bedrock groundwater quality from 9 on island monitoring wells.

River water monitoring program includes 8 metals (As, Cd, Cu, Fe, Hg, Pb, Se, Zn), major ions (Cl, SO_4) and fluorides. The river water quality data obtained since 1991 from stations around the island and from water intakes show that the water is of consistently good quality. In particular, the elevated fluorides concentrations recorded in 1988 are no longer obtained. Heavy metals originating from Clark Island (mainly Fe and Zn) are now detected only occasionally and in low concentrations. The MPC for drinking water were never exceeded.

The regional bedrock aquifer is a key component of the long term monitoring program. It used to constitute an important source of drinking water for the nearby residents. Measurable concentrations of iron and sulphates were detected in the bedrock groundwater in 1987-1988. The bedrock groundwater monitoring includes the seasonal measurement of 8 heavy metals (As, Cd, Cu, Fe, Hg, Pb, Se, Zn), sulphates and fluorides.

The bedrock groundwater underneath Clark Island is exhibiting continued decrease of iron, zinc, fluorides and sulphates concentrations from 1987 to 1996. No other parameter of interest is typically detected. The average decrease range from 32 (for sulphates) to 91 % (for iron) for the wells located underneath the confining cells. Figure 3 shows the yearly average concentrations of iron and sulphates measured in the bedrock groundwater from a downgradient monitoring well. It clearly shows that a general decrease in concentrations of the most highly mobile parameters (iron and sulphates) is taking place.

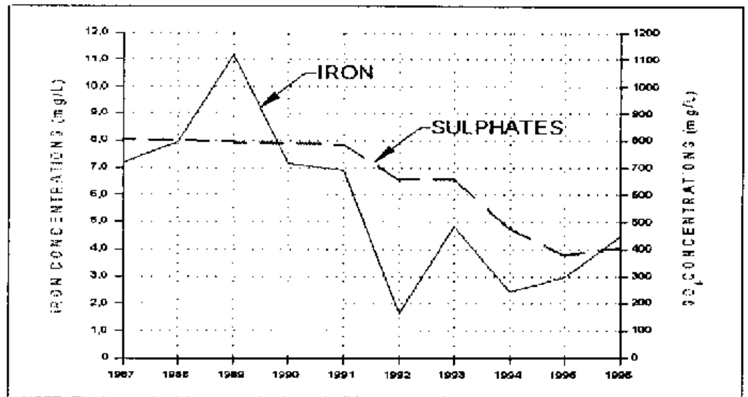

Figure 3 - YEARLY AVERAGE CONCENTRATIONS OF IRON AND SULPHATES IN BEDROCK GROUNDWATER

The monitoring program also includes regular pump outs of the leachate from the two confinement cells, visual inspections of their integrity, and settlement measurements. The quantities of leachate available for pumping is continuously diminishing. The settlements of both cells, after a five year operation, is below 100 mm.

CONCLUSIONS

The remediation of Clark Island has efficiently met the objectives of protecting present and future users of the site and stopping the contamination of nearby river water and deeper bedrock aquifer. The use of engineered confinement cells with HDPE geomembranes is an efficient way to contain contaminated soils and other wastes.

Moreover, the structural integrity of both confinement cells has been found to be adequate and no apparent sign of distress was noted after a five years operation period.

In 1994, based on the above conclusions, the QME officially reclassified the island as a category 3R site, i.e. a site that presents a low risk for the environment and no risk for human health.