W.B. Lewis Lecture

Cleaning-Up Abandoned Uranium Mines in Saskatchewan's North

By Laurier L. Schramm, President and CEO, Saskatchewan Research Council

ABSTRACT

Thirty-six now-abandoned uranium mine and mill sites were developed and operated on or near Lake Athabasca, in Northern Saskatchewan, Canada, from approximately 1957 through 1964. During their operating lifetimes these mines produced large quantities of ore and tailings. After closure in the 1960's, these mine and mill sites were abandoned with little remediation and no reclamation being done. The governments of Canada and Saskatchewan are now funding the clean-up of these abandoned northern uranium mine and mill sites and have contracted the management of the project to the Saskatchewan Research Council (SRC). The clean-up activity is underway, with work at many of the smaller sites largely completed, work at the Gunnar site well underway, and a beginning made at the Lorado site. This lecture presents an overview of these operations.

INTRODUCTION

Significant uranium mining and milling operations were launched during WWII under the War Measures Act. After WWII uranium mining and milling were kept under federal jurisdiction, under the Atomic Energy Control Act (1946). The Atomic Energy Control Board in turn licensed a number of small mines, plus the larger Gunnar and Lorado mines, in the late 1940s and early 1950s. Most of these mines were located on or near Lake Athabasca, in Northern Saskatchewan, as shown in Figure 1. Almost all of the uranium was sold via Eldorado, a federal Crown Corporation, to the US Atomic Energy Commission. Although the Board licensed these mine and mill sites, they did not impose any decommissioning or reclamation criteria on them when these operations ceased operations in the early 1960s. As a result, little to no decommissioning or reclamation was done between the 1960s and 2006.

In 2006, SRC became responsible for managing the cleanup of these sites, under contract to the Province of Saskatchewan [1]. Our top priority in this work has been to clean-up the sites and make them safe! In doing so it has been SRC's responsibility to develop and implement remediation options that are technically and economically feasible, maintain a financially responsible budget and due diligence (so contract tenders are bid competitively), and ultimately establish a cost-effective environmental monitoring program and minimize long-term care and maintenance at the site. Another goal has been to engage with the northern and Aboriginal communities and, where possible, develop and enable training, employment, and meaningful economic activity opportunities for these local residents.

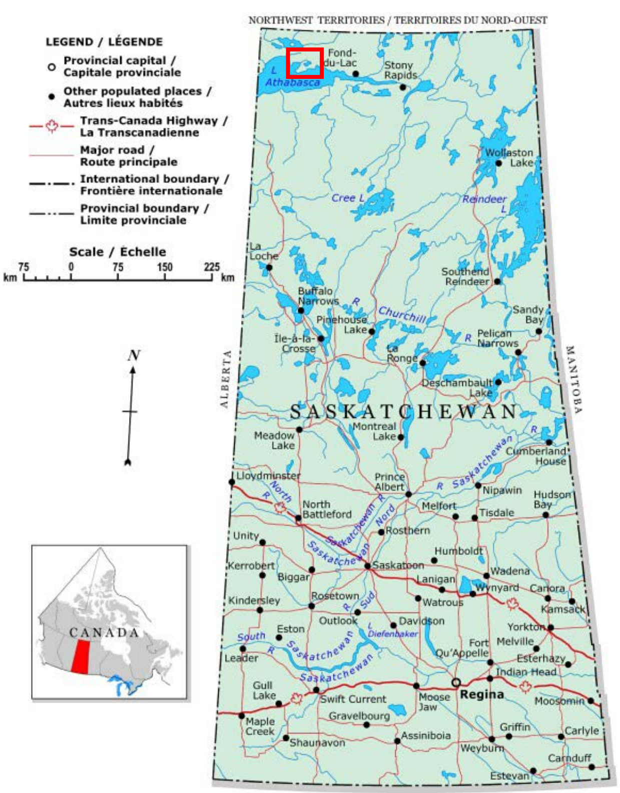

Figure 1. Abandoned uranium mine and mill site region (red square in extreme upper left corner of the

map. (Map from Natural Resources Canada, 2001.)

COMMUNITY ENGAGEMENT - BEGINNINGS

Although this project has many stakeholders, probably none have had more interests, hopes, and concerns than the local communities: in this case the residents of the Athabasca basin area. Our consultation process has included town-hall meetings, beginning with a full-communities launch town-hall meeting in 2007, and continuing update meetings ever since. Engaging with the mayors and Chiefs and representatives of the local, First Nations, and Métis communities, and with the invaluable advice and assistance of the Prince Albert Grand Council, we were able to establish a Project Review Committee (PRC) in 2008, with representation for each of the local communities: Uranium City, Camsell Portage, Fond du Lac, Stony Rapids, Black Lake, and Hatchet Lake. Also in 2007 we established a relationship with the Northern Saskatchewan Environmental Quality Committee (EQC), which was already in place to provide northerners with a mechanism to learn more about uranium mining activities, environmental protection measures, and the socio-economic benefits being gained in the region. Hosting field-trips for the EQC to the abandoned mine sites enabled community representatives to see first-hand the state of the sites and helped fuel constructive discussions about clean-up options and approaches.

Consultation occurs through public meetings, specific stakeholder meetings, the PRC and EQC, media interviews, information dissemination through radio, newspaper and magazines, a Project CLEANS website and numerous other interactions.

One of the first substantial points of discussion involved the 36 satellite sites and the order in which they would be cleaned-up. A full-community open-house was held in Uranium City early in 2007, at which all of the Athabasca basin residents were invited to learn about the satellite sites, their locations, physical characteristics, and immediate hazards. Following discussions of each site the community residents were invited to provide recommendations on prioritizing the clean-ups and they ultimately recommended groupings of first-, second-, and third-priority sites based on their assessments of proximity and safety hazards. Although SRC had to maintain authority over technical and contractual aspects of the work, engaging with the local communities and following their recommendations on the order of the satellite site clean-ups went a long ways towards gaining their support and “social license” for our subsequent work on these sites.

SATELLITE SITES

Some 40 years after abandonment, the satellite sites were found to contain numerous and diverse hazards beyond just the radiation issues that most people would expect. The legacy left behind from the 1960s included multiple mine shaft openings, raises (connecting levels in a mine), and adits (horizontal mine entrances). Although many, if not most of these were sealed at abandonment, 40 years of neglect had taken their toll and many of the original covers had corroded, collapsed, and/or fallen away leaving the shafts, raises, and adits open again. These sites also exhibited:

- Trenches, unstable ground, and liquid seepages,
- Standing or collapsed wooden/concrete structures, pump-houses, and core racks,
- Concrete pads and foundations,
- Ore carts, fuel tanks, water tanks, boilers (encased in asbestos), and cisterns,
- Extensive amounts of waste rock,
- Miscellaneous debris (vehicle chassis, drill rods, steel casings, barrels, pipes, and rails, etc.), and
- Radiation, asbestos, polychlorinated biphenyls (PCBs), explosives, and unknown chemicals.

Following site surveying, characterization, assessment and options analyses and prioritizations, and gaining regulatory approvals, the satellite site clean-ups have involved such things as:

- Collecting, isolating, and removing hazardous materials,
- Dismantling and removing standing tanks and other structures,
- Removing other substantial-sized debris,
- Backfilling adits, raises and other openings,
- Installing new caps (often stainless steel) on openings, and
- Re-covering the areas to return them to approximately pre-mining-era conditions.

In some cases we were able to deploy relatively new technologies such as the filling of some raises and other cavities with polyurethane foam (PUF). Such foams are well suited to filling irregular openings containing fragmented structural materials, yet offer substantial structural strength when hardened.

When capped with natural fill such PUF plugs are essentially invisible.

The first 8 satellite sites were substantially cleaned-up in 2009, the next 5 in 2010, and this work continues, although at a slower pace in 2011 and 2012 due to the ramp-up in clean-up activities at the large Gunnar site as will be discussed below. Figure2 shows a “before” and “after” illustration of work at one of the satellite sites.

Figure 2. Example of “before” and “after” views of an abandoned satellite uranium mine site in Northern Saskatchewan (Baska Uranium Mine, 2009.)

LORADO MINE AND MILL SITE

The Lorado mine and a mill site were commissioned in 1957 and operated until 1960. Lorado Uranium Mining Ltd. Used the mill to process ore from its own mine and also from other mines in the area. No decommissioning or reclamation work was conducted upon closure in 1960, but the mill itself was decommissioned in 1990. What remains are the tailings.

The Lorado mill tailings were originally placed in a small “pot hole” near Nero Lake, which eventually overflowed (~335,000 tonnes) into Nero Lake itself, with about 14 hectares of tailings remaining above the high-water line. Work to date has included site surveying, characterization, assessment and options analyses and risk reduction planning. In the meantime, public access has been restricted, and dust control measures have been implemented, including fencing and surface-chemical treatments.

GUNNAR MINE AND MILL SITE

The Gunnar mine and mill site was commissioned in 1955, beginning with an open pit mine that was operated until 1961 and continued with an underground mine until 1964 [2]. In addition to the open pit and underground mines, the mine and mill site included additional mining support facilities and maintenance shops, a uranium milling facility, an acid plant, tailings disposal facilities, and an entire small town including housing, school, hospital, shopping and recreation centres. No decommissioning or reclamation was conducted upon closure in 1964, except that the open mine pit was allowed to flood.

The open pit mine was approximately 300 m long, 250 m wide, and ultimately 116 m deep (Figure 3). The underground mine began production in 1957 and was operated until 1963, by which time it was over 600m deep. The mined ore averaged about 0.15% uranium content, and ultimately nearly 5 million tonnes were produced. Upon closure in 1964, decommissioning was limited to flooding the pit (Figure 4) and capping the shaft. Left behind were:

- a 48m head frame and associated mine shaft,
- a mill housing ore bins, crushing/grinding circuit, thickening circuit, leaching circuit, filtration circuit, clarification circuit, ion exchange circuit, precipitation circuit, and a filtration, drying, and packing circuit,
- laboratories, mixing areas, and storage annex,
- two acid plants and associated storage tanks,
- geology/mine, mine engineering, and heavy equipment maintenance shop buildings,
- water, fuel, and other storage tanks and power generation plants, plus above-ground utilidors for carrying water, sewage and steam, and
- much other unsalvaged major equipment, tanks, concrete floors/pads, structural concrete and steel structures, smaller buildings, scrap steel, and piping.

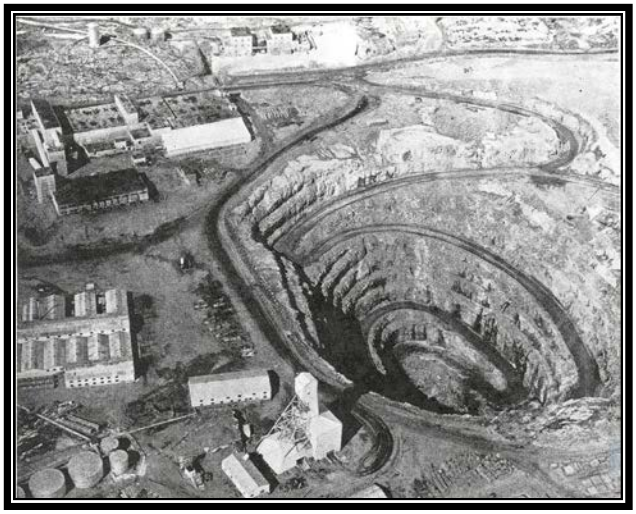

Figure 3. Gunnar Mine; open pit, circa 1962.

Figure 4. Gunnar Mine; flooded open pit in 2006.

Covering a huge area of the site are over 4.4 million tonnes of tailings and about 500m of the 25 cm diameter wooden-stave pipeline that had been used to transport them [3]. The tailings were originally discharged into a small lake (variously called Blair Lake or Mudford Lake); the tailings eventually overcame the lake (now called Gunnar Main Tailings) and flowed into another basin, Gunnar Central Tailings, which in turn eventually overflowed into Langley Bay (part of Lake Athabasca).

Also covering a substantial area of the site are about 2.8 million m^3 of waste rock, covering about 10 hectares [3]. The waste rock is located on the shore of Lake Athabasca and in some locations extends into the water of the lake proper.

Due to the remote location, the Gunnar site was self-contained and provided housing for all single and married employees, plus a school, hospital, community shopping, services, and leisure centre, in order to accommodate about 800 people.

REMOTE LOCATION HAZARDS

Working in the North brings its own complexities and hazards due to the remoteness of the locations described above, and to the sometimes severe weather and ground conditions. Spring activities can be limited by getting heavy equipment bogged-down in mud, summer activities by work stoppages or evacuations due to approaching forest fires, fall activities by early onsets of cold weather (- 42 °C in the fall of 2009) or heavy snow (fall 2010). Getting heavy demolition equipment, a 90-person self-contained camp, and heavy supplies (like 610,000 L of diesel fuel) to the Gunnar site has involved transport over winter ice roads on Lake Athabasca. These ice roads themselves can have an access window as short as a few weeks per year, that are relatively free of crack, heave, melting (thin ice), and storm hazards.

The vast majority of the on-site demolition and clean-up efforts have to be conducted during relatively short summer seasons.

MINE AND MILL SITE HAZARDS

The Gunnar site in particular has exhibited a broad range of types and levels of physical, chemical, and radiological hazards.

- Almost all of the buildings of all kinds had suffered leaking roofs, major decay, structural weakening and, in many cases partial ceiling collapses,
- A key hazard was created by the ubiquitous presence of asbestos, which was present in structural steel filler, wall insulation, siding, roofing, pipeline and vessel insulation, various other spray-on applications, and even in cinderblock and general litter,
- Other site chemical hazards included process chemicals like sodium hydroxide, magnesium oxide, calcium hydroxide, vanadium pentoxide, elemental sulphur, and Portland Cement (in quantities ranging from bottles, to barrels, to pallets, to tonnes). Less extensive were occurrences of oils and fuels (and spills thereof), paints, Freon, and PCBs.
- Numerous heavy metals and radionuclides are present in the flooded pit, waste rock, tailings and other areas. Many contaminants of potential concern have been identified [4], the principals being

selenium, mercury, and uranium.

- The radiation hazards have been summarized in more detail elsewhere [4]. Many buildings and locations around the site exhibit low gamma radiation levels (i.e., less than about 2 μSv/h at 1 metre), but some of the mill areas, fines piles, tailings areas, and waste rock areas exhibit higher levels. Similarly, some buildings exhibited radon levels requiring action. Both are of concern to a remediation workforce and had to be dealt with.

GUNNAR SITE HIGH-HAZARD REMOVAL

Following triage safety assessments the highest public safety hazards were addressed first. Some of the earliest steps involved securing of the site, and of building entranceways, to limit public access, and development of protocols for safe management of activities on the site. In parallel, hazard warnings were broadly and persistently communicated to all local communities, residents, and businesses.

The hazardous site-chemicals noted above were collected, packaged, and/or segregated depending on the quantities involved. About half of these were removed over the winter ice road in 2012 and sent for proper disposal, while the remainder is expected to be removed over the ice road in 2013. Vast amounts of asbestos were collected, all that could be safely collected in advance of actual building demolition, and packaged for disposal.

The most visible clean-up activities to date involved the demolition of the many (about 84) buildings and standing structures in 2010 and 2011.

Figure 5. Demolishing the Gunnar Head-Frame in 2011.

These demolitions included the mine, mill, and plant buildings, school, residences, above-ground utilidors and, of course, the iconic Gunnar head-frame structure (Figure 5).

During this process, constant care had to be taken to protect workers from asbestos, let alone the other hazards, and in many cases buildings had to be maintained under negative air pressure during indoor work (to guard against radon and asbestos), and then constantly sprayed during demolition (to knock-down asbestos dust and fibres). Following demolition the building and chemical materials were collected and transported to holding sites pending ultimate disposal, and the ground covered-over with clean fill (Figure 6).

Figure 6. Example of “before” and “after” views of building demolition at the Gunnar site (2010).

Consistent with our goal of making the various sites safe, from both public and environmental safety standpoints, it was also an over-riding priority to conduct the clean-up activities themselves as safely as possible. Key project results from the 2010 and 2011 demolition seasons were the achievements of zero lost-time injuries on site among any of our employees or our sub-contractors. This has been another huge accomplishment considering the hazards involved, and an aspect that has earned praise from regulators and other key stakeholders [5].

COMMUNITY ENGAGEMENT – SCALE-UP

As mentioned above, constructive engagement with local communities has been a priority from the outset. At an early stage, training in the tendering process was provided to local community people and companies. To the extent possible, project work was compartmentalized to enable local bidding and participation in a variety of light equipment and other tasks, in order to maximize the use of local companies and local workforces.

As the project neared the demolition phases, training opportunities were made available to all interested Athabasca basin community residents in order to ensure that they could be qualified to work on the demolition and related activities. In 2010 and 2011 fifteen different training courses (equipment operation, safety practices, asbestos removal, etc.) Were provided for about 110 northern residents. This was highly successful in that just over half of the 140-person demolition workforce in 2011 comprised local Athabasca-basin residents.

Active public consultations continue to be required as the remaining environmental assessments, remediation options and recommendations are further developed. Traditional knowledge and traditional land use studies are being conducted in order to feed-into this work the context of traditional uses of the area. Similarly, any planning for future land use will be subject to consultation with the local communities.

NEXT CHALLENGES

Subject to regulatory approvals, it is anticipated that the next major project phases will include:

- Disposal of the demolition materials,
- Capping of the mine shaft and vent raises,
- General site clean-up and additional surveys and characterizations related to the tailings and waste rock piles,
- Installation of a cover on some or all of the exposed mill tailings (Gunnar and Lorado),
- Rehabilitation of the waste rock piles and any other risk(s) as required,
- Re-vegetation of areas of the rehabilitated site as required, and
- Environmental monitoring during and after rehabilitation.

Several of the above aspects provide further potential opportunities to develop and demonstrate new technologies. One is in approaches to revegetation with native species to bring the sites back to close to their original conditions as quickly and effectively as possible, while providing self-sustaining habitats for wildlife. Another area is in the development of water treatment technologies suitable for remote northern sites.

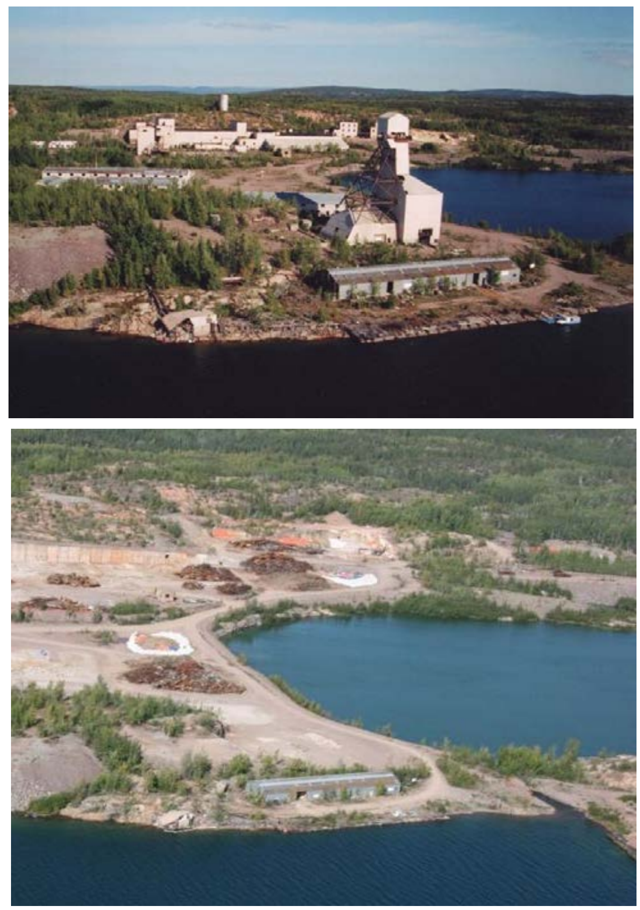

Figure 7. “Before” (upper) and “after” (lower) views illustrating clean-up progress at the Gunnar site (2011). Photos courtesy Woodland Aerial Photography.

Most of the above next steps will continue to require environmental impact assessments and approvals from the responsible provincial and federal authorities, including the Canadian Environmental Assessment Agency and Canadian Nuclear Safety Commission. Work on the Environmental Impact Assessments (EIAs) for the

Gunnar and Lorado sites is currently underway. These will provide detailed descriptions of the sites, existing environmental risks, remediation approaches and their impacts as well as a recommended remediation plans with mitigation measures and projected environmental outcomes. Much of the scientific information required for the EIAs has already been gathered. The remaining study and data needs will be determined by risk assessments and the development of remedial options.

PROJECTED ENDPOINTS

The goal is to have all of the sites remediated in a way that enables future public and traditional use of the sites and surrounding areas with minimal environmental and public safety hazards. However, some areas, such as the tailings management and land-fill sites may not be available for direct public uses such as camping or seasonal habitation.

The endpoint criteria are being developed with the intent of ultimately transferring the sites to the Saskatchewan government's long-term institutional controls program, thus providing long-term management and monitoring.

CONCLUSION

In the 1950s and 60s uranium mine remediation was not considered to be very important, leading to the abandonment of numerous mine and mill sites, with little or no remediation or reclamation. Now, more than 40 years later, not only are mine remediation and reclamation judged to be very important, but such aged legacy sites have deteriorated, creating even greater hazards to the public and to the environment.

Modern science and engineering is capable of presenting multiple options for dealing with the hazards and the clean-ups, emerging new technologies can help, and best practices continue to evolve. On the other hand this work demonstrates that cleaning-up such legacy hazards from the past can be huge undertaking, and can be tremendously expensive. When not properly planned-for from the beginning, the remediation phase of such industrial development can end-up costing almost as much as the value of the original extracted uranium. A key lesson is that mine and mill remediation and reclamation are best considered, planned-for, and budgeted-for, as part of a comprehensive, full-cycle approach to uranium development.

Wilfrid B. Lewis (1908 – 1987)

W.B. Lewis, for whom this award lecture series is named, is widely considered to be the 'father' of commercial nuclear power in Canada, including the CANDU and NPD reactor systems. Lewis believed that nuclear science and engineering can contribute to society by raising standards of living and improving quality of life, but that the inevitable hazards of developing and using any source of energy have to be properly dealt with [6]. In particular he felt that *"[a] nuclear waste disposal area … if properly planned and maintained … need cause no threat to people's health"* [6]. SRC's work on the abandoned uranium sites described above demonstrates that society does have the knowledge and the ability to deal with the residual footprint of uranium industry operations and that, if tackled properly and early enough, both public and environmental safety can be restored.

ACKNOWLEDGMENTS

The author would like to acknowledge the many scientists, engineers, and technologists, both within the Saskatchewan Research Council and beyond, for the work that has been completed to date, and the work still required, to fully remediate these abandoned uranium mine and mill sites.

REFERENCES

1. SRC, 2012, Project CLEANS Website, Saskatchewan Research Council, Saskatoon, www.saskcleans.ca.
2. Botsford, J.A., 1963, "The Gunnar Story," Canadian Mining Journal, 84(7), pp. 47-114.
3. BBT Consultants, 1986, "Gunnar Field Study," Prepared For Supply and Services Canada Under the National Uranium Tailings Program. NUTP No. - 155Q.2341-4-1674X (9 volumes). B.B.T. Geotechnical Consultants: IEC Beak Consultants Ltd; Sargent, Hauskins, Beckwith Concord Scientific Corp., March.
4. Muldoon, J. and Schramm, L.L., 2009, "Gunnar Uranium Mine Environmental Remediation - Northern Saskatchewan," Proc. 12th Internat. Conf. on Environmental Remediation and Radioactive Waste Management, ICEM'09/DECOM'09, Liverpool, UK, Oct. 11-15, ICEM2009-16102, 12 pp.
5. CNSC, Public Meeting Transcript - May 2, 2012, Canadian Nuclear Safety Commission, Ottawa, pp. 7-81,

www.cnsc.gc.ca/eng/commission/pdf/2012-05-02-Transcription-Meeting-Final-e.pdf.
6. Fawcett, R., 1994, Nuclear Pursuits: The Scientific Biography of Wilfrid Bennett Lewis, McGill-Queen's University Press, Montreal.