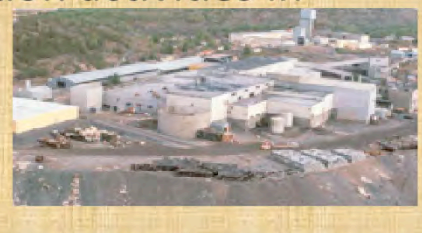
Surface Water Contamination from Saskatchewan's Decommissioned Beaverlodge Uranium Mine and Observations On Current Uranium Mine Operations

By Peter Prebble and Ann Coxworth

January 8, 2014 EMTF

Ottawa establishes its authority in the uranium mining field and opens the Beaverlodge mine.

- With onset of World War 2, the Canadian Government created Eldorado Mining and Refining to control all uranium exploration activities in Canada.



- Eldorado opened Beaverlodge uranium mine just east of Uranium City in 1952 **to supply the U.S. with uranium for its atomic weapons program.**

Uranium City was a community established in the early 1950s to facilitate the mining of uranium.

By 1956 Uranium City was Saskatchewan's fastest growing community.

Uranium supplied the essential raw material for the construction of thousands of atomic bombs.

Main Street of Uranium City in the very early 1950's

Photo: **Volkmar Wentzel**

Source: National Geographic Society, Stephen Bulger Gallery http://www.bulgergallery.com/dynamic/fr_artwork_display.asp?ArtworkID=3861y

http://www.bulgergallery.com/dynamic/fr_artwork_display.asp?ArtworkID=3861
Photo taken in 1950

The Beaverlodge mine operated until 1982, while other mines closed

When the U.S. signaled that it had enough uranium for its weapons program, many of the other mines (e.g. Gunnar and Lorado) around Uranium City ceased to operate.

However Eldorado Nuclear ran the Beaverlodge mine until 1982.

Following Eldorado's mine closure in 1982, most families left Uranium City. Today, the population is about 90 people.

Photo source: Encyclopedia of Saskatchewan, 2005 Photo taken in 2003 by Doug Chisholm

De-commissioning under AECB

- After 1982 closure, preliminary de-commissioning took place to meet standards of the day, completed 1985;
- “Eldorado and AECB concluded that all that could and should reasonably be done had been done”;
- However, in reality the region was still heavily contaminated.

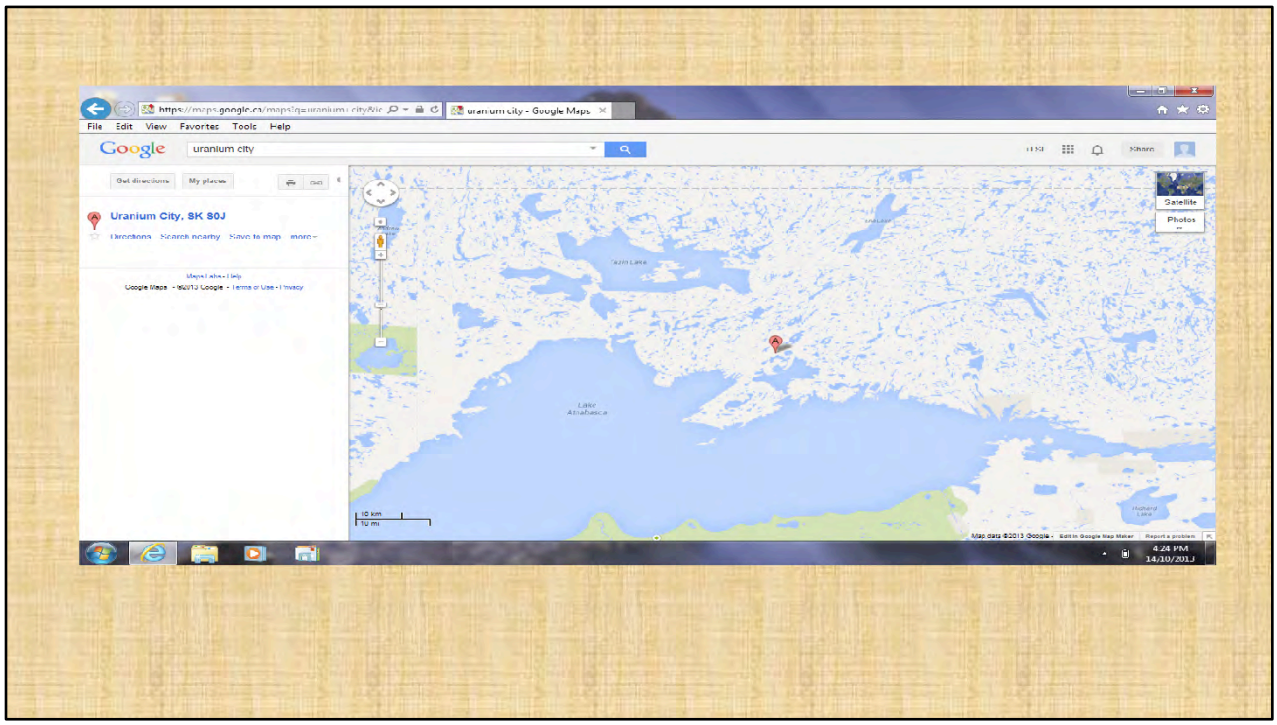
Creation of Cameco

- Cameco established in 1988 from merger of Eldorado Nuclear (federal) and Saskatchewan Mining Development Corporation (provincial).
- Meanwhile, a federal crown entity, Canada Eldor Inc., was set up to honour financial obligations linked to Eldorado's Nuclear former operations (eg: Beaverlodge mine).

Recent history

- 1988 Canada Eldor contracted Cameco to manage Beaverlodge site;
- AECB transitioned into the Canadian Nuclear Safety Commission and in 2005 issued an initial licence for the decommissioned Beaverlodge mine; renewed it for 3 years in 2010;
- Cameco has carried out many studies and done some preliminary remediation.

- SES reviewed Cameco's plans for the next 10 years and participated in April 2013 hearings for 10 yr. licence renewal;
- Plan includes intention to pass responsibility to Province during licence period;
- 10 year licence renewal approved May 2013.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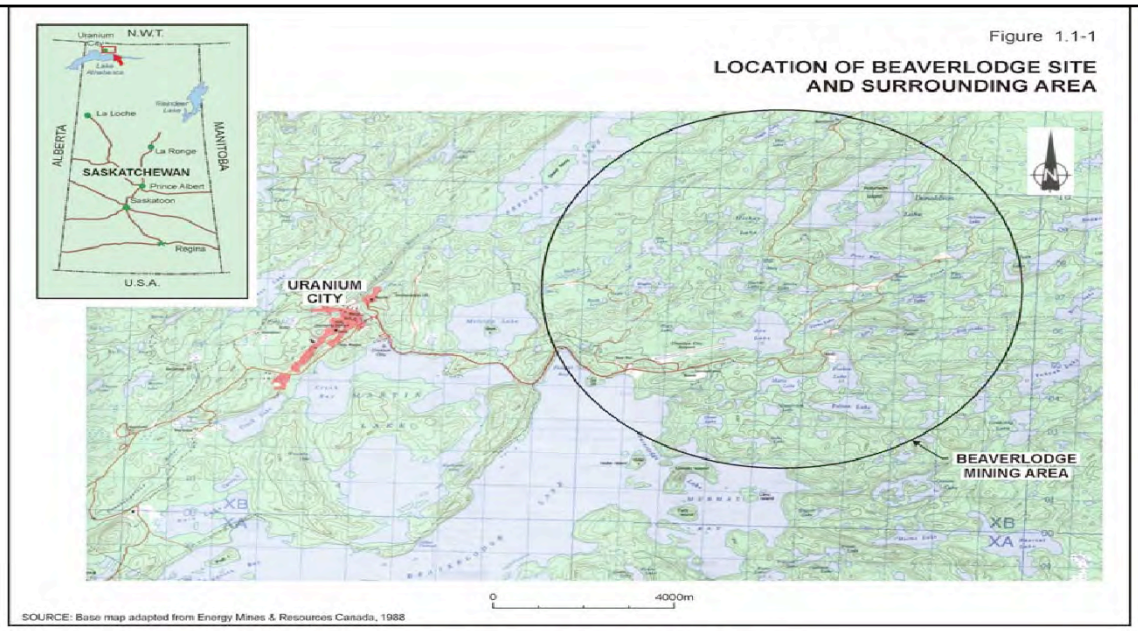
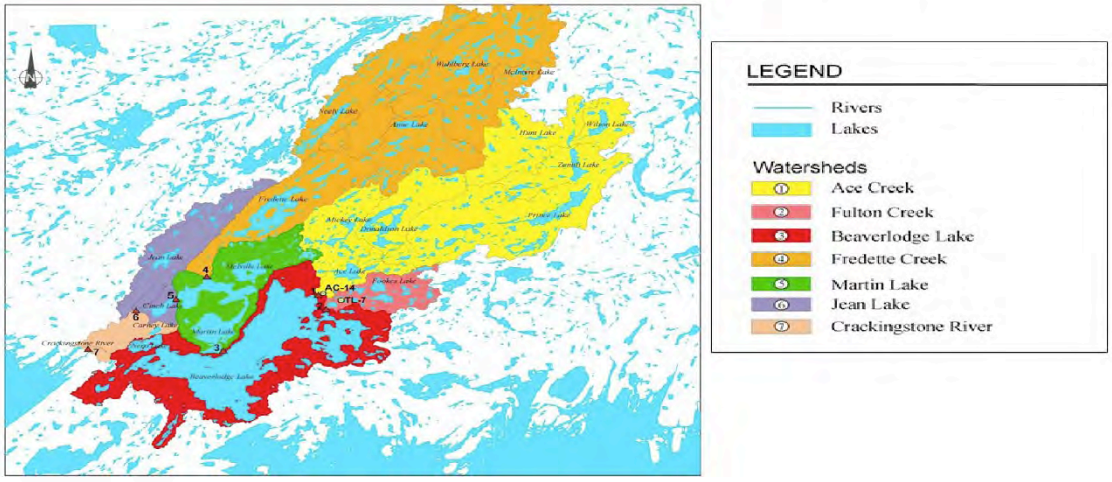


Source: FIGURE 1.1 – Location of Uranium City and the former Beaverlodge Mining Area, in:
CNSC Staff Submission on the Decommissioned Beaverlodge Mine and Mill Site – License Renewal, February 1, 2013
(image supplied to CNSC courtesy of Cameco Corporation)

Enlarged version of map
Source: FIGURE 1.1 – Location of Uranium City and the former Beaverlodge Mining Area, in: CNSC Staff Submission on the Decommissioned Beaverlodge Mine and Mill Site – License Renewal, February 1, 2013
(image courtesy of Cameco Corporation)

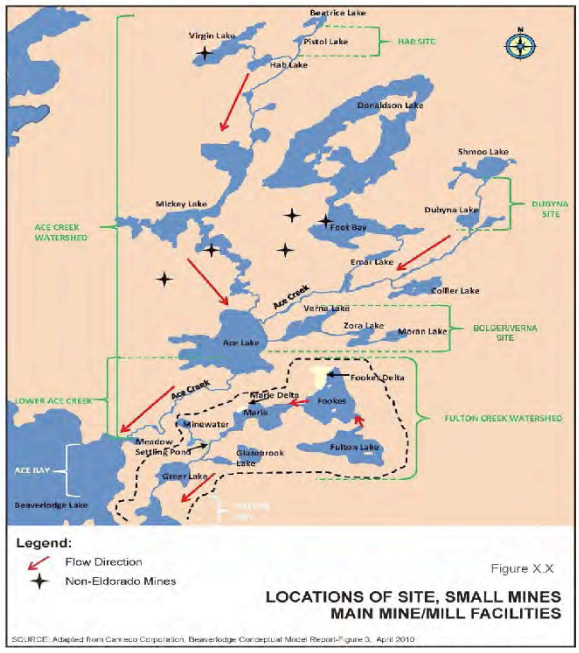
Eldorado Nuclear's Beaverlodge Operations have contaminated 5 northern Saskatchewan watersheds: Ace Creek, Fulton Creek, Beaverlodge Lake, Martin Lake and the Crackingstone River.



Clarify that Eldorado's mining operations were primarily in Ace Creek watershed, that the tailings management area was in Fulton Creek watershed, and that the untreated mine effluent contaminated Beaverlodge Lake and downstream waters. Ultimately waters flow from Martin Lake into Cinch Lake and then into the Crackingstone River. Only when the Crackingstone River flows into Lake Athabasca (dilution effect) are Saskatchewan Surface Water Quality Objectives met.

Sources/Nature of the contamination

- Flowing mine water, boreholes
- Waste rock
- Milling tailings on surface
- Tailings under water
- Sediment
- Downstream problems, esp. Beaverlodge Lake
- Of major concern- U, Ra, Se



Source for map: CNSC Staff Submission, as per earlier slide (ibid) Figure 1.2 Map of Beaverlodge Area (courtesy of Cameco Corporation)

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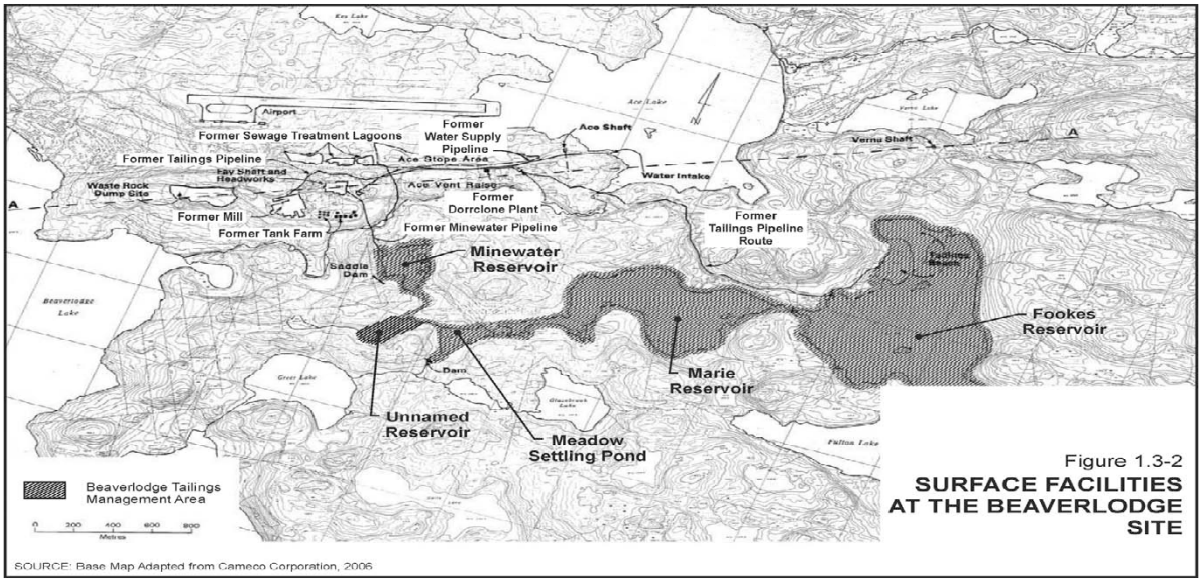


Figure 1.3-2
SURFACE FACILITIES AT THE BEAVERLODGE SITE

SOURCE: Base Map Adapted from Cameco Corporation, 2006

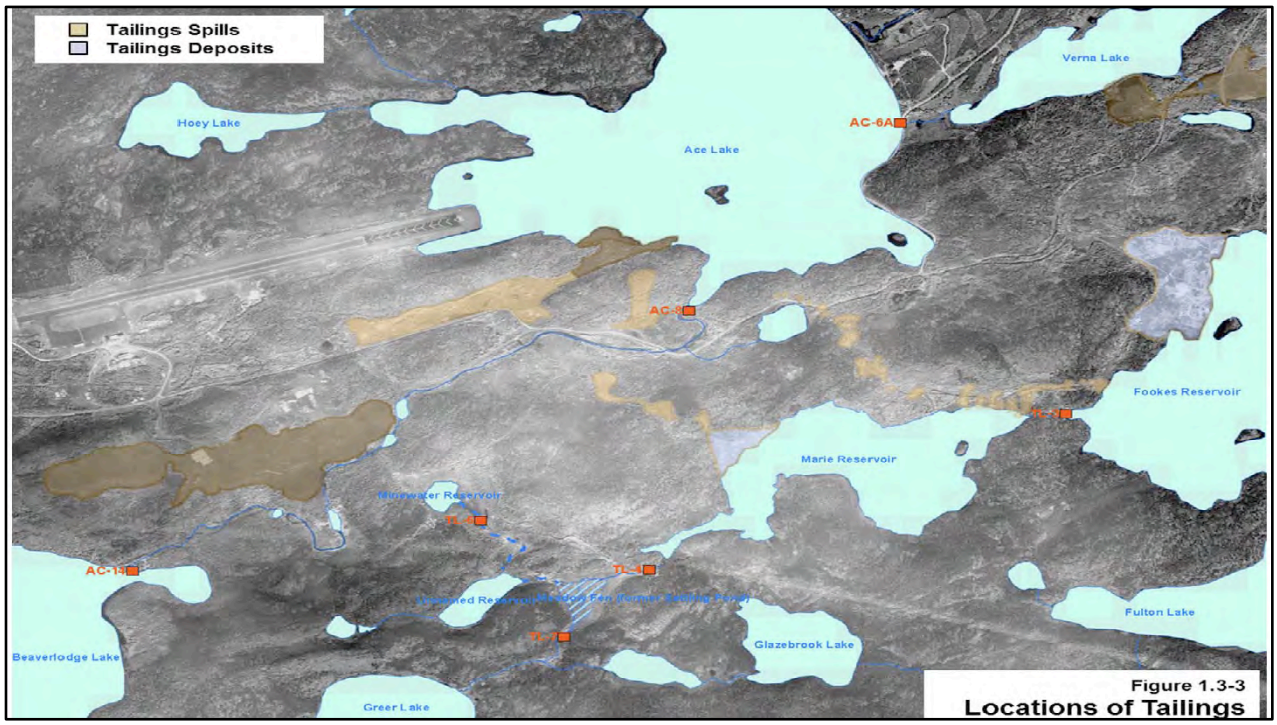


Figure 1.3-3
Locations of Tailings

Downstream contamination is most severe in Beaverlodge Lake (57 square km) For example, uranium levels in the lake are 8 to 9 times higher than Saskatchewan Surface Water Quality Objectives.

Cameco proposes only modest further decontamination, arguing that a full site cleanup would make little difference to the quality of surface water in Beaverlodge Lake.

Cameco proposes 5 actions including:

(a)divert Zora Creek around the Bolger waste rock pile

(b)plug flowing and non-flowing boreholes at old mine sites to prevent potential groundwater outflow;

Three other planned Cameco actions by Cameco

(c) perform a gamma survey of waste rock and tailings areas and cover easily accessible areas that have elevated gamma fields;

(d) continue monitoring water quality throughout the Beaverlodge area;

(e) develop a regional long-term monitoring program – especially for Beaverlodge Lake.

There are other sources of contamination to Beaverlodge Lake. The most notable is the abandoned Lorado uranium mill, which operated on the west side of the lake.

Lorado processed uranium ore from 1957-1960, dumping tailings into a small water body known as Nero Lake & leaving 14 hectares of fully exposed tailings onshore. Saskatchewan Research Council has begun remediation, using funds paid to the Saskatchewan government by Encana.

The Lorado Mill is adjacent to Hanson Bay of Beaverlodge Lake. In addition to Gunnar and Lorado, SRC is remediating 36 small satellite mine sites near Beaverlodge Lake. (Source: Project Cleans Fact Sheet) Encana, the most recent owner, paid the SK government over $23 million to cover remediation costs. (Source: Conversation with Dianne Allen of SRC)

Beaverlodge remediation plans bear little relationship to current Mine Decommissioning Guidelines

Saskatchewan Guidelines for Northern Mine Decommissioning and Reclamation state that areas disturbed by mining operations "should be reclaimed to an ecological (physical and biological) condition that will be similar to what was observed in the area prior to disturbance".

Remediation plans vs Provincial Decommissioning Guidelines (continued)

The Guidelines also state:

a) "Lake shorelines and river banks should be reclaimed to their pre-disturbed condition". "Surface water quality should be within the natural range of variation for the area."

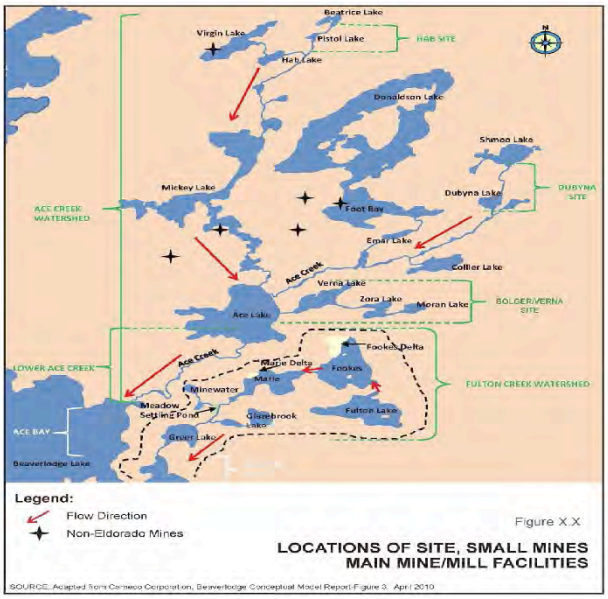
b) Regarding tailings: The potential for contaminants to "migrate from impacted areas within the project sites to ecosystems outside of the project area ….should be minimized through site specific mitigation measures…"

Current Exceedances of Saskatchewan Surface Water Quality Objectives For Protection of Aquatic Life (SSWQO)

Pistol Lake-Hab Lake confluence:
9 times SSWQO
for Uranium

Dubyna Lake discharge:
16 times SSWQO
for Uranium

Verna Lake discharge to Ace Lake:
12 times SSWQO
for Uranium



Source for map: CNSC Staff Submission, as per earlier slide (ibid) Figure 1.2 Map of Beaverlodge Area (courtesy of Cameco Corporation)

<u>Current Exceedances</u>

Ace Creek discharge to Beaverlodge Lake:

2 times SSWQO for Uranium

Meadow Settling Pond discharge:

13 X SSWQO for Uranium

7 X guideline for Radium

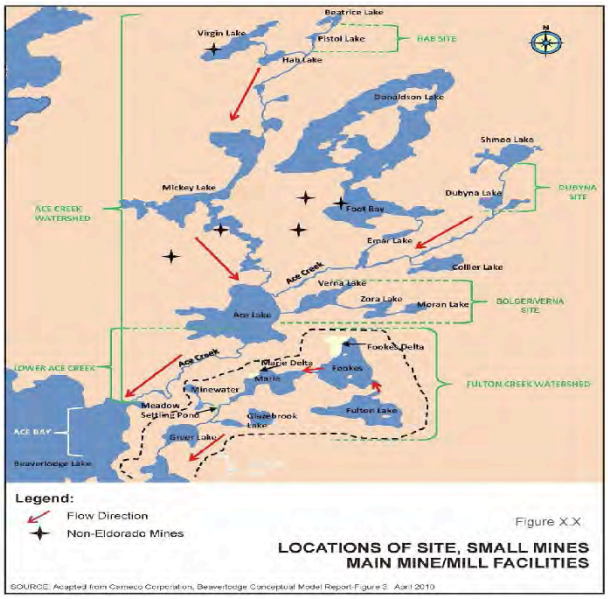
5 X SSWQO for Selenium

Greer Lake discharge to Beaverlodge Lake

24 X SSWQO for Uranium

25 X guideline for Radium

4 X SSWQO for Selenium



Source for map: CNSC Staff Submission, as per earlier slide (ibid) Figure 1.2 Map of Beaverlodge Area (courtesy of Cameco Corporation)

Cameco has proposed to the Canadian Nuclear Safety Commission that the upper bound for anticipated water quality in the lakes and reservoirs below become the official performance objective for moving Beaverlodge properties back to the provincial government.

Cameco's Proposed Annual Water Quality Performance Objectives, Uranium

Water Body	*Uranium Concentration (ug/L)*					
	2020		**2050**		**2100**	
	Upper	Lower	Upper	Lower	Upper	Lower
Dubyna Lake	**181**	**87**	**139**	**66**	**120**	**61**
Pistol Lake	**401**	**186**	**305**	**139**	**193**	**88**
Verna Lake	**213**	**118**	**150**	**82**	**129**	**72**
Ace Lake **16**	-	15	-	15	-	
Lower Ace Creek	**32**	-	**21**	-	**16**	-
Fookes Reservoir	**389**	**295**	**321**	**236**	**233**	**170**
Marie Reservoir	**374**	**297**	**354**	**268**	**276**	**217**
The Meadow	**410**	**313**	**366**	**271**	**277**	**216**

Source for table: Table 4.2-3 from Cameco's 'Beaverlodge Mine Site Path Forward, 2012'

SES note: The Saskatchewan Surface Water Quality Objective for Uranium is 15 ug/L

We continue to be concerned that Cameco's premise, in setting many of its site-specific performance objectives, appears to be that attaining "stability" is all that can be reasonably achieved. Under this scenario, it is then deemed to be "acceptable" for Beaverlodge properties to continue to be a significant source of contamination to downstream water bodies, even when Institutional Control is being applied for. While we understand the very difficult challenges Cameco faces in managing the Beaverlodge properties, we are concerned that the stage is being set for exceptionally contaminated properties to be returned into Saskatchewan's Institutional Control Program.

SES has asked CNSC to require much more ambitious performance objectives, and to add downstream water bodies like Martin Lake and the Crackingstone River to the list of water bodies for which performance objectives are set.

Cameco's Proposed Annual Water Quality Performance Objectives, Uranium

Water Body	*Uranium Concentration (ug/L)*					
	2020		**2050**		**2100**	
	Upper	Lower	Upper	Lower	Upper	Lower
Greer Lake	**301**	**250**	**275**	**219**	**221**	**179**
Ace Bay, Beaverlodge Lake	**123**	**88**	**77**	**58**	**42**	**27**
Fulton Bay, Beaverlodge Lake	**130**	**95**	**82**	**63**	**45**	**30**
Beaverlodge Lake	**132**	**96**	**82**	**62**	**44**	**29**

Source for table: Table 4.2-3 from Cameco's 'Beaverlodge Mine Site Path Forward, 2012'

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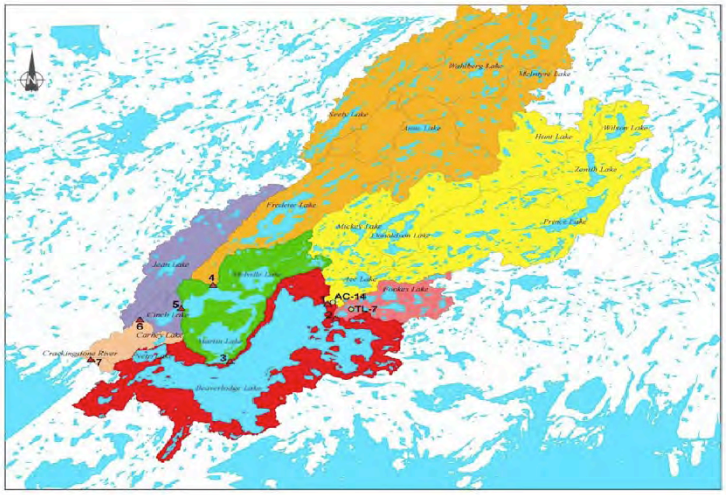
In addition to Beaverlodge Lake contamination, uranium and selenium levels are elevated above SSWQO in Martin Lake and uranium levels are above SSWQO in the Crackingstone River.



LEGEND

Rivers
Lakes

Watersheds

1 Ace Creek
2 Fulton Creek
3 Beaverlodge Lake
4 Fredette Creek
5 Martin Lake
6 Jean Lake
7 Crackingstone River

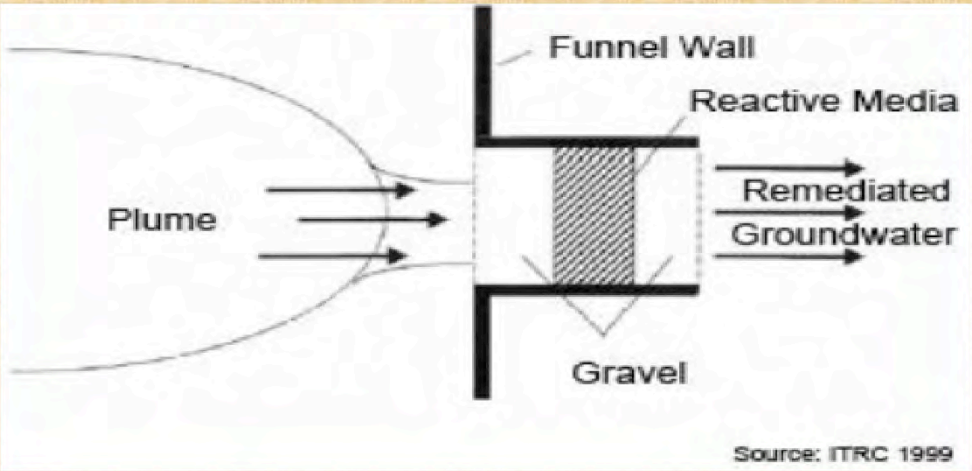
SES proposes two remediation options not currently planned for by Cameco. The most promising one is permeable reactive barrier technology.

Numerous studies carried out by, or for, the United States Environmental Protection Agency over the past 10 years indicate the excellent potential for management of uranium contamination in flowing surface or ground water using vertical permeable reactive barriers (PRBs).

In some cases uranium concentrations in surface waters have been reduced by 99%.

Special thanks to Dr. G. Lakshman of System Ecotechnologies Inc. Saskatoon

Permeable reactive barriers could be considered for use at several lake outlet points, along creeks and rivers, or in excavated groundwater flow channels.



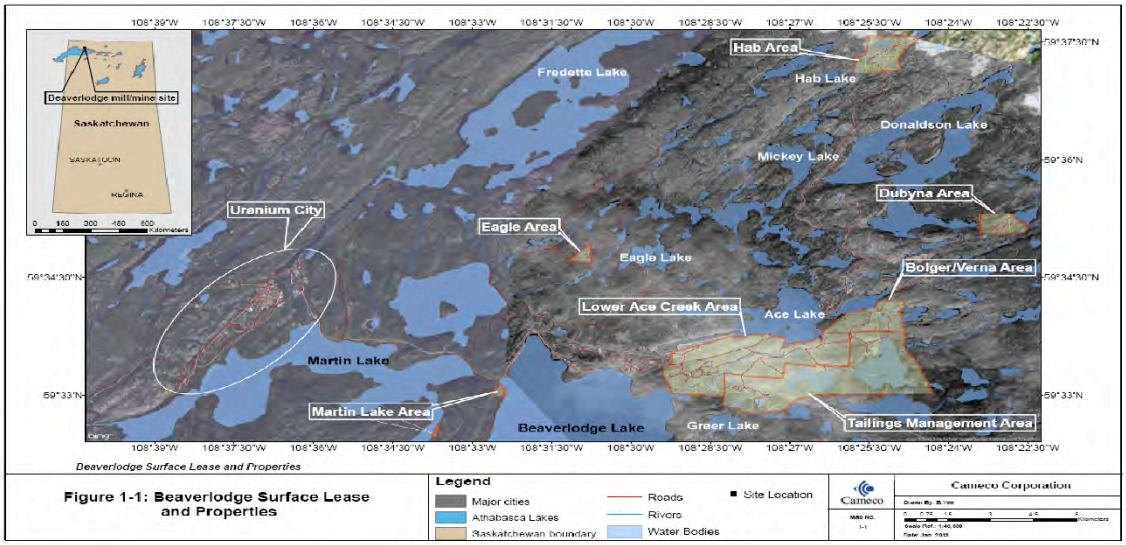
The second remedial option is ecological polishing.

Use of macrophytes, particularly the alga Chara (stonewort), to remove uranium and radium from solution.

Experience in the Link Lakes: Stonewort that was naturally occurring in Lower Link Lake has effectively converted dissolved uranium into a mineralized format which sinks into the sediment. Similar experience has been documented for locations in Germany and the United States.

Thanks to Margarete Kalin of Boojum Research in Toronto.

Note that in the Stonewort at the Rabbit Lake mine site was successfully transplanted into Upper Link Lake. However, the research project was left uncompleted.

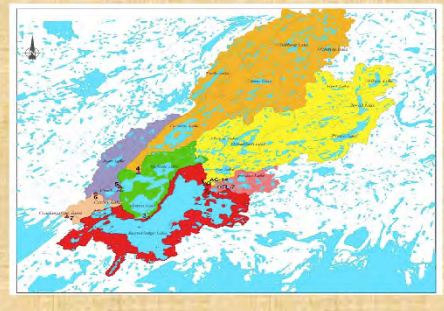


We think both approaches have potential to help clean up surface waters in the Ace Creek, Fulton Creek, Martin Lake and Crackingstone River watersheds. They deserve to be fully examined.

Source: Figure 1 – 3, Map of Beaverlodge area in: CNSC Staff Submission, February 1, 2013, ibid. Show areas on the map where these approaches might be applied. Note that remediation of Beaverlodge Lake using these techniques would likely hold far less promise.

Factors to consider when planning Beaverlodge remediation

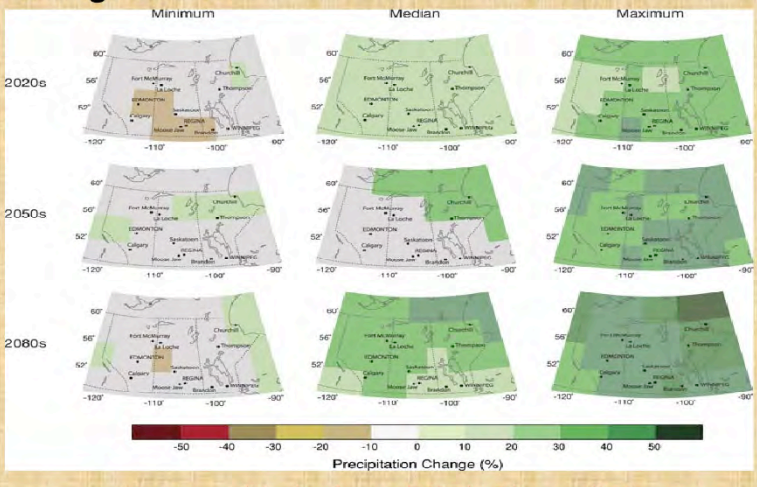
The most important factor is that a **regional approach** is needed to remediation.



Cameco should be asked to co-operate closely with SRC, not just on monitoring, but on achieving a reduction in levels of contaminants, wherever possible. The primary responsibility for funding a regional cleanup should lie with the Government of Canada.

A second factor to consider when planning site remediation is climate change. The Beaverlodge Lake area is likely to become wetter and subject to heavier precipitation events. This in turn suggests it would be wise to opt for a thicker cover for the tailings on site.

Climate change scenario maps for the Prairies showing minimum, median and maximum projections of changes in average annual precipitation.



http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca.earth-sciences/files/jpg/assess/2007/ch7/images/fig9b_e.jpg

Figure 9 b in *From Impacts to Adaptation: Canada in a Changing Climate, 2008*

We thus recommend the non-aqueous tailings on the Beaverlodge site receive an improved and thicker cover (a 1.5 metres cover that is a combination of waste rock plus a sandy-silty layer). This will provide a buffer against more intensive rainfall, against gamma radiation, and against chemical and biological processes acting on the tailings cover.

A third consideration is significant Hydrological Information Gaps

- Eldorado's underground uranium mine operations extended deep underground. (1800 metres).
- At present contamination from Eldorado's shut-down underground mine results from: tailings that were placed in the shafts at the time of decommissioning ,the flooding of the underground mine workings upon decommissioning, and the fact that contaminated water now makes its way back to the surface through flowing boreholes.
- Cameco is in the process of plugging these flowing boreholes. However, there may be longer or slower underground pathways that in the future will bring contamination to the surface at more distant locations.

Plans are proceeding step by step to return contaminated Beaverlodge mine sites to the provincial government with insufficient remediation.

- Plans are in motion that would see Beaverlodge mine/ mill properties returned to the Gov't of Saskatchewan in 10-15 years.
- The mechanism by which the mined-out properties are expected to be returned to the Province is the Institutional Control Program. In fact, 5 small Beaverlodge properties have already been returned.

Once CNSC and Saskatchewan Ministry of Environment approval for Institutional Control occurs, ongoing costs for the properties are presumed to be minimal.

Canada Eldor Inc. will be required to post a one-time bond to cover the cost of occasional monitoring and maintenance, plus a small additional sum to take account of unexpected events.

Reasons why the Beaverlodge properties should not be allowed into the Institutional Control Program in the next decade.

1. The current level of surface water contamination on several Beaverlodge properties is too high.
2. There are a number of remedial options for the Beaverlodge site that Cameco has not yet properly explored.

Reasons why the Beaverlodge properties should not be allowed into Institutional Control in the next decade

3. Eldorado Nuclear has caused serious pollution problems in downstream water bodies. Prior to Institutional Control, significant remediation work in the entire region should be financed by Canada Eldor Inc. (Gov't of Canada).

4. A longer delay before transferring the properties to Institutional Control would increase the likelihood that remedial technologies will advance sufficiently in the interim to adequately tackle the contamination problems that the Beaverlodge site and Beaverlodge Lake presents.

Lessons Learned from Beaverlodge

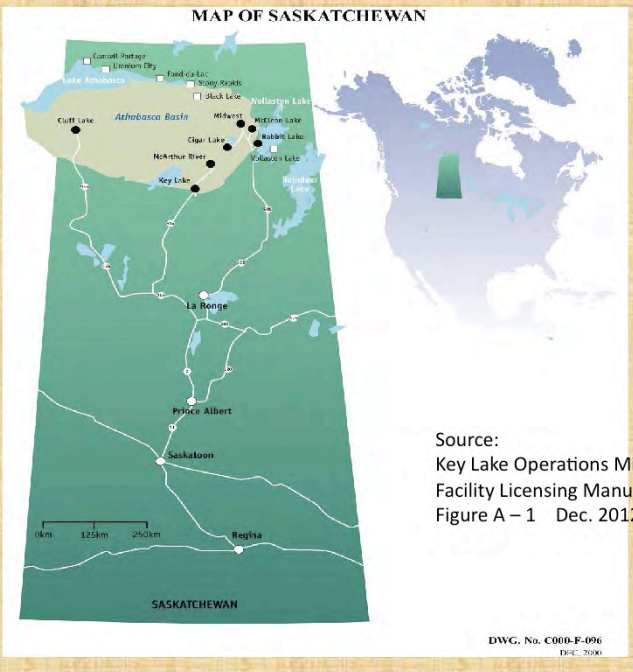
- Uranium mining in the Beaverlodge Lake area has been done at a high cost – both in terms of nuclear weapons proliferation and in terms of local environmental damage.
- There is a very high cost to inadequate environmental regulation. As a result there are often enormous challenges posed when cleanup and remediation do finally get underway.

Lessons Learned from Beaverlodge

- The Beaverlodge case study is a lesson with applicability to other poorly regulated industries in Canada. Examples include venting and flaring of methane by the oil & gas industry, hydraulic fracking by the oil & gas industry, and widespread creation of toxic tailings ponds in the Alberta oil sands.

Oil sands tailings

There are significant legacy issues at Saskatchewan's existing uranium mines.



Source:
Key Lake Operations Mining Facility Licensing Manual
Figure A – 1 Dec. 2012

For example, at the Rabbit Lake mine/mill: tailings, waste rock piles and mined out open pits are close to many lakes, including Wollaston Lake.

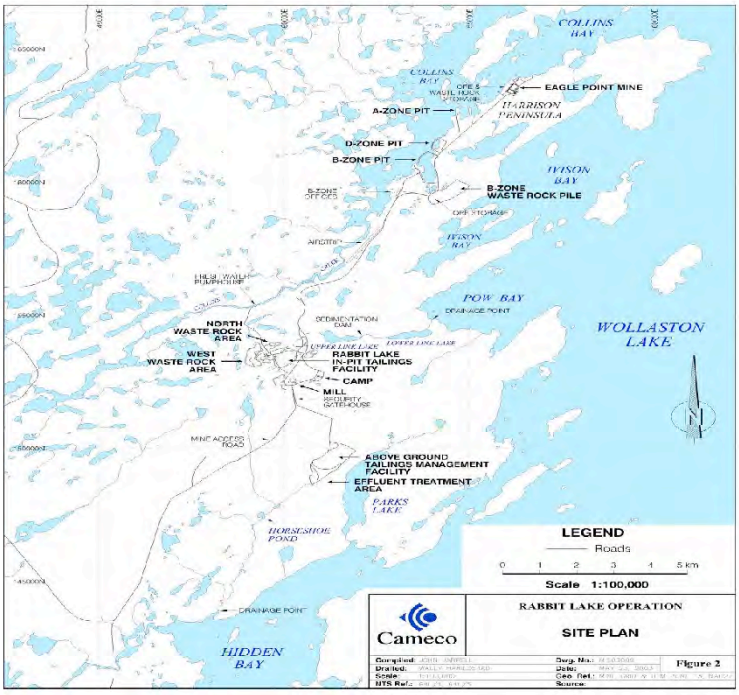
Photo Source: http://www.miningwatch.ca/article/surviving-mine-canada-s-uranium-district-and-western-mining-action-network-conference-2011

Rabbit Lake Operations Site Plan

Mining areas are in the northern part of the site

Effluent treatment area extends south towards Hidden Bay

Map source:
Mid-Term Report on
The Safety Performance
Of the Rabbit Lake
Operation, p. 36
(CNSC June 9, 2011)



In: Mid-term Report on the Safety Performance of the Rabbit Lake Operation
Page 36
09 June 2011 Prepared by CNSC Staff

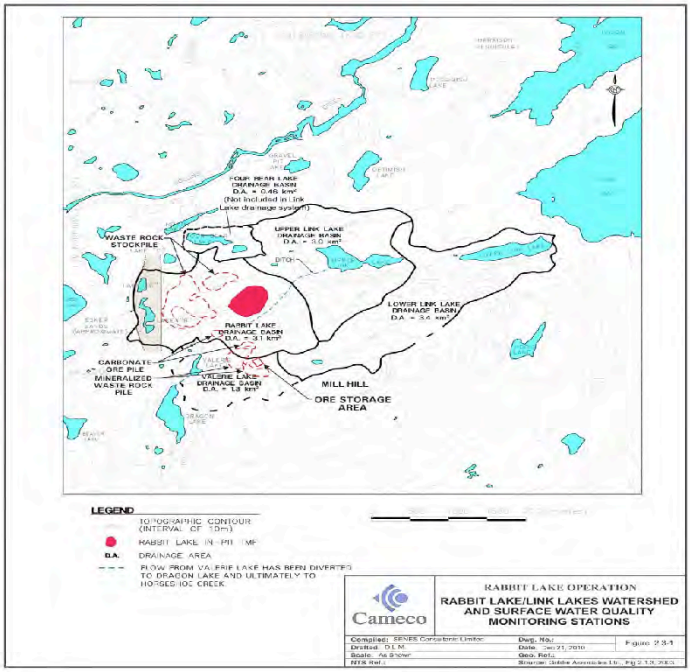
Note: Cameco expects the accumulated contaminant mass in Horseshoe Creek to ultimately be released over a period of years. Horseshoe Creek flows 9 km to Hidden Bay.

Effluent loading at Rabbit Lake

While Cameco's effluent treatment at Rabbit Lake has improved significantly over the past 4 years, total loading to the environment over the history of the mine site is high. When the mine first opened in 1975, there was no effluent treatment. Going back just a decade, annual loading at the final point of discharge averaged over 22,000 kg for molybdenum, 1,200 kg for uranium, 100 kg for nickel and 50 kg for arsenic.

(data covers the period 2003 to 2005)

Upper and Lower Link Lake are heavily contaminated with uranium and heavy metals. An EcoMetrix report done in 1999 estimates uranium loading in the upper 5 centimetres of Link Lake sediment at 57,000 kg. Remediation will be challenging for Cameco. Several options are under review.

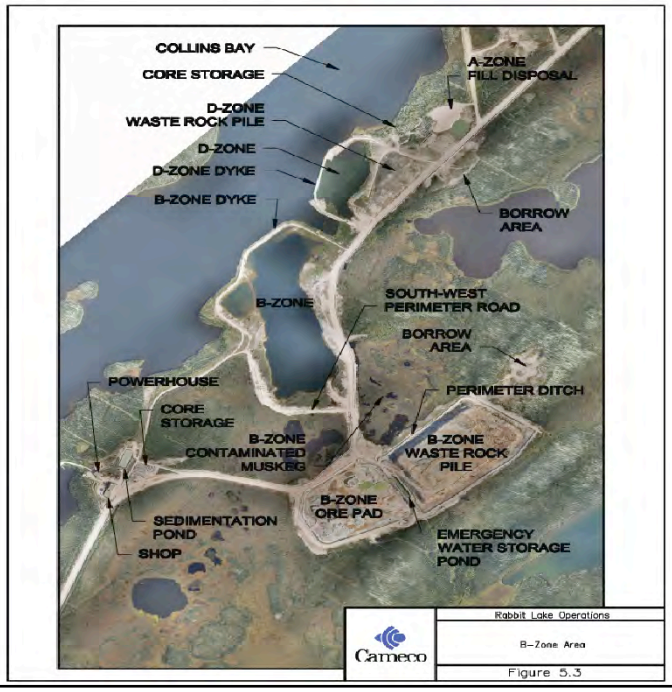


Rabbit Lake Operation Integrated ERA and SOE 2005-2009 SENES 2010
The Link Lakes have been impacted by the effects of dewatering and removal of sediments from Rabbit Lake, discharge of mine slimes and mine water, discharge of drainage from the mill complex, discharge of drainage from ore stockpiles and waste rock storage area, and discharge of cooling waters. There have been no direct releases to Link Lakes since 1997.
Sediment quality guidelines are exceeded for many primary contaminants, and for the most parts, substantial recovery has not occurred.
In addition to uranium loading, Ecometrix reports 190,000MBq of Radium 226 in the upper 5 cm of the Link Lakes sediment.

The B Zone mined out pit is partially flooded, but the dyke is not yet breached. The surface water in the B Zone area does not currently meet Saskatchewan Surface Water Quality Objectives for nickel or for arsenic.

The dyke for D Zone open pit is now breached and flooded with water from Collins Bay.

Slide Source: CNSC Staff Submission
To CNSC Board, May 24, 2011
Figure 4.2.1



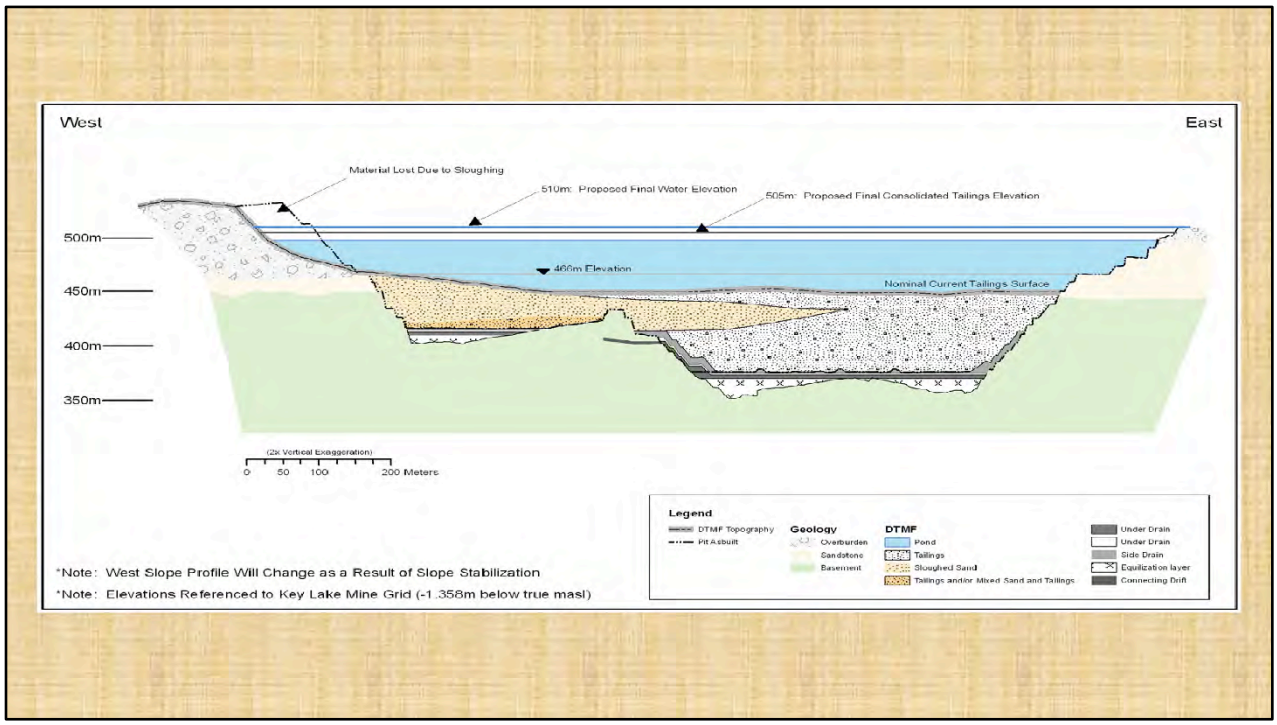
"The D and B Zone Areas" Slide source: Canadian Nuclear Safety Commission Staff Submission to CNSC Board, May 24, 2011
Mid-Term Report on the Safety Performance of the Rabbit Lake Operation Figure 4.2.1
In 2011 nickel levels were 0.096mg/L compared to SSWQG of 0.025mg/L
In 2011 arsenic concentrations were 0.009 mg/L compared with the SSWQG of 0.005 mg/L
CNSC staff acknowledge this slide is provided courtesy of Cameco

Key decisions ahead on over 14 million tonnes of radioactive tailings and large waste rock piles

- The Rabbit Lake site is faced with critical reclamation and decommissioning decisions that will impact surface water quality for centuries into the future. In our judgement, the residents of Wollaston Post and Hatchet Lake First Nation should be fully involved in reclamation decisions and monitoring on a month to month basis, but are not.
- One example of a key reclamation decision is the calibre of covers Cameco ultimately places on their waste rock piles and tailings facilities. That in turn will be driven by whether regulators require surface water around these facilities to meet SSWQO.

6.5 million tonnes of radioactive tailings at the 53 hectare Above Ground Tailings Management Facility
7.95 million tonnes of tailings at the Rabbit Lake In Pit Tailings Management Facility
The federal FEARO Panel reviewing Rabbit Lake in the mid 90's recommended major participation by the Wollaston Post community, but this has not happened.

Deilmann Tailings Pit at Key Lake Uranium Mine



Deilman Pit at Key Lake site

The issue of surface water contamination from uranium extends beyond the uranium mine site

- Surface water contamination from Saskatchewan's uranium is not limited to impacts in northern Saskatchewan.
- When the uranium is sent overseas, impacts on surface water can be even more severe in other parts of the nuclear fuel cycle.
- A good example is Cameco's sales of uranium to the Fukushima Daiichi nuclear reactor in Japan.

Fukushima: 3 reactor meltdowns and 80,000 people unable to return home

Not only did Japan and its people suffer radioactive contamination, but the surrounding ocean was also contaminated with fission products.

Immense release of cesium, strontium & plutonium over land and sea. Prevailing winds blew much of the radioactivity offshore. Radioactive iodine exceeded regulatory limits by 4,000 X several hundreds metres from the reactor site.

Over 2 years later surface water contamination problems near the site are still very serious

- Almost 6,000 workers at Fukushima Daiichi struggle to contain the huge buildup of toxic water at the shut-down reactor site.

- TEPCO has admitted that groundwater flowing down from the hills behind the Fukushima plant has been mixing with radioactive water from the reactor basements. It flows into the sea at a rate of about 300 tonnes per day.
- Fishermen south of Fukushima Daiichi have not been able to fish commercially since the disaster, while those north of the plant are very restricted in their catch.

In October TEPCO revealed highly contaminated water had seeped out of storage tanks, and probably ended up in the Pacific Ocean.

Fukushima has shaken parts of the global nuclear industry

- Fukushima demonstrated conclusively that even when operators successfully shut down a nuclear power station, a serious accident is difficult to prevent if electricity is unavailable to run the pumps that circulate water to cool the spent uranium fuel bundles.
- Japan has currently shut down all 54 of its nuclear reactors.
- Germany plans to phase out its entire nuclear power industry by 2022, and is on track to do so.

The link between uranium / nuclear reactor exports and nuclear weapons proliferation continues to be of concern. India is a case example.

- India first achieved atomic weapons in 1974 by using a nuclear reactor supplied by Canada (Cirus reactor) as a source of plutonium, and as a cover for its atomic bomb program.
- Today India has more than 80 nuclear weapons, including hydrogen bombs.
- Despite this, Cameco has been lobbying Ottawa for the last several years to permit uranium sales to India.

The Government of Canada is now allowing uranium sales to India

- Canada has recently entered into a nuclear co-operation agreement with India and Cameco is poised to start uranium exports.
- With Canadian uranium for its civilian nuclear power program, and without the restrictions imposed by the Non-Proliferation Treaty, India will be more free to use its domestic uranium supply for expanding its atomic arsenal.

Concluding Observations on Saskatchewan's uranium industry

- Local environmental practices in Saskatchewan's uranium industry have certainly improved when compared to early mining operations, but there are still major issues to be addressed at the mine sites.
- Even with today's remediation technologies, it may not be possible to clean up legacy problems like Beaverlodge Lake or the Links Lakes.

Concluding Observations

- So-called 'acceptable standards' are often found to be unacceptable 10 or 20 years later; thus today's regulatory framework should incorporate the precautionary principle.

- Proper remediation should be a pre-requisite for allowing decommissioned mine sites to enter Institutional Control.

An example is how views on the risk of selenium have changed over the past 10 years.

Concluding Observations

- The Government of Canada and the uranium industry are still not addressing the crucial issue of the link between uranium exports and nuclear weapons proliferation, one major reason why an expansion of nuclear power is ill advised. Nor can the industry resolve the on-going problems with reactor safety.