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Proposed Tailings Management at the McClean Lake Project: Designing for Decommissioning

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PROPOSED TAILINGS MANAGEMENT AT THE McCLEAN LAKE PROJECT: DESIGNING FOR DECOMMISSIONING

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Abstract: Cogema Resources Inc. (Cogema) is currently developing the McClean Lake Project in Northern Saskatchewan. The development includes the mining of several uranium ore bodies and the construction and operation of an associated mill and tailings depository. The proposed tailings depository consists of tailings deposition into a mined out open pit, similar to the existing in-pit "pervious surround" method employed at Cameco's Rabbit Lake mine. However, due to the high grade of the Project's tailings, several modifications were made to the original design of the tailings facility and the tailings placement methodology. These modifications will provide the necessary radiation and environmental protection required for handling and placement of high grade tailings.

The modifications made to the "pervious surround" disposal concept include the deposition of tailings as a thickened (engineered) paste below a water cover and the incorporation of a unique groundwater pumping methodology which provides "hydrodynamic containment" of porewater expressed during consolidation. In addition these measures will ensure that tailings density is maximized and the hydraulic conductivity of the tailings mass is minimized by the end of operations. The provision of a water cover also eliminates consolidation problems associated with freezing. At the completion of milling activities, a soil cover will be placed above the tailings surface to consolidate the most recently deposited tailings and to provide a permanent barrier between the tailings and the terrestrial environment. At the time groundwater conditions are restored to pre-mining levels (flood back of the cone of depression), the tailings will be sufficiently consolidated, resulting in a low permeability tailings mass (ie. plug) contained within a higher permeability host rock. Contrasting permeability's will cause groundwater to flow around the tailings mass rather than through it, similar to that of the pervious surround system. The subaqueous thickened tails deposition will ensure that decommissioning activities can proceed shortly after tailings placement with a minimal release of heavy metals and radionuclides to the environment.

Introduction

The McClean Lake Project is located in northern Saskatchewan, approximately 750 km north of Saskatoon (Figure 1). The development includes the mining of several uranium ore bodies, and the construction and operation of an associated mill and tailings depository. In addition to milling McClean Lake project ores, ores from the nearby Midwest and Cigar Lake project sites are proposed for processing at McClean Lake in a joint effort between mining companies to reduce the number of mills and tailings facilities in Northern Saskatchewan. This was in part motivated by the fact that fewer mills and tailings depositories would result in fewer environmental impacts to the northern region of Saskatchewan.

Tailings management at McClean Lake is considered by Cogema to be a high priority in terms of environmental and radiation protection. To ensure optimum protection, the tailings handling and disposal methodology at the McClean Lake JEB Tailings Management Facility was designed to:

- limit the exposure of workers and the general public to radioactive wastes;
- minimize the leaching of radionuclides and heavy metals to the environment;
- ensure ease of operation and rapid decommissioning through design optimization; and
- limit or prevent the need for continued maintenance after closure.

The proposed tailings disposal concept utilizes the mined out JEB open pit as a tailings disposal facility, similar to the existing in-pit pervious surround system employed at Cameco's Rabbit Lake mine. Upon completion of mining, preparation of the pit for tailings will begin, consisting of the construction of a granular underdrain, horizontal drift and a vertical raise.

Initially, the Pervious Surround Method was selected and approved as the best suited tailings management system for the containment of McClean Lake and Midwest tailings (approved for the McClean Lake Project in 1993), however concerns remained in regards to the formation of ice lenses in the tailings mass and fugitive dust emission. In consideration of the high-grade Midwest and newly incorporated Cigar Lake tailings, there was also a concern of a net increase in radiation exposure which would require additional radiation protection measures for workers within the vicinity of the JEB tailings management facility. These concerns led to the modification of the approved JEB "Pervious Surround System", by changing it to a paste underwater tailings disposal facility, which is also based on the same long term containment and flow diversion concept.

By the newly proposed "paste underwater" method, the tailings will be deposited in a thickened paste form under a cover of water. The mode of tailings placement and the unique tailings management methodology will provide containment of expressed tailings porewater, while maximizing the density and minimizing the hydraulic conductivity of the tailings mass during the operational phase. The provision of a water cover above the tailings provides a shield against gamma radiation, prevents dust emissions and reduces radon emanation. In addition, the water cover eliminates consolidation problems associated with freezing by preventing the formation and accumulation of ice lenses. The thickened tailings provides more predicable and homogeneous tailings properties which prevents solids segregation which is common to traditional slurry deposition techniques. At the completion of milling activities, a soil cover will be placed above the tailings mass to assist in consolidation and provide permanent containment. Collection and treatment of tailings porewater will continue for a few years after cover placement.

Environmental Considerations Arising from Cigar Lake Mining Corporation's Testwork

Numerous studies were performed on behalf of the Cigar Lake Mining Corporation (CLMC), which led to the concept of "paste tailings underwater disposal", as well as to various environmental recommendations pertaining to the milling and tailings disposal process. In their studies, CLMC not only considered an "engineered storage facility" but went a step further and considered "engineered tailings", integrating design considerations into the milling process to enhance the operability and environmental aspects of tailings management.

In the tailings testwork, extensive efforts were devoted to determining the most effective techniques available to consolidate the tailings without adversely impacting worker exposure to radiation. Testing demonstrated that paste tailings could be created by a "deep thickener" which produced a product in the range of 38 to 48% solids. The paste tailings can be pumped to a tailings disposal facility and subaqueously deposited without mixing with the overlying water, similar to the underwater placement of concrete.

Paste Tailings at Cluff Lake Operations

Although subaqueous paste tailings disposal is a relatively new concept, paste tailings are already being produced at Cogema's Cluff Lake operations, since February 1995. Through this work, Cogema has demonstrated on an industrial scale the feasibility of preparing and pumping paste tailings.

Proposed Tailings Management System

The evaluation of the JEB pit tailings management facility as a subaqueous disposal system was based on the testwork conducted by the CLMC for Cigar Lake ores and on the testwork conducted by Cogema (SEPA) for the McClean Lake and Midwest ores.

Optimization of the performance of the proposed JEB tailings management facility was based upon:

- the subaqueous deposition of paste tailings;
- enhanced tailings consolidation due to the pumping of the tailings (consolidation) porewater from the underdrain, and;
- the incorporation of a soil/ waste rock cover to be placed above the tailings at decommissioning.

Tailings Characterization

The proposed paste tailings produced at the JEB mill will consist of water and fine solid particles at a solids content approaching 40%. The fine particles in the paste mixture are comprised of mine tailings or naturally-occurring clays, silts and fine sands. The mineralogy of these particles range from quartz and feldspars to clays, micas, salts and chemical precipitates. The fine and ultrafine particles will provide stability by preventing rapid settling and particle size segregation.

The paste mixtures are Bingham fluids whose apparent viscosity is not constant but decreases considerably with increasing shear rates. The paste tailings gradation is dominated by particles in the medium to very fine size fraction with only about 15% of the particles exceeding 0.2 mm in size. Consequently, paste flows in pipes can be assumed to remain basically homogenous. Practical experience from other programs has indicated that pastes can remain motionless in pipelines for several days and can then be remobilized without pipeline plugging occurring.

Preparation of the Pit

Following excavation and mining of the JEB orebody, the JEB pit will be prepared for use as a tailings management facility. The tailings management facility will include the installation of a drift and raise, and the placement of a basal underdrain consisting of blast rock and free draining granular filter material, as illustrated in Figure 2. The horizontal drift will be backfilled with sufficiently coarse rock and hydraulically connected to the drift. The collection of consolidation flows during operations and a few years immediately after operations will be collected from the raise. The pit will be maintained in a fully dewatered state prior to the placement of tailings.

Operational Sequence

Paste tailings will be deposited subaqueously under a water cover (up to 10 m in thickness) throughout the tailings placement phase of the JEB tailings management facility operations. The paste tailings will be pumped from the mill facility to a floating barge on the ponded water within the tailings management facility. Tailings will be subaqueously placed through a tremie pipe attached to a rotational placement boom assembly located on the barge (Figure 2). The tremie pipe will inject fresh tailings into previously deposited tailings at the tailings surface in the same manner in which concrete is placed under water. This application ensures that the tailings do not mix with ponded water during placement thus maintaining paste consistency, density and homogeneity.

Water Management

Water management is a key component in the operation of the tailings management facility. It includes the groundwater surrounding the pit, ponded water above the inpit tailings and porewater expressed from the tailings during consolidation. The control and management of water resources will be provided by integrated pumping from the perimeter dewatering wells, the underdrain drift and raise and from the pond. Groundwater inflows into the pit will be controlled primarily by the perimeter dewatering wells where hydraulic head will be maintained throughout tailings placement at a level approximately 2 m above ponded water level (to provide hydrodynamic containment). In addition, a downward vertical gradient will be maintained between the pond level and the water level in the underdrain sump which will ensure the collection of tailings porewater (resulting from consolidation) in the underdrain for subsequent treatment. Water levels (head) in the underdrain will be permitted to rise with ongoing tailings placement. The proposed containment philosophy will allow all groundwater to flow towards the underdrain where it is collected and subsequently treated. Collection and treatment of the underdrain water will minimize the operational impacts to the surrounding groundwater and downgradient receptors. The need for hydrodynamic containment will diminish when adequate consolidation is achieved near the end of operations. Figure 3 illustrates the proposed water management methodology for the JEB pit tailings management facility.

Water will be collected from the underdrain, perimeter wells and the pond via piping systems. Clean and contaminated (if any) water will be collected in independent pipelines from the perimeter dewatering wells and directed either directly to the treated effluent disposal area or to the water treatment plant. All water pumped from the pond and underdrain sump through operations will require treatment prior to discharge to the environment.

Tailings Consolidation

Immediately following placement, the tailings will undergo self-consolidation resulting from inherent selfweight. Since the tailings are produced in a paste form with a low moisture content, the time required for consolidation will be minimized. In addition, the water management strategy described above will excellerate the consolidation process, resulting in a high degree of consolidation by the end of operations. Consolidation will continue with ongoing tailings displacement and the placement of the final cover at closure.

Results from tailings consolidation analyses predict that the elevation of the final consolidated tailings mass will be within the in-pit bedrock, a few years following placement of the cover. The total quantity of tailings to be deposited, estimated at 3,000,000 tonnes and a total volume of 3.26 million m^3 results in an estimated average dry density of 910 kg/m^3 and a maximum dry density of 1080 kg/m^3 (at the base of the pit).

Decommissioning

At the completion of tailings placement, the ponded water within JEB pit will be pumped to the water treatment plant for treatment to meet the Metal Mining Liquid Effluent Regulations. A minimum depth of ponded water will be left above the tailings surface to provide radiation protection. A 3 m thick granular filter layer will be placed on top of the tailings surface to permit the collection of porewater expelled during the consolidation of the most recently deposited tailings due to both self weight and cover loading. Following placement of the filter and drainage layer, the pit will be backfilled with excavated drift and sandstone materials to an elevation slightly above ground surface.

A vertical raise will be installed through the backfilled material from ground surface down to the upper drainage layer. This will provide for the collection of consolidation flows which will originate in the most recently deposited tailings in the upper portion of the pit, largely due to the surcharge loading of the cover material. Concurrent pumping from the underdrain and upper drainage layer (at base of cover) will be continued until consolidation flows have been reduced to a level where long term impacts to the environment will be acceptable; this period is estimated to be up to 5 years following the placement of the cover. The surcharge loading will enhance the degree of consolidation of the tailings mass and result in a lower rate of contaminant release over the long term due to porewater expulsion.

Groundwater Flow and Contaminant Transport Simulations

Computer modelling was used to establish the groundwater flow regime and to determine the mass transport of contaminants from the tailings facility. Groundwater modelling was first used to identify the potential transport pathways to receptors and to estimate flowrates. Contaminant transport modelling then focused on determining, firstly, the total mass of contaminant leaving the JEB tailings management facility and, secondly, the concentration and total mass transport predicted to reach the primary receptors, Fox Lake and Pat Lake, through the groundwater pathway.

A detailed groundwater flow model was set up using MODFLOW[1] to simulate the groundwater flow from the proposed JEB tailings management facility. Particle tracking analysis was conducted using MODPATH to evaluate advective groundwater flow paths from the tailings management

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1 MODFLOW is a quasi-three dimensional finite difference simulation of groundwater flow within a porous media developed at U.S. Geological Survey.

facility. Long-term advective and diffusive contaminant transport from the decommissioned JEB tailings management facility, was then simulated using MT3D.[2]

The MODFLOW model utilized conservative assumptions with respect to the hydraulic conductivity of the drift and the continuity of fault zones between the pit and Fox and Pat Lakes. Figure 4 illustrates the geological strata and the material properties used in the MODFLOW analysis. The MT3D model used conservative and constant source terms assuming no source depletion for the duration of the simulations. In consideration of these conservative assumptions, long-term environmental loadings to surrounding surface water receptors are likely less than predicted herein by the mass transport simulations.

The particle tracking results (Figure 5) illustrate that the majority of groundwater flow that passes through the pit area is directed toward the east arm of nearby Fox Lake. In the long term post-decommissioning period, only a very small portion of groundwater flowing towards Fox Lake will have originated from within the tailings mass while most will have originated from outside of the tailings. This is due to the high in situ permeability of the Athabasca Sandstone and the relatively low permeability of the consolidated tailings. The relatively high in situ permeability of the altered sandstone ($1.8x10^{-6}$ m/s) in comparison to the consolidated tailings mass ($1x10^{-8}$ m/s to $3x10^{-7}$ m/s), will serve as a natural pervious surround diverting flows around the tailings mass while minimizing advective flow gradients through the tailings mass.

Transport analysis were undertaken for arsenic, radium-226 and sulphate. Other chemical constituents including uranium, cadmium, copper, lead, nickel, and zinc were not assessed due to low mean source concentrations relative to the Saskatchewan Surface Water Quality Objectives (SSWQO).

The transport simulations indicated that for the parameters modelled, the fully mixed concentrations in Fox Lake and Pat Lake (downstream of Fox Lake) would be well below the Saskatchewan

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2 MT3D is a computer model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater flow systems in either two or three dimensions. MT3D uses a mixed Eulerian-Lagrangian approach to the solution of the advective-dispersive-reactive equation.

Surface Water Quality Objectives (SEPS 1988) at concentrations of at least 200 times less for radium-226 and 60 times less for arsenic. The tailings depository is expected to have a negligible impact on the long-term water quality of downstream Collins Creek.

Conclusion

The proposed subaqueous paste tailings disposal system and associated operating methodology for the McClean Lake Project is well suited for the local hydrogeological conditions and the proposed tailings characteristics. Subaqueous disposal minimizes radiation exposure and dust emissions and eliminates consolidation problems associated with freezing. Paste thickening of the tailings and the tailings placement methodology will prevent solids segregation and promote homogeneity and isotropy within the tailings mass. Milling the ore to controlled specifications will produce "engineered" tailings which will allow the short and long term behaviour of the tailings to be predicted with a higher degree of accuracy and confidence than for tailings deposited by traditional slurried disposal methods. The use of engineered tailings, the use of subaqueous disposal techniques and the incorporation of the proper water management methodology will ensure that environmental protection and worker and public safety will be maintained. In addition, these principles will ensure more rapid decommissioning of the JEB tailings management facility at closure.

Acknowledgments

Clifton Associates Ltd. and Golder Associates were the primary consultants involved in the technical studies and assessment which support tailings management at McClean Lake.

References:

1. Saskatchewan Environment and Public Safety (SEPS), 1988. Saskatchewan Surface Water Quality Objectives. Water Quality Branch, WQ110.

Figures:

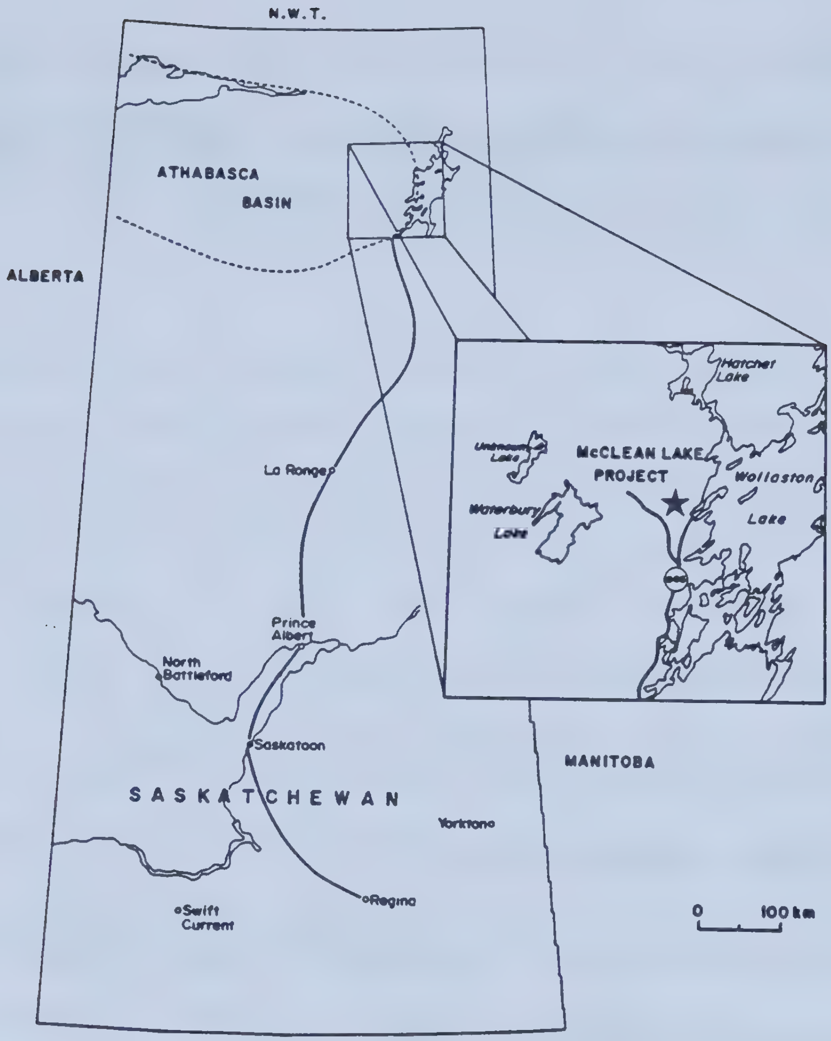

Figure 1 Location of the McClean Lake Project

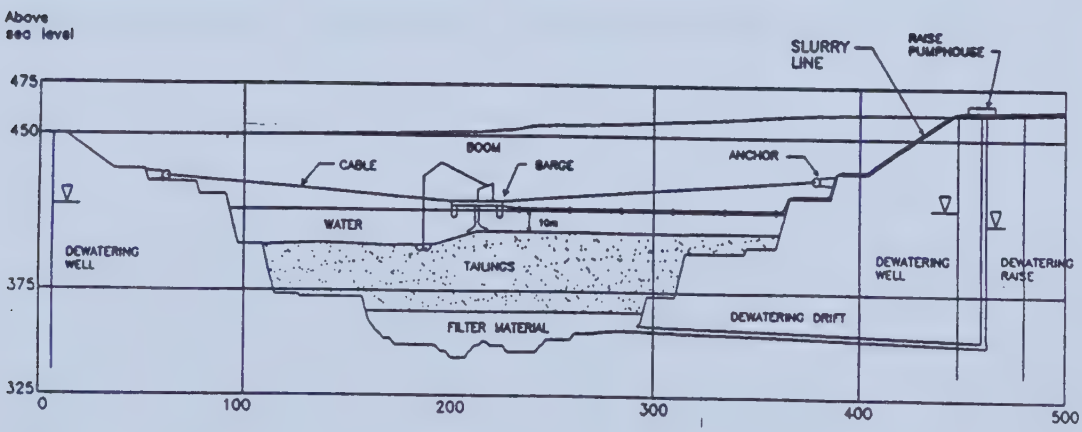

Figure 2 Cross-section of the JEB Tailings Management Facility

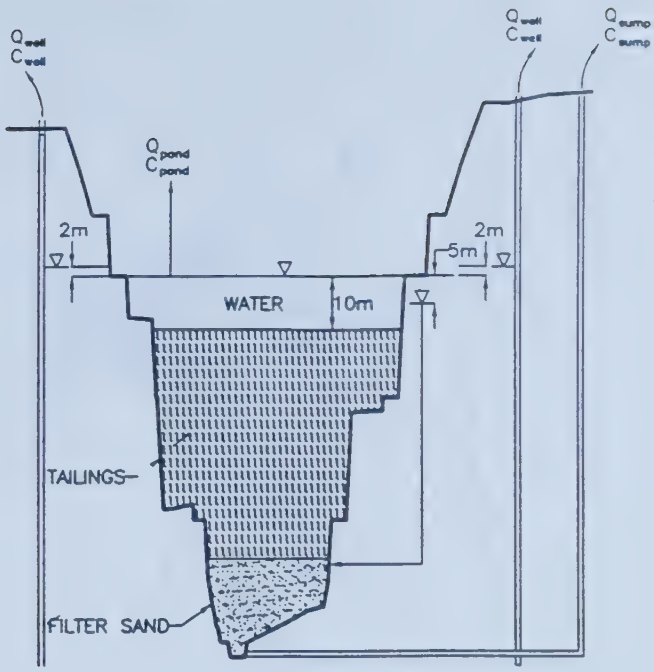

Figure 3 Water Management Strategy

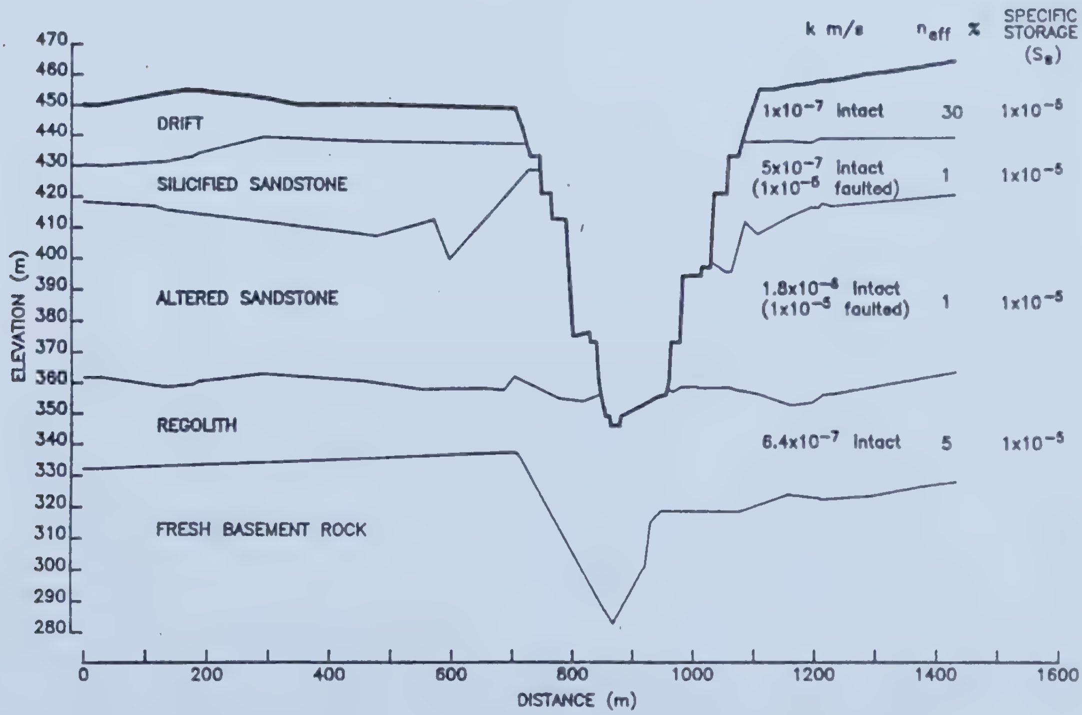

Figure 4 Local Stratigraphy including Material Properties used in the Analysis

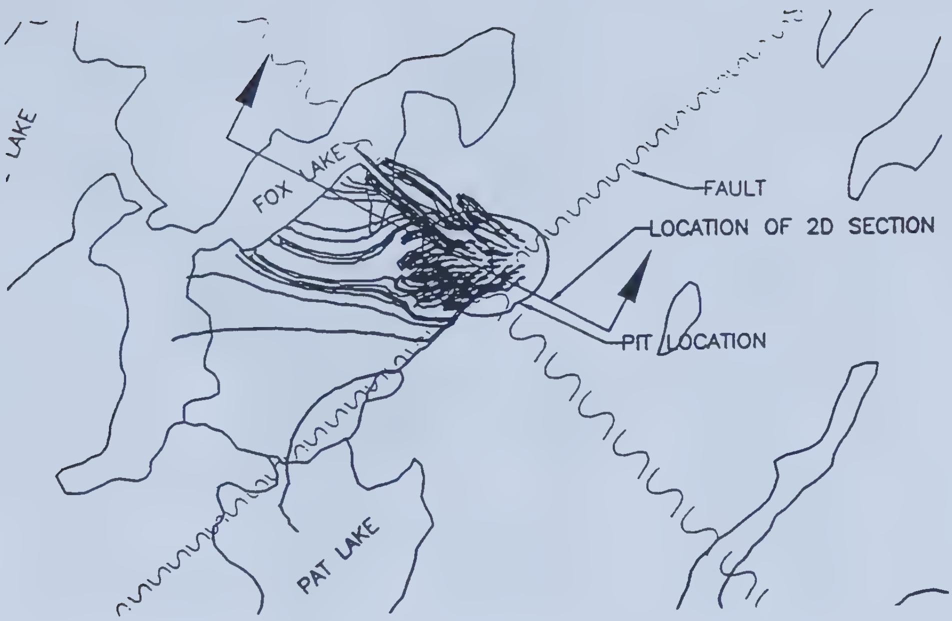

Figure 5 Contaminant Transport Pathways

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