A NEW APPROACH FOR DESIGNING, SAFE OPERATION AND DECOMMISSIONING OF HIGH GRADE URANIUM MILL FACILITIES

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ABSTRACT

COGEMA Resources Inc.'s operation at McClean Lake will consist of milling and processing ores from the richest uranium deposits in the world. These deposits, located in the Athabasca basin of northern Saskatchewan, Canada, include those of Cigar Lake, McClean Lake and Midwest Projects.

All the ores from these deposits will be processed at the McClean Lake JEB mill. The ore grades vary up to 30% uranium, and in some cases pure massive pitchblende is encountered.

The McClean Lake JEB mill, is designed with an initial capacity of 6 million lb. U_3O_8 annually. Following approval of the Cigar Lake Project by both governments, the capacity of the mill will be expanded to 24 million lb. U_3O_8.

Although the initial grade of ores to be processed at the JEB Mill (2% uranium to 4.75% uranium) are much less than those expected from Cigar Lake (up to 30% uranium), they are still high enough to warrant special radiation protection measures.

The philosophical tenet for the mill design includes health, safety and environment protection for the short and long term. Thus, the design ensures a maintenance free solution after decommissioning to protect future generations and the land.

To this end, the ore receiving facility for Cigar Lake and Midwest ores will be remotely operated to protect employees from gamma radiation.

The leaching area of the mill is based on a two-floor concept with an elevated concrete slab of about 40 cm separating the upper and lower floors. The vessels also have concrete cells around them and access is strictly restricted to protect personnel.

A dual ventilation system has been established in the mill with specific pressure gradients. With the single pass ventilation, a positive pressure will be maintained in the clean areas (control rooms) and a negative pressure will be kept in the potentially contaminated areas, from where the air will be exhausted to the atmosphere.

Due to the presence of radiation and other industrial hazards, the mill has been zoned according to different processes to reduce the risk of exposures and fire.

Once the Cigar Lake and Midwest ores are leached in their dedicated leaching circuits, the ore streams will be blended with the McClean Lake ores to control the slurry grades below 10% uranium, a more manageable level.

Upon processing of the ores to make the product yellowcake, the wastes will be managed. The tailings management scheme at McClean Lake has been designed principally to ensure maximum containment of contaminants in the long term by channeling clean ground water around the clay-like consolidated tailings, via the "path of least resistance". When

processing of Cigar Lake and Midwest ores commence, a paste tailings preparation step will be added to the mill to reformat the tailings into a paste like consistency. These paste tailings will be deposited sub-aqueously in the mined out JEB pit, at the McClean Lake facility. The paste tailings will be deposited underwater from a floating barge. The paste tailings system ensures long term containment of contaminants and allows for a quicker decommissioning.

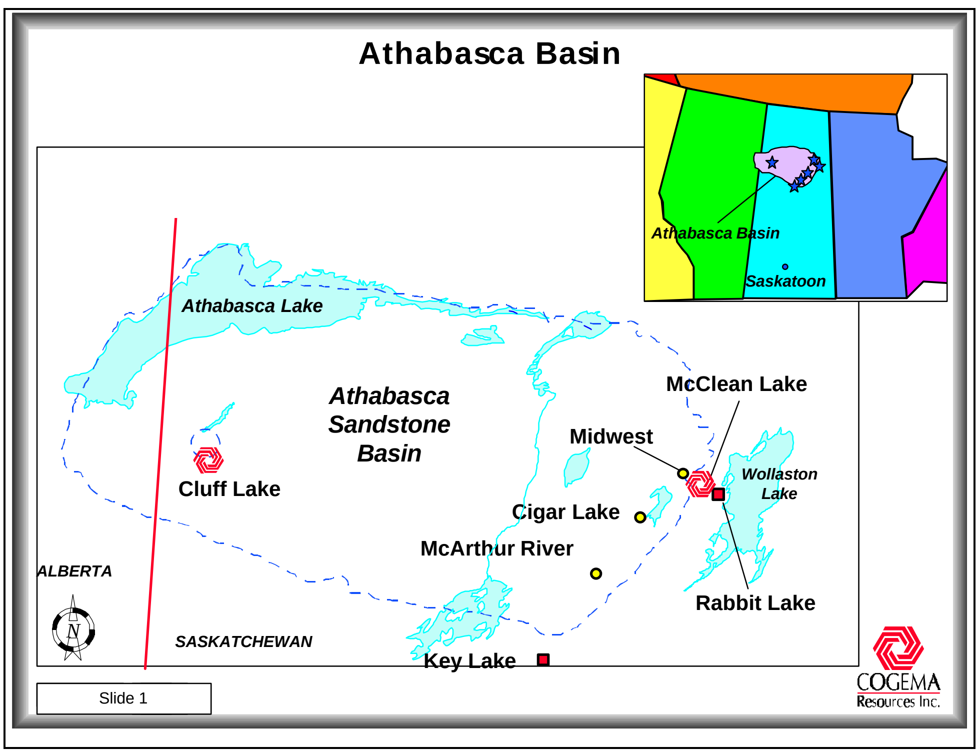
The advantage of the sub-aqueous system for tailings management ensures that personnel are shielded from gamma radiation. Also, there are no airborne dust emissions and radon emanation is significantly reduced due to the water cover.

The water cover also eliminates the exposure of the tailings to atmospheric oxygen and the potential for acidic drainage.

Financial assurance for decommissioning the McClean Lake facility is available to secure funds for the future. These funds have been posted under the auspices of both federal and provincial governments. It ensures that there will be no burden on the future generations and the environment is safe and well protected.

INTRODUCTION

The McClean Lake deposit is located in the Athabasca Basin in northern Saskatchewan, Canada where the highest grade uranium orebodies in the world are located *(Slide 1 - Athabasca Basin)*. These high grade orebodies typically include the Cigar Lake and McArthur River Projects and to a lesser extent, the McClean Lake and Midwest Projects. Consolidated reserves in this area exceed 1 billion lbs. U_30_8, with ore grades ranging from 2% uranium to almost 70% uranium.

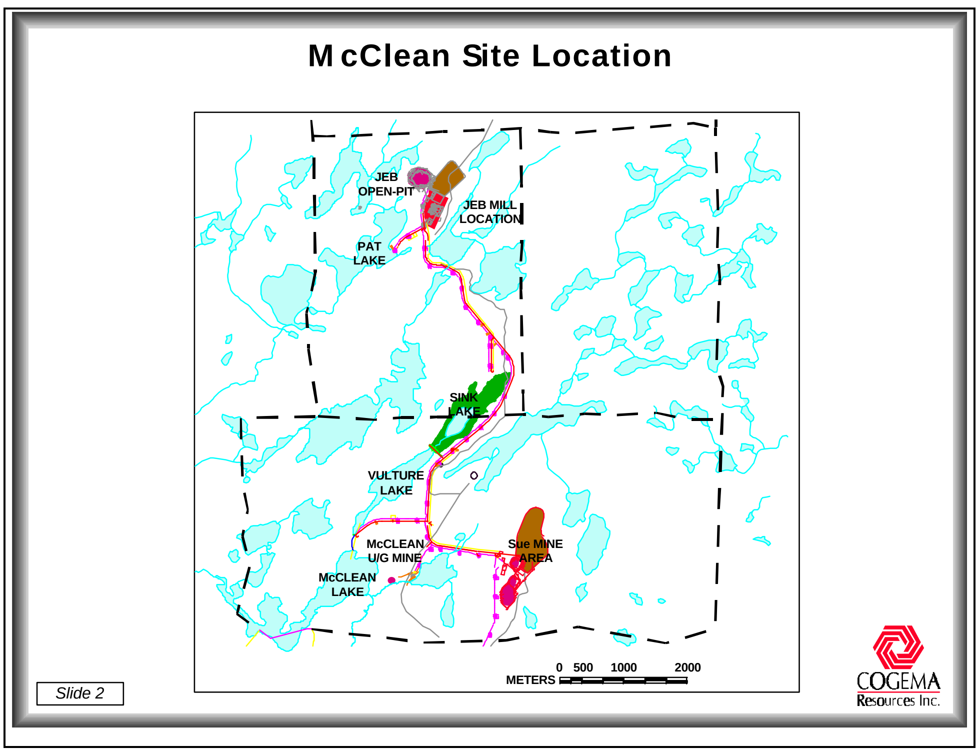


Because the Cigar Lake ores will be processed at the McClean Lake Mill when mining commences, the project design philosophy at McClean Lake took into account several issues including health, safety and environmental protection for the short and long term.

For example, the decommissioning scenario of the tailings management facility will provide a maintenance free solution in the long term to protect future generations and the land; the mill design and tailings management facility incorporate all the elements of radiation protection, risk management, environmental protection and safety.

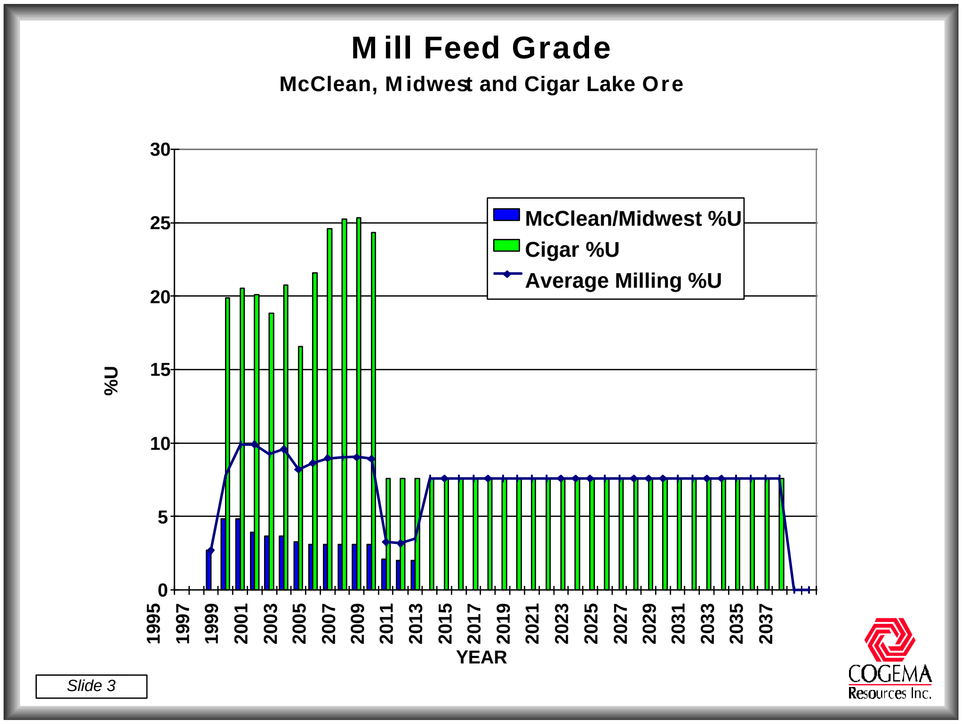
PROJECT OVERVIEW

The McClean Lake Project consists of four open pits and one underground mine namely; the JEB open pit, Sue A, B and C open pits and the McClean underground *(Slide 2 - McClean Site Location)*. The mill, the construction of which is almost completed, is designed with an annual capacity of 6 million pounds U_30_8 to process the McClean Lake and Midwest projects ores. Processing of these ores will maintain the life of the project for about 14 years. When mining of Cigar Lake ore commences, the McClean Lake mill (renamed the JEB Mill) will be expanded to a capacity of 24 million pounds U_30_8 a year.



Mill feed grades from the McClean / Midwest Projects would range from 2% uranium to 4.75% uranium *(Slide 3 - Mill Feed Grade)*. The grade from Cigar Lake will vary up to a maximum of 30% uranium during the first decade of production. Although the grades from McClean / Midwest are lower than those expected from Cigar Lake, they are high enough to warrant special radiation protection measures.

The concepts of shielding and containment of contaminants have been incorporated in the innovative methods of mining, milling and tailings management *(Slide 4 - Radiation Protection Concept for High Grade U Deposits)*. In the mine, workers will be shielded from high radiation areas by the natural innocuous basement rock; in the mill, engineered structures and suitable design methods will shield and protect workers from radiation and in the tailings impoundment area, a water cover will shield and protect workers from radiation and dust.



MCCLEAN LAKE MILL DESIGN

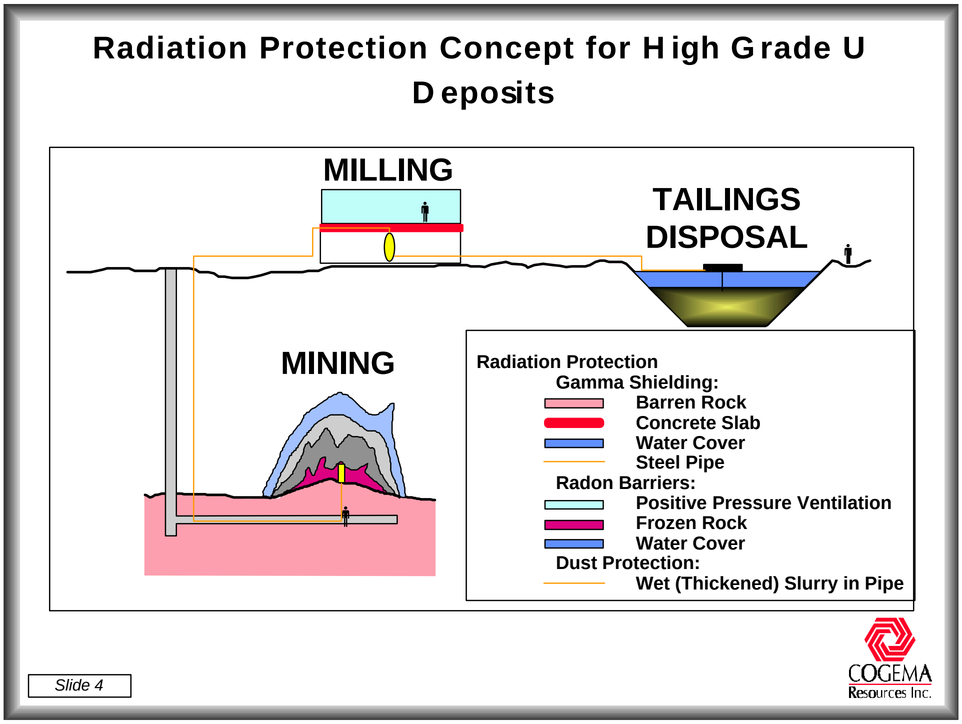
The mill design considered the chemistry, the mineralogy and the radioactivity of the ores to be processed. Although a conventional milling process is appropriate for processing most of the ores at McClean Lake, the most significant difference for reflection in the design principle is the uranium grade of the ores, especially Cigar Lake's.

The milling process is largely conventional and includes an ore receiving circuit, an atmospheric and pressure leaching circuit, stripping and purification, solvent extraction, precipitation, bulk neutralization and packaging and drying.

ORE RECEIVING

The Cigar Lake and Midwest ores will be shipped to McClean Lake as a high density slurry with a high solids content by weight. The slurry will be shipped in steel containers on B train trucks to the McClean Lake ore receiving facility. The full container will be picked up by remote equipment and its contents will be emptied into a dilution sump. The empty container will be washed prior to shipment back to Cigar Lake or Midwest. This measure is designed to prevent the spread of contamination in the facility and on the roadways.

The contents of the dilution sump will be pumped to a re-pulp tank and into storage pachucas ready for leaching.



LEACHING CIRCUIT

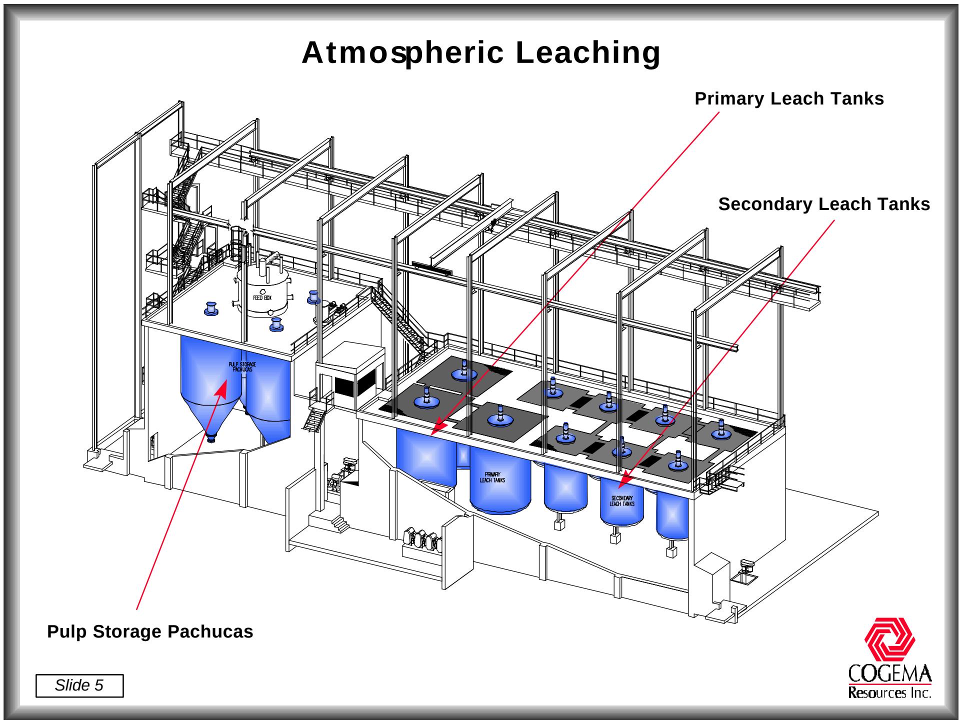
Due to the high grade of the Cigar Lake ore and the high arsenic and nickel content of the Midwest, Sue A and Sue B ores, these ores will be leached in pressure leaching circuits using steam, oxygen and sulphuric acid as a lixiviant.

The design used in the leaching circuit area is called the "elevated shielding slab concept" (*Slide 5 - Atmospheric Leaching*) and is based on a two floor design aimed at protecting operating personnel from significant gamma emitting sources.

The two floors are separated by an elevated concrete slab of approximately 30 - 40 cms thick. The thickness of the slab has been calculated to provide the right amount of shielding from the high grade ores being processed. All the operating switches, valves, energizing equipment etc. are located on the upper floor above

the slab. Operating personnel will also be located on the second floor, separated from the process and further shielded from potential gamma radiation by the concrete floor.

On the lower level, radioactive process tanks are contained within individual cells to control contamination and to reduce the number of sources of gamma radiation exposure in any one area. These cells are constructed of a combination of steel, concrete and lead where required. Each cell is provided with sumps, appropriate sloping floors and floor surfaces, for ease of clean-up should there be a spill. Sump pumps and process pumps are located outside the concrete cells, which house the tanks where significant gamma emitters are expected. All these measures are designed to protect operators and maintenance personnel from gamma emitting sources. Access to the interior of these cells is strictly limited.



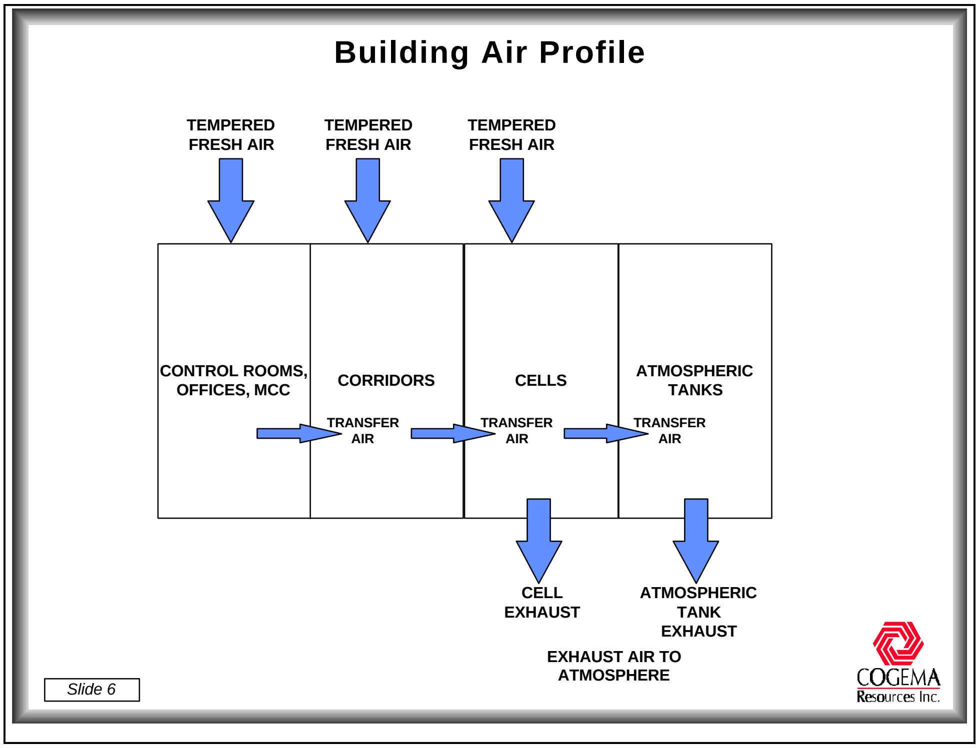
BUILDING AIR DESIGN

For the purposes of ventilation and radiation protection, the mill is divided into three areas *(Slide 6 - Building Air Profile)*:

- Clean areas that require no special radiation protection measures such as Control rooms.
- Low radiation areas that require capture of radon and radon progeny, uranium bearing dust and/or aerosols, but do not contain significant gamma radiation sources, such as, purification and precipitation circuit, solvent extraction and stripping, and packaging and drying.
- High radiation areas such as slurry receiving, storage vessels and leaching circuits that receive and process high grade ores.

A dual ventilation system has been designed with positive pressure gradients from the “clean” areas to the potentially contaminated areas of the mill. The two speed ventilation rates will control and exhaust, not only radon and radon progeny, but also chemical fumes and steam. The single pass ventilation system will provide fresh outside air to replace the air exhausted from the building and the process circuits. The single pass ventilation ensures that workers will always breathe fresh air while potentially contaminated air is exhausted to the outside.

In addition to the ventilation system, area exhaust fans are mounted on the roof to exhaust any radon and radon progeny that may accumulate in the cells where the vessels are located. Process tanks are exhausted to the outdoors and maintained at a lower pressure than the ambient air in the cells to prevent radon leakage. In each cell, the process vessels and equipment are equipped with ventilation hoods and exhaust fans to control airborne releases.



In case of an upset condition, the dual speed ventilation fans can be adjusted to increase the extraction ventilation capability and control the rate of airborne radiation. In the event of an exhaust fan failure, the positive pressure produced by the general ventilation system is sufficient to maintain a reduced airflow in the proper direction through the cell openings and the process ventilation system.

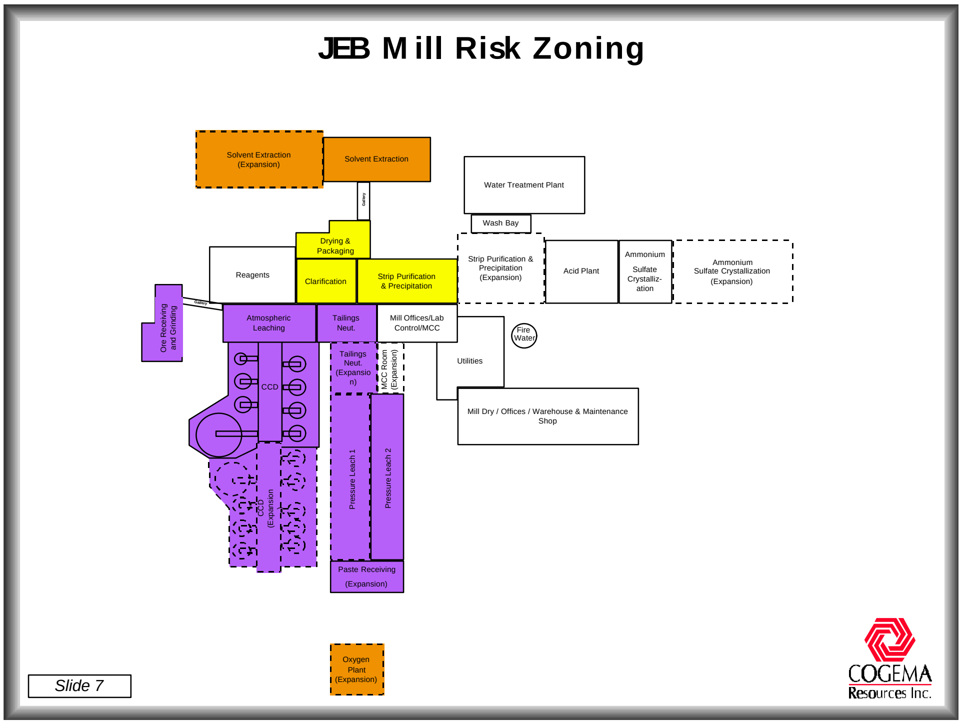
MILL RISK MANAGEMENT

In addition to the control of radiation, the mill has been zoned according to the different unit operations to control other industrial hazards *(Slide 7 - JEB Mill Risk Zoning)*. Areas where high gamma radiation, radon and radon progeny are potential hazards have been grouped together. Areas where there is a risk of fire or danger of ingesting uranium have also been located differently. Areas representing more conventional industrial hazards, such as chemical irritants, caustic or acidic chemicals are sited around the periphery of the facilities.

WASTE MANAGEMENT SYSTEM

Tailings Neutralization & Effluent Treatment

The waste neutralization circuit will combine the various waste streams (from counter current decantation (CCD) underflow, raffinate, process water, waters from the water treatment plant, solvent extraction, acid plant, crystallization circuit and the molybdenum eluate) neutralize and treat them before any release to the environment. Bulk neutralization was selected as the preferred process the tailings. Bulk neutralization will entail the addition of ferric sulphate in the neutralization circuit to optimize the absorption of arsenic onto ferric oxides followed by the addition of barium chloride to remove radium 226 from solution. This combination of treatment methods will ensure that the long term arsenic concentration in the pore waters will be approximately 1 mg/L and the radium 226 source terms will be approximately 5 Bq/L for the combined McClean Lake, Midwest and Cigar Lake tailings. Primary treatment of the liquid effluent will occur immediately after neutralization followed by solid / liquid separation which will remove the majority of residual contaminants. Secondary treatment is then required for the final polishing prior to recycling to the process or release to the environment.

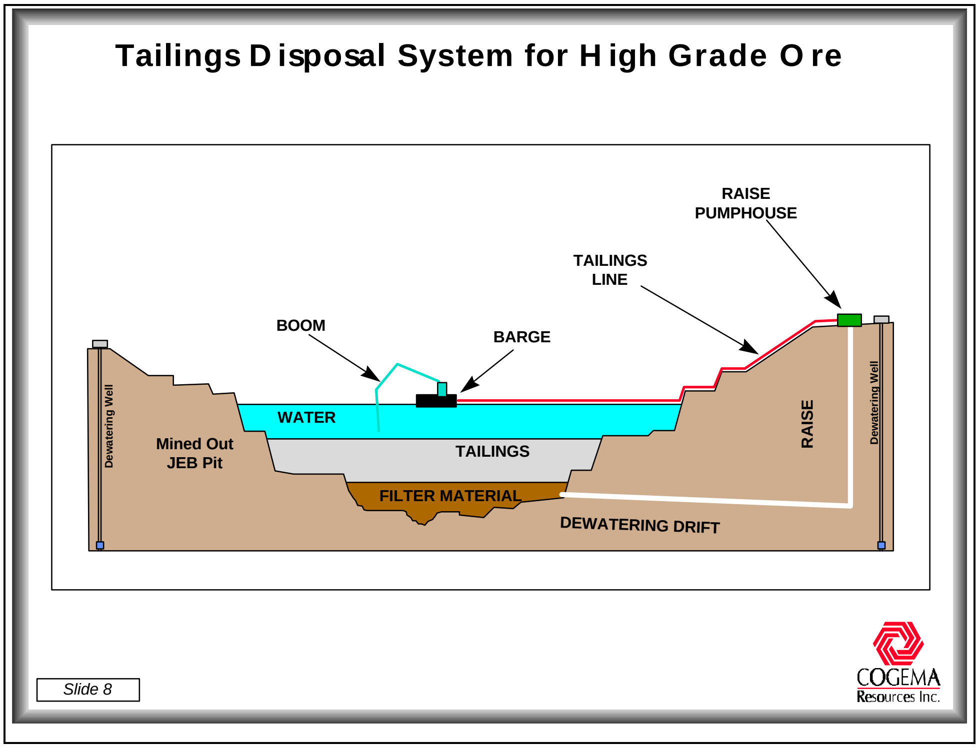


Tailings Preparation

Tailings from the Midwest and Cigar Lake ores require special management due to the potentially high pore water radium levels, arsenic, gamma fields and radon emanation rates from the tailings surface. The design of the tailings preparation process therefore included a two stage thickening process in which treated solutions will be mixed with the tailings being neutralized and reformatted to paste tailings. The advantage of the subaqueous paste tailings system is that the water cover ensures that personnel are shielded from gamma radiation. There are no airborne dust emissions and radon emanation is significantly reduced due to the shielding effect of the water cover.

Tailings Disposal

The JEB tailings management facility will combine an engineered tailings from three uranium projects into a single facility. The subaqeous tailings management system operates on the principle of providing a permeability contrast between the tailings and the surround, to ensure long term containment of contaminants when operations cease (*Slide 8 - Tailings Disposal System for High Grade Ore*). The tailings management system design consists of a dewatering drift or raise connected to a pump chamber. In addition, an underdrain system consisting of gradated drainage filter comprising of layers of drainage rock, filter gravel and sand will be placed at the base of the JEB pit. Tailings will be delivered to the JEB tailings management facility as a paste and will be placed subaqeously from a barge to minimize segregation of the tailings, eliminate concerns of freezing and dusting and to control radiation and radon emanation from the pond.



The "paste tailings subaqueous" system works by virtue of the contrast in permeability provided by the site specific higher permeability country rock around the JEB open pit and the consolidated tailings. During the mining of the JEB ore, perimeter dewatering wells were installed around the periphery of the JEB pit to maintain the pit in a dewatered state. These wells will be used to intercept clean ground water inflow to the JEB tailings management facility, by maintaining the surrounding acquifer at a slightly higher level than the tailings pond level to ensure consistent hydrodynamic containment throughout tailings placement. A differential head will also be maintained between the pond level and the water level in the underdrain sump to promote the consolidation of the tailings and enable consolidation waters (pore waters) to be collected and either recycled to the mill or treated in the water treatment plant to releasable water quality specifications. The permeability contrast also ensures maximum containment of contaminants in the long term by channeling clean ground water around the clay-like consolidated tailings, via the path of least resistance.

One of the key aspects of subaqueous paste tailings disposal is the reduction in contaminated water volume that requires treatment and hence guarantees less chemical loading to the environment. The tailings management facility and its associated systems are designed to be highly flexible and have adequate redundancy and over capacity to respond to a variety of operating conditions which may be imposed.

MONITORING

A monitoring program has been developed to provide data for operational control and to measure the long term geochemical/geotechnical performance of the tailings management facility against predictions. Short term data will be obtained from instrumentation installed during construction.

Operational control data will be collected from water level measurements from perimeter wells, tailings pond and raise water system, Eh probes for changes in water chemistry and piezometric head data from the network of piezometers located around the site. Long term monitoring will comprise of in-situ pore water samples for chemical analysis and consolidation measurements.

DECOMMISSIONING

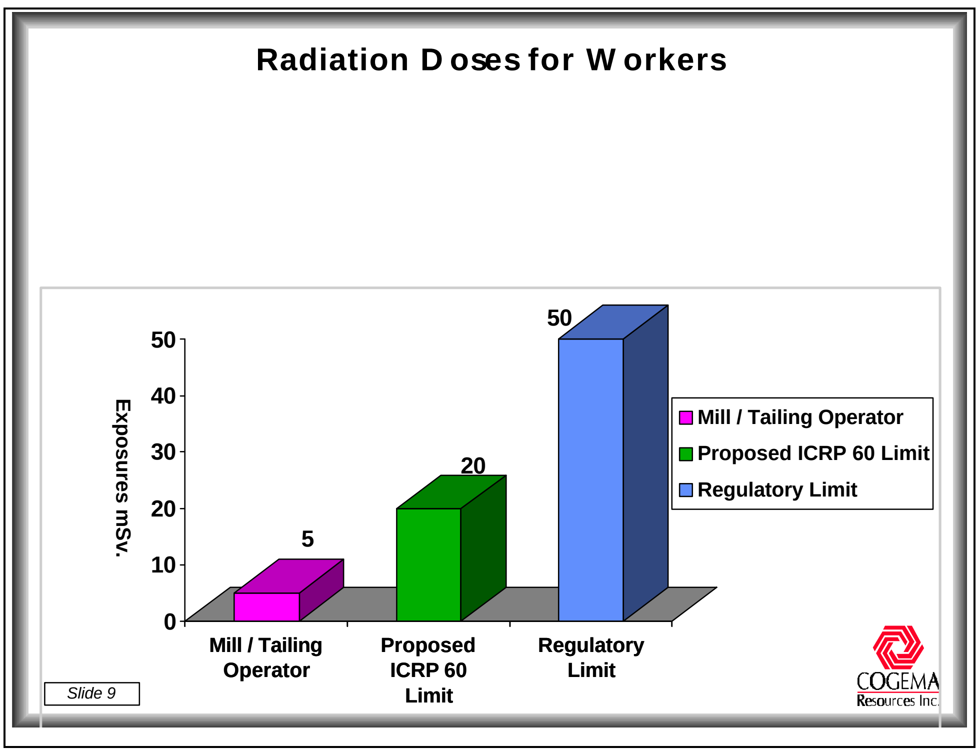
At decommissioning, the tailings are expected to consolidate to a maximum. Pumping from the perimeter and raise wells and treatment of contaminated water will continue until the tailings are consolidated. At that time, the wells will be shut down and a cover placed on the tailings. Final decommissioning will consist of back filling the pit completely with waste rock and overburden which will consolidate the tailings further and provide proper shielding to recreate pre-development conditions. Re-vegetation will then be implemented.

Long term monitoring will confirm that the tailings disposal is functioning according to design and predictions.

A financial assurance for decommissioning has been posted to both governments to cover the projected costs of decommissioning the facility. This initiative has been taken to ensure that there will be no burden on future generations as a result of the company's activities and the environment and the people will be safe and well protected.

RADIOLOGICAL and ENVIRONMENTAL IMPACT

Radiological studies based on time study calculations were conducted for the most exposed group of workers, the mill/tailings operators *(Slide 9 - Radiation Doses for Workers)*. These workers will receive radiation exposures of about 5mSv/year on average. This includes both gamma radiation and radon progeny exposures, assuming 1WLM is equivalent to 5mSv.



Potential radiological exposures to critical hypothetical receptors in the vicinity of the McClean Lake Project were estimated for the operating and decommissioned phases *(Slide 10 - Radiation Exposures to Hypothetical Receptors at McClean Lake)*. These receptors were assumed to receive part of their subsistence from the project area. The results indicate that the most exposed receptor will receive maximum radiation exposures of 307µSv/year, which is about 10% of natural background radiation, during the operating phase and 3.6μSv/year (about 0.1% of natural background radiation) during the decommissioned phase.

Radiation Exposures to Hypothetical Receptors at McClean Lake

	% of Background	Natural Background Radiation
Operating Phase:		
Maximum	**10**	**3000 μSv/yr**
Decommissioned Phase:		
Maximum	**0.1**	**3000 μSv/yr**

Slide 10

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The McClean Lake project has the potential to affect both surface and groundwaters by discharge of treated effluent from the mill facility and seepage from the disposal of tailings. However, the concern for surface water impact is significantly reduced by virtue of a three stage water treatment system which treats the waters to remove radionuclides and heavy metals prior to release to the environment. Monitoring programs have been designed to ensure that the effluent meets all applicable government regulations and licenses prior to discharge.

Similarly, potential groundwater contamination is highly unlikely during the operating phase since hydrodynamic containment will be maintained at all times.

Atmospheric radon concentrations have been estimated to determine the potential risks to members of the public during the operating and post-operating phases of the project. In both instances, the incremental radon concentrations decrease rapidly with distance falling below 1Bq/m^3 beyond the McClean Lake property. In comparison, the background radon levels range between 10Bq/m^3 and 30Bq/m^3, based on pre-operational monitoring data.

CONCLUSION

Technological innovations and engineering design have made it feasible for high grade uranium deposits such as Midwest and Cigar Lake to be mined and their ores processed in a safe and environmentally friendly manner. At the McClean Lake site, high grade uranium ores will be processed in the mill, without dilution with low grade or waste rock materials. All this is being achieved without sacrificing the high standards with respect to radiological and environmental goals. The proposed tailings management facility represents the state of the art in the industry for engineered tailings, deposition techniques and control of releases of contaminants.

This project has been designed in such a way that the risks are reduced and the impacts are minimal in the long term.

REFERENCES

COGEMA Resources Inc., McClean Lake Project, Environmental Impact Statement (EIS), 1991.

COGEMA Resources Inc., Midwest Project, Environmental Impact Statement (EIS), 1995 and 1996.

COGEMA Resources Inc., McClean Lake Project, JEB Tailings Management Facility, 1997.