Kiggavik Project
Final Environmental Impact Statement

Tier 3 Technical Appendix 2R
Preliminary Decommissioning Plan

September 2014

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Attachments

ACRONYMS

AANDC	Aboriginal Affairs and Northern Development Canada
ABA	Acid Base Accounting
AECB	Atomic Energy Control Board (replaced by CNSC)
ALARA	As Low As Reasonably Achievable
ARC	AREVA Resources Canada
bcm	bank cubic metres
CAD	Canadian Dollars
CEAA	Canadian Environmental Assessment Agency
CCME	Canadian Council of Ministers of the Environment
CNSC	Canadian Nuclear Safety Commission
COPC	Constituents of Potential Concern
CSA	Canadian Standards Association
CSR	Comprehensive Study Report
DDP	Detailed Decommissioning Plan
DEIS	Draft Environmental Impact Statement
EA	Environmental Assessment
EC	Environment Canada
EIS	Environmental Impact Statement
EMP	Environmental Monitoring Program
EN	Engagement Comments
ERA/HRA	Ecological Risk Assessment/Health Risk Assessment
ERAP	Emergency Response Assistance Plan
FA	Financial Assurance
FEIS	Final Environmental Impact Statement
FUP	Follow-up Program
GC	Government of Canada

GN .... Government of Nunavut
HC .... Health Canada
IAEA .... International Atomic Energy Agency
ICP .... Institutional Control Program
IMS .... Integrated Management System
INAC .... Indian and Northern Affairs Canada (now AANDC)
ISO .... International Standards Organization
IOL .... Inuit Owned Lands
IQ .... Inuit Qaujimajatuqangit
KIA .... Kivalliq Inuit Association
LAA .... Local Assessment Area
LTMP .... Long-term Monitoring Program
MMER .... Metal Mining Effluent Regulations
MROVP .... Mine Rock Optimization and Validation Program
mSv .... milliSievert
NIRB .... Nunavut Impact Review Board
NTI .... Nunavut Tunngavik Incorporated
NWB .... Nunavut Water Board
OHSAS .... Occupational Health & Safety Advisory Services
PDP .... Preliminary Decommissioning Plan
RAA .... Regional Assessment Area
RP .... Radiation Protection
TMF .... Tailings Management Facility
TOVP .... Tailings Optimization and Validation Program
U .... Uranium
WSA .... Water Security Agency
WTP .... Water Treatment Plant

1 Introduction

1.1 Overview

As part of the regulatory approval process, the regulatory authorities overseeing the approval anddevelopment of uranium mines in Canada require the proponent to develop and submit preliminary decommissioning plans, including financial security. As operator of the Kiggavik Project (Project), AREVA Resources Canada (ARC) will be responsible for maintaining and updating these decommissioning plans and financial assurance.

This Technical Appendix 2R provides preliminary plans and estimated costs for decommissioning the Kiggavik Project, as the project is described in this Final Environmental Impact Statement (FEIS). The cost estimate encompasses the full development of the known uranium reserves, as descrbed in the project assessment basis (Volume 2, Section 20.1.1). Section 9.6 of the NIRB Guidelines describes the FEIS requirements for the Mine Closure and Reclamation Plan. Section 9.6.1 describes the requirement for a Care and Maintenance Plan in the event of a temporary closure of the Project. Section 9.7 describes the requirement for Follow-Up and Adaptive Management Plans. Conformity with all of these requirements is detailed in Volume 1Main Document, Technical Appendix 1A, Conformity Table.

This plan is a dynamic one,in the sense that it will be updated as the Project advances through licensing, construction, and operation. The primary licensing authorities will be the Canadian Nuclear Safety Commission (CNSC) and the Nunavut Water Board (NWB). This plan has thus been developed to be consistent with the future licensing requirements of these regulatory authorities with respect to decommissioning planning and financial assurance. It will be updated at the licensing stage to reflect the final detailed design for construction. The plan has also been developed to be consistent with the Nunavut Tunngavik Incorporated (NTI) Reclamation Policy for land uses carried out on Inuit Owned Lands (IOL).

This proposed preliminary decommissioning plan includes sufficient detail to ensure that it is, in light of existing knowledge, technically feasible and appropriate in the interests of protecting health, safety, security, and the environment. This Preliminary Decommissioning Plan will be updated and revised each time an application is submitted to the regulatory agencies for a significant addition to the facilities to be constructed and/or operated. These updates will incorporate further details on decommissioning, based on the detailed design of the additional facilities to be constructed or operated. In particular, it will be important that the financial assurance (FA) be based on material quantities which reflect actual amounts to date plus new amounts committed by the application under consideration.

The PDP and FA will thus be regularly updated to reflect a FA based on technically feasible decommissioning activities which will achieve the decommissioning objectives and various quantitative measures of success. Detail such as precise revegetation plans and detailed decommissioning drawings will only be developed as part of the Detailed Decommissioning Plan (DDP). Preliminary scheduling of decommissioning activities can be found in Table 4.2-1. Scheduling of individual tasks will be provided in the DDP.

1.2 Scope

In keeping with the concept of "life-cycle" planning, this plan has been prepared for the site as it will exist at the end of the operations phase. It is recognized that should the scope of development vary from that which is expected, future versions of the plan will reflect those changes.

As per CNSC guidance (Regulatory Guide G-219) and various Nunavut guidelines (referenced in Section 1.3), details regarding the following subjects will be presented in the Detailed Decommissioning Plan at the end of Project operations. Providing a level of detail consistent with the stage of development is in keeping with the requirements of Standard N294-09, Decommissioning of Facilities Containing Nuclear Substances (CSA 2009). General commitments only with respect to the following are included in this Preliminary Decommissioning Plan:

- Materials and Waste Management
- Radiological Surveys
- Human Factors
- Conventional Health, Safety, and Security
- Emergency Response
- Quality Assurance

Information on decommissioning of the core storage area is also included. However, in keeping with the *Nunavut Mineral Exploration and Mining Strategy* (GN, 2007) this would not be undertaken until such time as AREVA is instructed to do so by the Minister responsible.

Geographically, the Project mine site can be considered to consist of infrastructure in three main areas: Kiggavik, Sissons, and the Baker Lake port and staging facilities. The roads connecting these areas are also included.

1.3 Legal Context

Federal and territorial acts, regulations, objectives, standards and guidance documents have been reviewed for the preparation of this plan.

The federal documentation reviewed includes the following:

- Nuclear Safety and Control Act and Regulations, principally the General Nuclear Safety and Control Regulations, Uranium Mines and Mills Regulations, and Radiation Protection Regulations (CNSC 1997; CNSC 2000a; CNSC 2000d; CNSC 2000e);
- Regulatory Policy Statement P-223, Protection of the Environment (CNSC 2001);
- Regulatory Policy Statement P-290, Managing Radioactive Wastes (CNSC 2004);
- Regulatory Guide G-206, Financial Guarantees for the Decommissioning of Licensed Activities (CNSC 2000b);
- Regulatory Guide G-219, Decommissioning Planning for Licensed Activities (CNSC 2000c);
- Regulatory Guide G-320, Assessing the Long Term Safety of Radioactive Waste Management (CNSC 2006);
- Regulatory Document RD/GD-370, Management of Uranium Mine Waste Rock and Mill Tailings (CNSC 2012);
- Standard N294-09, Decommissioning of Facilities Containing Nuclear Substances, Canadian Standards Association (CSA 2009); and,
- Canadian Environmental Quality Guidelines (CCME 2002) which includes guidelines for water, sediment and soil quality.

Documentation specific to Nunavut which has been reviewed includes the following:

- Nunavut Waters and Nunavut Surface Rights Tribunal Act (GC 2002);
- Nunavut Water Board, Guide 4 – Completing and Submitting a Water Licence Application for a New Licence (NWB 2010);
- Northwest Territories Water Regulations SOR/93-303 (GC 1993);
- Mine Site Reclamation Policy for the Northwest Territories (INAC 2002);
- Mine Site Reclamation Guidelines for the Northwest Territories (INAC 2007);
- Nunavut Tunngavik Incorporated Reclamation Policy (NTI 2008); and,
- Environmental Guideline for Contaminated Site Remediation (GN 2009).

1.4 AREVA Intent

Decommissioning at AREVA's uranium mining sites in Canada involves the removal or stabilization of all constructed structures and the reclamation of disturbed areas such that:

- The environment is safe for non-human biota and human use;
- Long-term adverse effects are minimized;
- The reclaimed landscape is stable and self-sustaining; and,
- Restrictions on future land use are minimized.

In addition, any restrictions on future land use should not prevent traditional land use including casual access with trapping, hunting, or fishing as the primary site activities.

AREVA's decommissioning practice is to begin clean-up and reclamation on areas soon after mining or when other operations are complete. By having a progressive reclamation program during the mining and milling operational phase, a significant portion of work described in the PDP will be complete when operations cease.

In development of this Technical Appendix, AREVA also relied on experience gained developing and decommissioning Saskatchewan mining projects including: dialogue with provincial and federal regulators, various EIS's and support documents, preliminary decommissioning plans for the McClean Lake Operation and Midwest Project and the decommissioning activities undertaken at the Cluff Lake Project.

AREVA has carried out extensive stakeholder consultations (Tier 2, Volume 3, Public Engagement and Inuit Qaujimajatuqangit, Part 1, Public Engagement), and the project plans have benefited from the knowledge and advice resulting from these consultations. Existing processes for consulting stakeholders will be continued as the project progresses. AREVA notes that many of the comments received to date relate directly or indirectly to decommissioning and anticipates continued interest and input to this subject.

1.5 Financial Assurance

The purpose of the mine operator providing a financial assurance or financial security is to ensure neither the government (i.e. taxpayer), nor the landowner of lands leased for mining, are burdened with the cost of decommissioning a mining facility. In the event the operator becomes financially unable or unwilling to undertake or complete implementation of approved decommissioning plans, regulatory agencies would access funds provided as financial assurance and then oversee the decommissioning and reclamation work.

A cost estimate for implementation of the Mine Closure and Reclamation Plan is not required by the NIRB Guidelines. AREVA has developed this preliminary cost estimate both to be consistent with future licensing requirements for financial assurance, and to respond to interest about the decommissioning costs. Information on costing assumptions is contained in several documents, including CNSC Regulatory Guides G-206 and G-219, INAC Mine Site Reclamation Policy for Nunavut, and the NTI Reclamation Policy. Key common requirements are listed below:

- An independent contractor carries out the work;
- the value of salvageable material and ore reserves are not credited toward the cost of decommissioning; and,

- contingency allowances which vary from 5 to 25% are applied to the cost estimates. These allowances fall within the category of accurate estimates, based on CNSC Regulatory Guide No. G-206.

Section 7 summarizes the cost breakdown resulting from the current estimate of preliminary decommissioning costs. The total estimated cost is $159 million CAD. The decommissioning plan and cost estimate will be updated as part of the licence applications which will be required to construct the Kiggavik Project. Updates will incorporate decommissioning and reclamation requirements identified in the Project Certificate and project related licenses and permits.

1.6 Organization and Content

The content of Technical Appendix 2R of the DEIS has been retained for the FEIS, and additional information has been incorporated. This additional information comes primarily from supplemental information provided during the review process, mostly through responses to Information Requests and Technical Comments.

The original organization of Technical Appendix 2R of the DEIS has been retained to the extent practical, but some changes have been made to improve the integration of new information. The organization is described below.

- Section 1 Introduction
- Editorial revisions to the text
- Addition of Sub-section 1.6
- Section 2 Decommissioning Planning
- Applicable sub-sections from the DEIS Appendix 2R, with editorial revisions, and additional information have been grouped into this section which now focuses on decommissioning planning. The sub-sections describing supporting programs required to successfully manage decommissioning, and to protect health, safety and the environment during decommissioning, have been relocated to Section 5.
- Section 3 Ongoing Monitoring and Progressive Reclamation
- Editorial revisions to the text
- Expanded to include all major activities which are carried out during the operations phase in support of future decommissioning. For example, this section now includes additional information, provided by AREVA during the review process, on research programs implemented during operations to support future decommissioning.
- Section 4 Decommissioning Implementation
- Continues to describe the work generally associated with “decommissioning”. That is, the removal or stabilization of all constructed structures, and the reclamation and revegetation of disturbed areas . A sub-section has been added to address temporary or premature closure of the Kiggavik Project.

- Section 5 Supporting Programs
- Those sub-sections of Section 2 in DEIS Appendix 2R which described the management system, EHS, and other supporting programs are now Section 5 with some editorial revisions.
- Section 6 Post-Decommissioning Performance Predictions and Monitoring
- This section has been added in order to:
- Provide a brief summary and cross-references to the long-term predictions for the potential environmental effects from the decommissioned site. The methodology and results for these analyses were contained in other Volumes of the DEIS. From comments received, it is clear that linkages between the description for project decommissioning (Tier 2, Volume 2, Chapter 13 and Tier 3, Technical Appendix 2R) and the impact predictions in other Volumes should be provided in the FEIS.
- Consolidate information related to post-decommissioning monitoring, in order to incorporate additional information provided by AREVA during the review process, and to improve its alignment with the NIRB Guidelines.
- Section 7 Financial Assurance
- Preliminary cost estimate for decommissioning, previously Section 5 of DEIS Technical Appendix 2R.
- Section 8 References
- Updated list of references.
- Attachments A through E
- Incorporate additional information provided by AREVA during the review process.

2 Decommissioning Planning

2.1 Decommissioning Objectives

2.1.1 General

As outlined in Section 1.4, decommissioning involves the removal or stabilization of all constructed structures and the reclamation of disturbed areas. AREVA's key decommissioning objective is to remove, minimize, and control potential contaminant sources and thereby minimize the potential for adverse environmental effects associated with the decommissioned property. The preliminary decommissioning plan is designed to achieve a Project end-state that will be safe for human and non-human biota, be chemically and physically stable, allow utilization for traditional purposes, and minimize potential constraints on future land use planning decisions. AREVA believes that by progressively reclaiming the Project site as various mining areas are completed and addressing any environmental issues that arise within those areas during the operational phase that the need for care and maintenance activities and long-term institutional control can be minimized.

The preferred end state is a return to a revegetated natural setting with no visible industrial-made objects above surface. All above ground facilities will be removed while minimizing or eliminating immediate and long-term environmental, health, and safety hazards. This plan will return the site to an acceptable aesthetic state that is safe, physically and chemically stable, and meets radiological objectives in accordance with the *Nuclear Safety and Control Act* (CNSC1997).

Returning the area to a near undisturbed state is of paramount importance. To accomplish this, the following principles will be followed:

- Conduct all demolition activities with due regards to, and management of, environment, health and safety hazards to workers and to the environment,
- Recycle or dispose of any remaining chemicals, using existing operational practices and waste management procedures, and in accordance with all applicable provincial and federal regulations, and
- The decommissioning radiological objectives are based on the need to keep future radiation doses to the general public below the regulatory limits and consistent with the ALARA (as low as reasonably achievable) principle.

In general, decommissioning objectives for final landform features are:

- Regrading for geotechnically stable slopes (3:1 maximum) which are safe for human and wildlife access.
- Restoration of natural drainage patterns.
- Revegetation of disturbed areas similar to the natural surroundings.

2.1.2 Regulations, Criteria, and Guidelines

Criteria to which decommissioning activities will be subject:

- For water quality, the adoption of federal Canadian Council of Ministers of the Environment (CCME) Guidelines (CCME 2002) and provincial Saskatchewan Surface Water Quality Objectives (WSA 2006) as guidelines for downstream receiving waters in the absence of surface water quality guidelines. For specific aspects such as open pits, a site specific risk assessment will be conducted to determine water quality objectives for the protection of wildlife and public health.
- For sediment quality, CCME - Canadian Environmental Quality Guidelines (CCME 2002), Interim Sediment Quality Guidelines (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc) will be met at designated locations on-site, or where these objectives are not deemed appropriate, criteria will be established through consultation and scientific literature. Site specific sediment quality objectives will be developed at the time that the final Detailed Decommissioning Plan is prepared. This assessment and licensing process is expected to occur within the context of regional objectives and with a reliable inventory of chemical characteristics data, which will be available at that time.
- For air quality, Guideline: Air Quality - Sulphur Dioxide and Suspended Particulates (GN 2002) and the Canadian National Ambient Air Quality Objectives (HC 1994) will be met on-site;
- For open pits, criteria for in-pit water and sediment quality will be defined on a site-specific basis following further study and discussion with the regulatory agencies; and,
- The design criteria specified by Environmental Guidelines for Site Remediation, Department of Sustainable Development (GN 2009) for the decommissioning, cleanup and reclamation of northern mine sites.

In terms of post closure radiological safety, the regulatory requirement is to restore impacted areas to a level such that the incremental effective doses to traditional land users will not exceed 1 mSv per year above natural background levels. Radiological release criteria for decommissioning will be developed based on the results of a formal future land use assessment involving local stakeholders in the region. The analyses to develop the criteria will be based on the ALARA principle, incorporating a dose constraint of 0.3 mSv per year to ensure the public dose limit is not exceeded.

2.2 Integrated Approach to Environmental Protection

2.2.1 AREVA's Integrated Approach

As outlined in Technical Appendix 2T Environmental Management Plan, AREVA's Environmental Protection Framework provides an integrated approach to facility design, mitigation, and environmental assessment, and outlines how the outcomes of these processes are integrated into facility construction, operation and decommissioning. Furthermore, the Environmental Protection Framework outlines how the results of monitoring and follow-up programs are incorporated into evaluation processes which facilitate the identification of continual improvement initiatives and adaptive management requirements, when necessary. The framework also outlines the mechanisms by which these processes and initiatives are communicated to stakeholders. It can be seen that decommissioning is not an isolated phase of the project, but rather the final step in an integrated approach to environmental protection.

As part of the environmental assessment process, mitigation measures are incorporated into the Project to avoid and minimize potential adverse environmental effects. Mitigation measures consist of industry best technologies and practices and incorporate the learning-based experiences of other development projects. Mitigation measures can generally be classified as mitigation by design, and mitigation by management, as outlined in Table 2.3-1.

2.2.2 Designing for Decommissioning

Decommissioning is not an isolated phase of the project. The project starts with a "design for decommissioning" approach which considers the end state of facilities during the design process. Facilities are then constructed and operated to achieve the predicted performance, so that decommissioning represents the final step in an integrated approach to environmental protection. This environmental framework is further detailed in Tier 1, Volume 1, Main Document, Section 1.6.2.

2.2.3 Operational Performance Evaluation

Thus, while the end-state broad goals for decommissioning and criteria for success may be simply stated, the requirements for achieving success are embedded within the facilities designs, and in processes (with their own goals and criteria for success) to be followed during the construction and operations phases. For example, one of the requirements for long-term protection of surface water is adequate containment of constituents of potential concern (COPCs) within the tailings mass. This will be achieved by the use of in-pit TMFs (a project design decision), by engineering the tailings geotechnical and geochemical characteristics during operations through the tailings preparation and placement processes, and by placement of a cover of local natural soil and waste rock during decommissioning. While final contouring and revegetation of the cover are important to achieving a stable and self-sustaining landscape with an aesthetic appearance similar to the natural surroundings, the cover design and shape has little effect on COPC containment. COPC containment is substantially dependent on the original design choice of in-pit TMFs, and the operational processes for tailings engineering. It is impractical to repeat all of the information related to this integrated approach to environmental protection in the Preliminary Decommissioning Plan. The appropriate other sections of the FEIS are referenced in Table 2.3-1.

2.3 Significant Decommissioning Concerns and Proposed Mitigation

2.3.1 Summary of Concerns and Proposed Mitigation

Table 2.3-1 lists the significant closure and reclamation concerns and the proposed mitigation actions and provides a reference location for further detail. Further information on AREVA's integrated environmental protection framework is outlined in Technical Appendix 2T Environmental Management Plan.

Table 2.3-1 Significant Decommissioning Concerns and Proposed Mitigation Actions

Concern	Mitigation Type	Proposed Mitigation	Phase of Mine Life	Reference
Erosion Control	Design, Management	Erosion control incorporated into facility design Regrading of disturbed areas, restoration of natural drainage patterns, and revegetation. Progressive reclamation when practical	Construction, Operations, Decommissioning	Volume 2 – Project Description, Volume 2 Appendices, and Appendix 5O
Tailings Management				
Physical containment	Design	Conversion of mined out pits to TMFs TMF closure cover to isolate tailings from environment	Construction, Operations Decommissioning	Volume 5 - Appendix 5J
COPC containment	Design	Hydraulic containment during operations Tailings geochemical and geotechnical characteristics engineered through tailings preparation and placement processes for optimal long term performance following TMF closure. Long term performance analyzed with and without permafrost continuation	Operations	
			Decommissioning	

Table 2.3-1 Significant Decommissioning Concerns and Proposed Mitigation Actions

Concern	Mitigation Type	Proposed Mitigation	Phase of Mine Life	Reference
Mine Rock Management				
Potential for metals leaching and/or ARD	Design	All of the mine rock will be segregated for safe and environmentally sound management according to its geochemical characteristics (Type 1, Type 2, Type 3)	Operations	Volume 5 - Appendix 5F
		Type 3 mine rock will be temporarily stored on a lined pad with runoff collection for treatment.	Operations	
		Type 3 mine rock will subsequently be disposed in mined out pits (with tailings in a TMF at the Kiggavik site, and in the Andrew Lake pit at the Sissons site), Disposal below the water table to prevent exposure to atmospheric oxygen is widely recognized as best practice to minimize metals leaching and prevent ARD resulting from continuing oxidation of the mineralization in Type 3 mine rock.	Decommissioning	
Surface mine rock stockpiles	Management	Type 2 mine rock, and Type 1 mine rock surplus to construction, uses does not pose environmental risk due to metals leaching and/or ARD formation, and will be managed in surface stockpiles.	Construction, Operations	
		Surface stockpiles will either be constructed with geotecnically stable (3:1) slopes, or recontoured after completion of mining.	Decommissioning	
		Surface stockpiles will be revegetated for aesthetic appearance similar to the surrounding land.	Decommissioning	
Industrial Waste Management	Management	Industrial wastes will be sorted into different categories and each category appropriately managed as per the Waste Management Plan. Materials salvaged at decommissioning for off-site recycle, reuse, or return to supplier will be monitored to confirm that regulatory requirements for removal off-site are met. Wastes resulting from	Construction, Operations, and Decommissioning Decommissioning Decommissioning	Volume 2 - Appendix 2S and Appendix 2R

Table 2.3-1 Significant Decommissioning Concerns and Proposed Mitigation Actions

Concern	Mitigation Type	Proposed Mitigation	Phase of Mine Life	Reference
		dismantling/demolition of buildings, equipment and site infrastructure facilities will be disposed in a TMF at the Kiggavik site or with Type 3 mine rock in the Andrew Lake pit.		
Liquid Effluent Release				
Effects in the receiving environment	Design, Management	The quantity and quality of treated liquid effluent released to the environment will be maintained within the envelope used in the integrated Ecological Risk Assessment/Health Risk Assessment (ERA/HRA), so that there will be no need for remediation of sediments, or other parts of the natural environment, at decommissioning.	Construction, Operations, and Decommissioning	Volume 8 – Appendix 8A
Facility decommissioning	Management	All materials associated with the collection and treatment of contaminated water will be removed and disposed of during decommissioning, This includes not only the WTPs, but also collection ditches and ponds, pipelines, HPDE or other liners when present, and any other materials potentially contaminated by contact with contaminated water.	Decommissioning	Volume 2 – Appendix 2R
Revegetation	Management	Revegetation is important to achieving a stable and self-sustaining landscape with an aesthetic appearance similar to the natural surroundings. Revegetation will be used to mitigate erosion of reclaimed areas.	Decommissioning	Volume 2 - Appendix 2R
Long-term Risk Assessment (including Radiological Safety)				
Assessment for routine releases of gaseous and liquid effluents	Design	The integrated ERA/HRA assesses the impacts from routine releases of gaseous and liquid effluents.	Construction, Operations	Volume 8 – Appendix 8A
	Management	No significantly adverse effects are predicted, so there are no remediation requirements at decommissioning.	Decommissioning	
Accidents and malfunctions Residual	Management	All necessary remediation will be carried out at the locations of spills and leaks immediately after the occurrence, so that there will be no outstanding requirements at decommissioning.	Construction, Operations, and Decommissioning	Volume 10 – Appendix 10B

Table 2.3-1 Significant Decommissioning Concerns and Proposed Mitigation Actions

Concern	Mitigation Type	Proposed Mitigation	Phase of Mine Life	Reference
contamination of soils at operational sites		All material that could pose a health risk to people and/or wildlife at operational areas will be removed and disposed in a TMF or covered with clean rock and/or soil.	Decommissioning	Volume 2 – Appendix 2R
		The CNSC requirement is that the 1 mSv/a dose limit for a member of the public must not be exceeded by exposure to any small amounts of residual material with radioactivity contents above natural background amounts. Any actual doses will be less than the limit, because a further CNSC requirement is that an analysis be done to show that remedial measures meet the ALARA (As Low As Reasonably Achievable) principle for radiation protection.	Decommissioning	CNSC Radiation Protection Regulations
		AREVA has directly relevant experience from decommissioning the Cluff Lake site in consulting local community representatives to establish what the future uses of the site will be after decommissioning, performing the ALARA analyses, and performing detailed field surveys of gamma radiation levels at the decommissioned site to show compliance with the CNSC requirements.	Decommissioning	Volume 2 – Appendix 2R
Environmental Management System	Management	All of AREVA's operations have an IMS system which meets all regulatory and internal requirements, and additionally, is certified to the international ISO 14001 standard.	Construction, Operations and Decommissioning	Volume 2 - Appendix 2T

2.3.2 Consideration of Alternatives

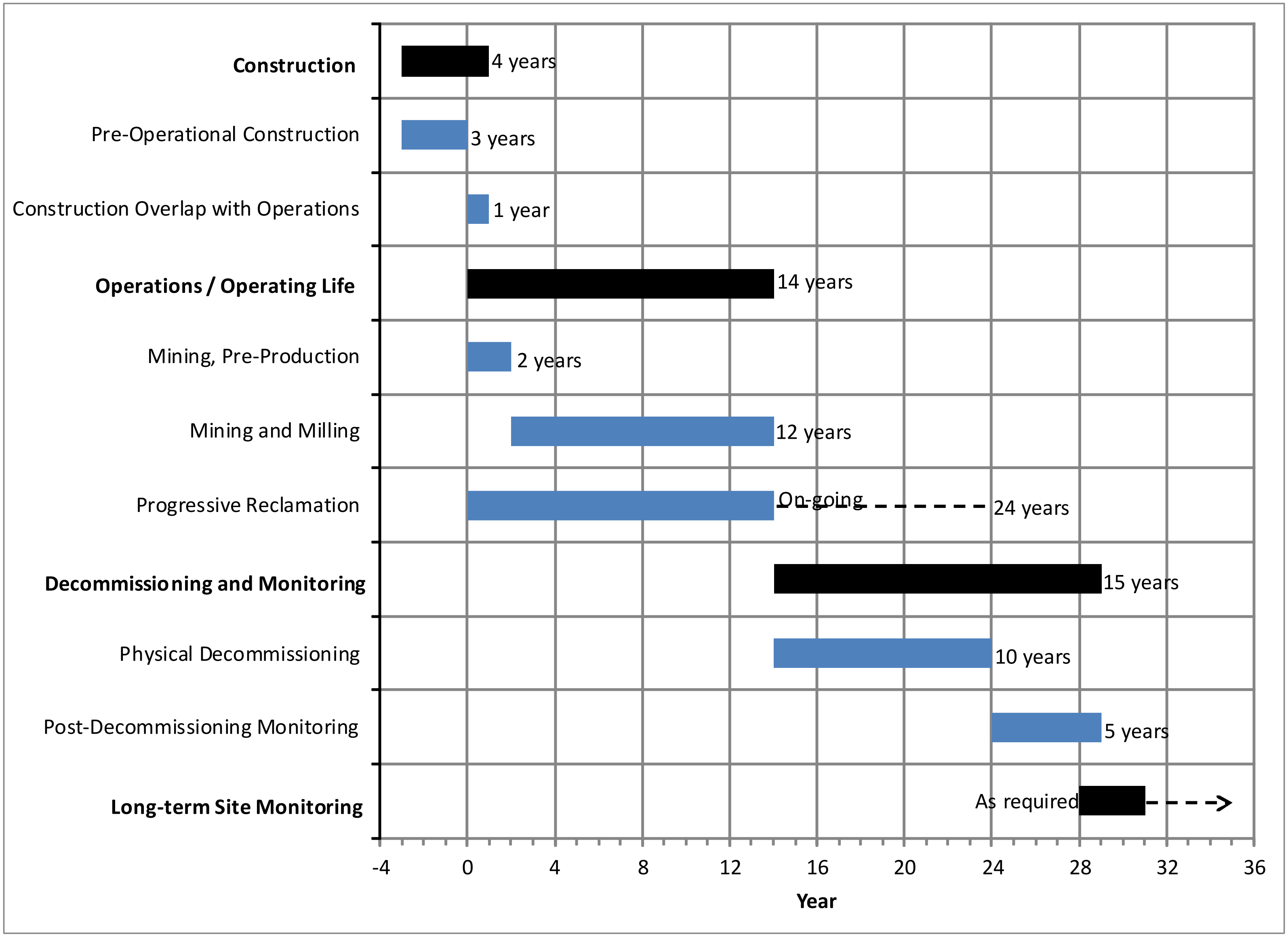
Alternatives for implementing various aspects of the Kiggavik Project are discussed in Technical Appendix 2A Alternatives Assessment. Numerous criteria were used to evaluate alternatives; these criteria can be broadly summarized as follows:

- Potential effects on the physical environment, including groundwater, surface water, geology, terrain, air quality, and noise;
- Potential effects on the biological environment, including fauna and flora;
- Potential effects on socio-economics, including demographics, employment and family;
- Potential effects on land use, including harvesting, recreational and community uses;
- Potential effects on culture;
- Public acceptability;
- Technical challenges and considerations; and,
- Economics.

Decisions on alternatives are made at the Project design stage, so that the discussion on alternatives in Technical Appendix 2A has no impact on decommissioning. Thus, Section 15 of Technical Appendix 2A, which briefly describes the approach to decommissioning and reclamation is adopted from this Technical Appendix 2R.

2.4 Schedule

The anticipated schedule for the Kiggavik Project, based on a projected 14-year operating life, is shown in Figure 2.4-1 below and is discussed in Volume 2 Project Description, Section 4.5. The figure indicates the anticipated 10-year period for physical decommissioning activities followed by a 5-year period of post-decommissioning monitoring. The preliminary schedule of decommissioning activities is discussed further in Section 4.2.1.



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Date: 9/15/2014

FIGURE 2.4-1
PROJECT SCHEDULE OVERVIEW

ENVIRONMENTAL IMPACT STATEMENT
APPENDIX 2R

KIGGAVIK PROJECT

AREVA

AREVA Resources Canada Inc - P.O. Box 9204 - 817 - 45th Street West - Saskatoon, SK - S7K 3X5

File: Q:\SHEQ\GIS\KIGGAVIK\2014\EIS\Volume 2 - Project Description\Volume 2 - Tier 3\Appendix 2R - Preliminary Decommissioning Plan\Maps\MXD\Figure 2.4-1 Project Schedule Overview.mxd

2.5 Research Programs

Four research programs are important to validating key assumptions related to predictions of long-term performance of the decommissioned facilities:

1. Tailings Optimization and Validation Program (TOVP): To validate that produced tailings achieve the required geotechnical and geochemical characteristics and to optimize the tailings preparation and placement process (Technical Appendix 5J Tailings Characterization and Management).
2. Mine Rock Optimization and Validation Program (MROVP): To validate that the Type 1 and Type 2 mine rock stockpiles do not pose significant environmental risk due to metals leaching or acid rock drainage and validate the Type 3 mine rock pore water characteristics (Technical Appendix 5F Mine Rock Characterization and Management).
3. Environmental Performance Reporting: It is anticipated by AREVA that the regulatory agencies will require periodic reports which will provide a series of comprehensive "snapshots" of environmental parameters at, and near to, the Project site. Successive reports will show any changes over time relative to baseline conditions. At AREVA's northern Saskatchewan operations, these reports are called Environmental Performance reports. Although the basic Environmental Performance reports are not a research activity, AREVA uses the data collected for these reports on an iterative basis to review, and update as warranted, the models and input parameters used in the Ecological and Human Integrated Risk Assessment (ERA/HRA). From time to time, a small focused research project may be required to further clarify models and/or input parameters.
4. Revegetation: AREVA acknowledges that a site specific research program is needed to optimize revegetation of disturbed areas. AREVA's commitments with respect to vegetation are to implement progressive reclamation at the earliest practical times and to establish a research program to identify and refine best practices for revegetation, specific to the Project site. The research program will utilize both field experience at progressive reclamation sites, and follow-up/benchmarking with other Arctic sites. This will also be a topic in ongoing consultations with community representatives.

2.6 Operational Record Keeping

Operational records will be maintained during operations for the purpose of updating this Preliminary Decommissioning Plan and to assist in the preparation of the final Detailed Decommissioning Plan prior to actual decommissioning. Operational records will include:

- Records of spills and cleanups;
- Inventories of reagents and chemicals;
- Locations of waste disposal grounds and inventories of waste material;
- Locations and inventories of reusable material storage areas;

- Results of investigations and studies such as the Tailings Optimization and Validation Program;
- Locations of revegetation areas and the relative success of various revegetation efforts;
- Radiation survey data; and,
- Environmental monitoring data collected as part of the Environmental Monitoring Program.

2.7 Reclamation Planning

2.7.1 End State

As the sites are remotely located, subsequent developed land uses are not probable; therefore, the planned end-state is a landscape similar to the surrounding natural setting, safe for wildlife, and with no constraints on carrying out traditional uses such as hunting and trapping. Security of the tailings, potentially problematic (Type 3) mine rock, and other contaminated materials will have been established by depositing these materials into mined out pits (the TMFs and the Andrew Lake pit), and closing these facilities with covers to isolate the contaminated materials from humans and the environment. Detailed surveys will be carried out throughout all disturbed areas to confirm that there are no significant risks to wildlife or humans from any residual materials. The sites will continue to be safe for traditional use by future generations of indigenous people with minimal future institutional control. AREVA anticipates providing a perpetual care fund for these minimal requirements.

It should be noted that due to the severe climate conditions, including short growing season and high winds, and due to the limited surface soils, revegetation of impacted areas will not occur as quickly or to the extent that is seen in northern Saskatchewan operations; therefore, AREVA will take precautions to minimize the loss of permafrost and the impacts on vegetation in disturbed areas in order to reduce the amount of future reclamation required.

2.7.2 Scope of Reclamation Activities

At the end of operations, key areas and facility components will be inspected and detailed decommissioning objectives developed. Generally, decommissioning activities conducted to achieve the preferred end state would include the following:

- Removal of all buildings by dismantling, salvaging or disposing into a TMF (Kiggavik area) or the Andrew Lake pit (Sissons area);
- Removal of all building contents; salvaging where practical and landfilling where impractical;
- Closure of the TMFs;
- Removal of all surface pipelines and culverts for salvage or disposal;

- Treatment of water from settling ponds to regulated effluent release quality;
- Deposition of radiologically or chemically contaminated materials, including the accumulated contents of the contaminated landfill and any unreclaimed materials from the landfarm, into the TMFs;
- Disposal of mill reagents and remaining materials at the hazardous waste pad according to license and regulatory conditions or return materials to supplier for recycling;
- Decommissioning and closure of the End grid underground mine including plugging the portal and all ventilation raises (and shaft if one is used);
- Kiggavik and Sissons water treatment plants will be dismantled and the building materials and sludges from treating TMF consolidation water will be disposed of in the Main Zone TMF under the final TMF cover;
- Removal and burial of sediments and HDPE liners from the settling ponds into the Main Zone TMF;
- Disposal of Kiggavik Type 3 mine rock into the TMFs;
- Disposal of Type 3 mine rock into the Andrew Lake open pit and construct cover;
- Breaching and subsequent removal of Andrew Lake dewatering structure and re-establishment of natural flow patterns;
- Dismantling the incinerator, covering all domestic and industrial landfills, and disposal of remaining materials and closing the landfarm and the sewage solids storage area;
- Fracturing and burial of concrete foundations and slabs;
- Re-contouring earthworks to a natural appearance with slopes generally less than 3H:1V;
- Removal of culverts from roads and re-establishment of natural flow paths;
- Re-contouring those sections of road which have steep gradients and/or ditch slopes;
- Re-establishment of indigenous vegetation while making the best practical usage of plants which have established on their own;
- Processing, continued storage or disposal of core samples dependent upon direction from the Territory;
- Removal of soils with elevated radioactivity in cleared areas; and,
- Confirmation of acceptable radiological conditions based on clearance criterion.

Once decommissioning of an area has been completed, visual inspection of the site will confirm the state of completion of decommissioning activities. Greater detail is presented in Chapter 4 of this PDP.

2.7.3 Topography and Hydrology Considerations

The site is located in the “Barrenlands”, well north of the tree line in the continuous permafrost zone. For the most part, the area has a gently rolling topography with a few low escarpments associated mainly with east-west trending faults.

The Kiggavik and Sissons deposits are located within the Anigaq River watershed which is located within the Hudson Bay drainage basin. The streams within the Anigaq River watershed eventually flow into the Anigaq River, which drains into the western edge of Baker Lake. Baker Lake drains into Chesterfield Inlet, which further drains into Hudson Bay. Watersheds that are adjacent to that of the Anigaq River system include the Thelon River and Qinguq Creek, both of which drain into Baker Lake.

2.7.4 Restoration of Natural Aesthetics

On completion of mining and milling activities, the project site area will be returned to a re-vegetated state similar to its surroundings. The decommissioning plans include demolition and removal of site facilities and cleaning of all site areas that may have become contaminated. For example, closure of the TMFs will include the placement of a layer of sand and an erosion barrier of waste rock over the tailings. The surface of the final cover will be graded to blend into the existing topography and re-vegetated. Closure of the mine rock stockpiles will include re-contouring to a long-term stable slope, promoting natural succession of native vegetation, and providing conditions for wildlife access. Upon completion, the surface landscape will blend in with the surrounding landforms to the extent that there will be minimal long-term alteration of the area.

2.7.5 Landform Stability

Landforms will be constructed in order to meet appropriate physical stability criteria. For example, permanent mine rock stockpiles will be constructed in a layered approach to increase stability while minimizing segregation and settlement. Upon decommissioning, the primary landforms remaining will consist of permanent mine rock stockpiles, covers at decommissioned tailings management facilities, sealed openings to the End Grid underground mine, and quarries and borrow pits. Post-closure physical stability monitoring will be conducted to ensure long-term stability of these reclaimed sites.

2.8 Mine Rock Mass Balance

It is noted that all Type 3 mine rock will be safely disposed of in the TMFs or in the mined out Andrew Lake pit. An estimated production mining rate for rock and overburden material quantities is provided in Volume 2 Project Description, Table 5.2-1, and total volumes are provided in Table 6.5-1. Type 1 and Type 2 mine rock volumes are not a significant factor in achieving satisfactory long-term performance for environmental protection.

As indicated in Volume 2 Project Description, Section 6.7, investigation into the geochemical properties of mine rock at the Kiggavik and Sissons sites will continue during operation as part of a Mine Rock Optimization and Validation Program (MROVP). This program will focus on Type 3 mine rock and will provide further insight into the geochemical characteristics of the materials to validate AREVA's proposed long-term management plan.

2.9 Updating the PDP

The Preliminary Decommissioning Plan (PDP) and financial assurance (FA) will be regularly updated over the life of the Project to reflect a FA based on technically feasible decommissioning activities which will achieve the decommissioning objectives for the current Project phase. The final decommissioning detail will not become available until the PDP and FA are advanced to the Detailed Decommissioning Plan (DDP) at the time of Project closure.

At such time that ore reserves are exhausted and the operational phase of the Project is completed, AREVA would file an application with the CNSC, NWB, and KIA (landowner) for final decommissioning of the Kiggavik Project. The PDP would be updated to include specific details regarding the detailed decommissioning of each area affected by the Project in a DDP to support the decommissioning application. It is AREVA's intention that the DDP would facilitate a seamless transition from operations to decommissioning phases. Detail such as decommissioning drawings, revegetation plans, and scheduling of individual decommissioning tasks will be provided in the DDP.

3 Ongoing Monitoring and Progressive Reclamation

ARC's strategy is to maximize reclamation activities during the operational life of the mine site. This approach offers several distinct advantages including the opportunity to identify technically challenging issues well enough in advance that required alterations and adaptations do not become time-critical. Site reclamation will be more advanced and easier to manage should circumstances result in AREVA's inability to complete reclamation activities. This on-going reclamation program will ensure that, when the entire site is ready for decommissioning at the end of the Project, AREVA will have gained valuable experience in reclamation in the Arctic environment. This Arctic experience will expand on the experience already gained from the Cluff Lake site decommissioning and progressive reclamation work performed at other AREVA-operated northern mines.

With this approach, equipment and manpower will be present to perform works and to manage and tend to minor issues such as erosion over a long time span thereby producing a very stable final condition by the time final decommissioning begins. By tending to contamination issues such as minor petroleum or chemical spills in a complete manner at the time of occurrence, there will not be an accumulating and increasingly difficult remedial requirement into the future.Radiological surveys will be conducted periodically and clean-up activities conducted accordingly to prevent accumulation or spread of radiological contamination.

An important complementary part of preparing for decommissioning starts with the design of the Project. That is, decommissioning is not an isolated phase of the project, but rather starts with a "design for decommissioning" approach. The facilities are then constructed and operated to achieve the predicted performance, so that decommissioning represents the final step in an integrated approach to environmental protection. This approach is discussed in Volume 1 Main Document, Section 1.6.2.

This section identifies the major activities carried out during earlier stages of the Project to support final decommissioning.

3.1 Mine Rock Characterization and Segregation

Due to the large volume of mine rock, it is important that mine rock be characterized and appropriately segregated as it is mined. This section briefly describes this activity. Further detail is provided in Technical Appendix 5F Mine Rock Characterization and Management.

3.1.1 Mine Rock Characterization

A study was conducted to characterize the low grade material from the Kiggavik and Sissons deposits, to assess the leaching behaviour and to compare the results with those from other uranium deposits in Northern Saskatchewan. The results are utilized in decisions regarding the use of mine rock, stockpile designs and decommissioning activities. The clean Type 1 and Type 2 mine rock at Kiggavik and Sissons was also investigated to ensure that water quality from potential construction material and on-land stockpiles will not be at risk for contamination by leaching.

The mine rock characterization study was conducted mainly in the laboratory and involved chemical analyses of the rock, including metal analysis, acid base accounting (ABA), humidity cell testing, customized leach tests to assess metal leaching, and flooded column tests to evaluate the “equilibrium” concentrations of metals in pore water for an in-pit disposal scenario. Table 3.1-1 provides a summary of the various mine rock material expected to be excavated during the development of the Kiggavik and Sissons deposits and the segregation criteria.

Based on the mine rock characterization study results, Type 1 mine rock is expected to be suitable for general construction and will be used, when available, during construction of haul roads, pads, berms, etc.

3.1.2 Mine Rock Segregation

Segregation of mine rock will be conducted during mining operations based on the criteria presented in Table 3.1-1. This will ensure that all potentially problematic mine rock is disposed of appropriately for the long-term protection of the environment.

Table 3.1-1 Mine Rock Segregation Criteria

Type	Description	Criteria
Mine Rock Type 1	Mine rock that can be used as construction material	U < 40 mg/kg S < 0.1 %
Mine Rock Type 2	Mine rock that can be permanently stockpiled and managed above ground	U < 250 mg/kg S < 0.1 %
Mine Rock Type 3	Potentially problematic mine rock that requires specific management (i.e., in-pit disposal)	U > 250 mg/kg and/or S > 0.1% All material not considered to be Type 1 or Type 2 as described above or not considered to be ore
Ore	Cut-off	U >900 mg/kg pending market condition when operation starts

Notes:
U: Uranium content in milligrams per kilogram (mg/kg)
S: total sulphur content in percent

During open pit mining, waste rock will be segregated according to uranium grade as determined by radiometric scanning. Operational procedures will be used to ensure that special waste and clean waste rock are effectively categorized, separated and transported to the appropriate stockpile area. Segregation of waste rock is based on the following:

- systematic radiometric scanning of blast hole cuttings in clean waste zones to detect anomalous radioactivity levels;
- systematic sampling of blast hole cuttings and if necessary analysis by the X-ray fluorescence (XRF) method to detect anomalous metal content (e.g., uranium, arsenic);
- radiometric probing of blast holes in ore zones to define ore/waste boundaries;
- radiometric scanning of working faces during excavation to confirm blast hole scanning/probing results;
- overhead scanning of waste rock in the proximity of special waste or ore once loaded onto trucks;
- daily scanning of the clean waste rock disposal area to ensure that no special waste or ore was inadvertently placed; and,
- systematic sampling to assess acid generation potential of clean waste rock.

The uranium content of mine rock is estimated in the field by radiometric techniques and subsequently confirmed with drill cutting assay results. In addition, X-ray fluorescence (XRF) technology has been identified as a reliable field evaluation tool that can be used to directly determine potentially problematic metals in waste rock during mining. The XRF technology has greatly advanced in recent years, and it is generally accepted as a quantitative screening tool for environmental investigations and industrial site clean-up activities.

The above measures were successfully used to segregate “special waste” and “clean waste rock” at the McClean Lake Operation and it is proposed to apply them during mining of the Kiggavik and Andrew Lake deposits. Type 1 and Type 2 mine rock material will be placed in designated mine rock stockpiles. In the event that mine rock may not effectively be segregated, all questionable mine rock would be considered Type 3 mine rock, temporarily stockpiled, and subsequently disposed of in the Main Zone TMF or the Andrew Lake open pit during decommissioning.

Sampling and analyses of surface runoff and porewater at Type 1/Type 2 mine rock stockpiles will be initiated as the stockpiles are constructed. This is a component of the overall Mine Rock Optimization and Validation Program (MROVP).

3.1.3 Temporary Mine Rock Stockpiles

All potentially problematic mine rock (Type 3) excavated during mining at the Kiggavik and Sissons sites will be placed in temporary surface stockpiles. This material will then be placed on top of the tailings in the Main Zone TMF or deposited in the mined out Andrew Lake pit during the decommissioning phase. The volume of Type 3 mine rock, after excavation, is conservatively estimated to be 0.8 Mm3 at the Kiggavik site and 1.0 Mm3 at the Sissons site (see Table 6.5-1 of Volume 2 Project Description). The temporary mine rock stockpiles will be located as shown in Figures 4.4-1 and 4.4-3 of Volume 2 Project Description. Runoff and water percolating through the pile will be collected using ditches and a collection pond, such that the water can be recycled for use in the mill and/or treated before release.

3.1.4 Core Storage Areas

It is expected that exploration at AREVA sites will continue through a significant portion of the Project lifetime. Drill core will thus continue to accumulate.

The Government of Nunavut requires that all core remain on site when operations cease and the land is returned to the landowner. AREVA proposes that the portion of the core that exceeds radiological clearance standards for reclaimed areas of the site be disposed of by processing it through the Kiggavik mill or disposed of in a TMF depending upon the timing of cessation of operations. The racks, fences and buildings will be disposed of in a TMF.

3.2 Solid Waste Management

Segregation of solid wastes into various types will be initiated at the start of the Project and continue until generation of each type ceases. Management of the various waste types is described in Technical Appendix 2S Waste Management Plan.

3.3 Tailings Management

It is expected that the East Zone TMF will be filled with tailings early in the Project lifetime. Closure and reclamation of this TMF is thus expected to be completed during the Project operational phase. Closure of the Centre Zone TMF is also expected to begin during the operational phase. Depending on when closure is initiated, and on how long it takes for tailings consolidation, final reclamation of the Centre Zone TMF may extend into the decommissioning phase. This progressive reclamation of the East and Centre Zone TMFs will provide valuable information to optimize closure and reclamation of the Main Zone TMF during decommissioning.

Extensive investigations into the geochemical and geotechnical properties of tailings has been undertaken at Kiggavik and will continue to be undertaken as part of a Tailings Optimization and Validation Program (TOVP), similar to the program that was initiated at McClean Lake Operation, which has been a successful program for understanding and optimizing the behaviour of tailings produced at that site in Northern Saskatchewan.

Tailings characterization and management and the TOVP program are discussed in detail in Technical Appendix 5J.

3.4 Control and Monitoring of Effluent Release

Effects on surface water quality and potential toxicity to aquatic biota from treated effluent release will be mitigated by the design and operation of the water treatment plants (WTPs). The design of the WTPs will focus on the production of treated effluent which meets regulatory requirements and achieves surface water quality guidelines. Both effluent quality and the receiving environment will be monitored to ensure satisfactory WTP performance. This monitoring program will be carried out in each section of Judge Sissons Lake receiving treated effluent, as well as at the outlet of Judge Sissons Lake.

Aquatic organisms and fish populations will also be monitored regularly during mine operation, closure, and post-closure to determine whether effluent discharge from the WTPs are having measurable effects on valued ecosystem components. Under MMER, AREVA is required to conduct environmental effects monitoring (EEM) to determine if effluent release is having an effect on the receiving environment. The objective of EEM is to evaluate the effects of effluents on fish, fish habitat, and the use of fisheries resources by humans. These regulations require monitoring of effluent chemistry, effluent toxicity, and water quality in the receiving environment. The design of the aquatic receiving environment programs at the Kiggavik and Sissons Mines will be compliant with EEM guidelines but will be designed as an adaptive process taking into account the special issues in Northern Canada. Further information on effluent quality monitoring and EEM is discussed in Volume 5 Aquatic Environment.

During the final closure phase of the Project, there will be an ongoing requirement for water withdrawal, and effluent treatment and discharge (including domestic wastewater). The quality of site drainage and runoff waters, and porewater expelled from tailings during consolidation, will necessitate treatment before it can be discharged to the environment. Water treatment may be required for a number of years before tailings consolidation is complete and before the quality of untreated site drainage and runoff reaches a level where it can be allowed to flow directly into natural receiving waters.

3.5 Reclamation of Disturbed Areas

The AREVA decommissioning policy is to begin clean-up and reclamation in areas soon after mining or when other operations are complete. By having a progressive reclamation program during the milling and mining operational phase, a significant portion of work described in this PDP will be complete when operations cease. As stated in Section 1.4, decommissioning at AREVA's uranium mining sites in Canada involves the removal or stabilization of all constructed structures and the reclamation of disturbed areas such that:

- The environment is safe for non-human biota and human use;
- Long-term adverse effects are minimized;
- The reclaimed landscape is stable and self-sustaining; and,
- Restrictions on future land use are minimized.

In development of the PDP for the Kiggavik Project, AREVA also relied on experience gained developing and decommissioning Saskatchewan mining projects including dialogue with provincial and federal regulators, various EISs and support documents, preliminary decommissioning plan for the McClean Lake Operation (AREVA 2010b), and the actual decommissioning activities undertaken at the Cluff Lake Project.

Closure of the TMFs will be implemented as a progressive closure program as tailings deposition and consolidation occur. For instance, closure of the East Zone TMF will be implemented during the operational phase, while the Main Zone TMF will be closed and decommissioned upon termination of the milling operation. Closure activities will be conducted with the objectives of:

- stabilizing the surface of the tailings and prevent wind and water erosion;
- controlling the release of contaminants over the long-term; and,
- developing sustainable landforms comparable with local topography.

The Type 1/Type 2 mine rock stockpiles at both the Kiggavik and Sissons sites will be re-contoured to stable slopes and covered to encourage revegetation. AREVA will conduct studies on mine rock test plots during the operations phase to evaluate methods of revegetation. Mine rock stockpiles will be progressively reclaimed where possible. Surface drainage channels will be removed where possible and left in place where necessary to prevent ponding around the mine rock piles.

Progressive reclamation will also be carried out at borrow pits and quarries once there is no further need for them, and for any other surface disturbed areas once their use has been completed. These progressive reclamation acitivities will facilitate the revegetation research program described in Section 2.5.

Efforts to reclaim gravel pads and roads in Alaska (Peterson 2001) indicate various methods that have been used to optimize vegetation recovery in an Arctic environment. Successful methods identified the importance of fertilization and the use of indigenous vegetation. As a result, successfully revegetated areas have been observed to be increasingly frequented by wildlife. The progressive reclamation and revegetation studies proposed in Section 4.2.10 aim to achieve similar results for future reclaimed areas at the Kiggavik Project.

4 Decommissioning Implementation

4.1 Introduction

This section describes the activities which will be carried out during a 10-year physical decommissioning period, commencing at the end of milling operations. It is divided into four parts, beginning with a discussion of decommissioning logistics and Project components. Activities in each of the three major planning envelopes are then described.

4.2 Decommissioning Logistics and Project Components

4.2.1 Activities and Schedule

Decommissioning the Project area will involve four stages. The first stage is progressive reclamation carried out during the operational stage. This will also include the preparation of a Detailed Decommissioning Plan (DDP) for the Kiggavik Project. The second stage will include demolition of all buildings/facilities that are not required for continued monitoring and closure of all waste management facilities, including TMFs and WTPs. The third stage will be monitoring of the site to ensure that decommissioning objectives have been met. This stage will conclude with the demolition of remaining buildings required during the monitoring program. The final stage will be long-term monitoring on a campaign basis until the site is transferred to institutional control.

The PDP includes preliminary information and cost estimates for three planning envelopes. The planning envelopes cover the decommissioning activities associated with the following project components:

- Planning Envelope 1 – Kiggavik site

    - East and Centre Zone TMFs
    - Main Zone TMF
    - Permanent Type 1/Type 2 mine rock stockpiles
    - Mill/Camp/Maintenance complex
    - Concrete foundations and pads
    - Concrete batch plant area
    - Ore and temporary Type 3 mine rock pads
    - Kiggavik effluent treatment system
    - Solid waste management areas and facilities
    - Fuel and waste oil tanks
    - Explosive plant and magazine

- Airstrip and associated buildings

- Planning Envelope 2 – Sissons site
  - Andrew Lake open pit
  - Buildings
  - Permanent Type 1/Type 2 mine rock stockpiles
  - Ore and temporary Type 3 mine rock pads
  - Sissons effluent treatment system
  - Solid waste management areas and facilities
  - End Grid underground mine, including portal and ventilation raises
  - Fuel and waste oil tanks

- Planning Envelope 3 – Baker Lake and Staging Facilities
  - Baker Lake dock site and storage facilities
  - Winter road
  - All-season road (if constructed)

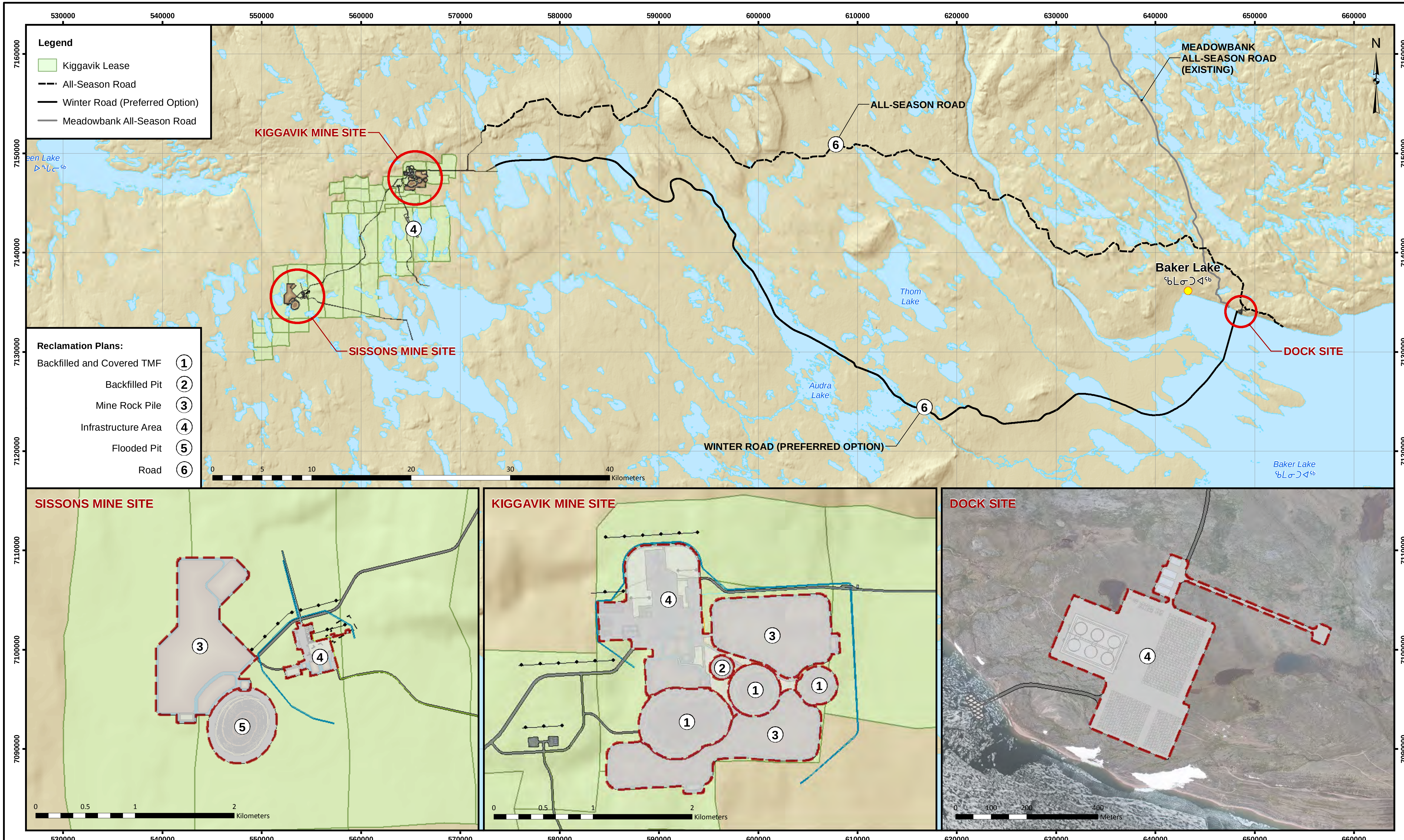
Table 4.2-1 and Figure 4.2-1 provide an overview of the proposed decommissioning activities and schedule subject to the decommissioning licence approval.

Table 4.2-1 Overview of Decommissioning Activities and Schedule

Phase	Timing	Key Activities
Progressive Reclamation	On-going Throughout Operations and Decommissioning	• Grading and reclamation of completed borrow pits and quarries • Ongoing characterization and segregation of mine rock produced • Tailings Optimization and Validation Program (TOVP) • Mine Rock Optimization and Validation Program (MROVP) • Closure and reclamation of East Zone and Centre Zone TMFs • Reclamation and re-vegetation of disturbed areas • Develop and obtain regulatory approval for a Detailed Decommissioning Plan (DDP) prior to end of operations

Physical Decommissioning	10 Years	• In-Water Decommissioning:
		  • Construct freshwater diversion structure to flood Andrew Lake Pit
		  • Remove freshwater diversions and re-establish natural drainage
		  • Remove and reclaim surface water containment ponds
		  • Remove all in-water and shoreline structures
		  • Cease freshwater withdrawal and treated effluent discharge
		• On-Land Decommissioning:
		  • Removal of salvageable equipment and materials
		  • Demolition and removal of site buildings, foundations, and tanks
		  • Disposal of Type 3 mine rock and contaminated materials into TMFs or pits
		  • Backfilling of TMFs and treatment of consolidation pore water
		  • Stabilization of underground mine workings and closure of surface access
		  • Contouring and re-vegetation of permanent mine rock stockpiles and pads
		  • Construct covers on industrial landfills and TMFs
		  • Re-vegetation of reclaimed areas
		  • Ongoing mine rock and tailings optimization and validation (MROVP/TOVP)

Post-Decommissioning	5 Years	• Remaining buildings offered to the local community • Post-decommissioning monitoring program • Radiological clearance surveys • Assess landform stability • Assess revegetation success • Complete Follow-up Program • Quantify any residual environmental effects • Transition to long-term campaign monitoring program
Long-Term Site Monitoring	As Required	• Perform long-term site monitoring program on a campaign basis until site transfer to institutional control



Projection: NAD 1983 UTM Zone 14N
Creator: CDC Revised: TL
Date: 07/03/2014 Scale:
Data Sources: *Natural Resources Canada, Geobase®, National Topographic Database, AREVA Resources Canada Inc.*

FIGURE 4.2-1
SUMMARY OF DECOMMISSIONING PLAN

ENVIRONMENTAL IMPACT STATEMENT
APPENDIX 2R - PRELIMINARY DECOMMISSIONING PLAN

Kiggavik Project
AREVA

AREVA Resources Canada Inc - P.O. Box 9204 - 817 - 45th Street West - Saskatoon, SK - S7K 3X5

File: Q:\SHEQ\GIS\KIGGAVIK\2014\EIS\Volume 2 - Project Description\Volume 2 - Tier 3\Appendix 2R - Preliminary Decommissioning Plan\Maps\MXD\Figure 4.2-1_summary_of_decommissioning_plan.mxd

4.2.2 General Procedures

The following general procedures will be adhered to throughout the decommissioning process:

- Ventilation equipment and the dust collection system will be cleaned prior to demolition
- All remaining piping will be flushed with water and blown out and disconnected at suitable locations
- All remaining contaminated areas will be washed down with clean water and those waters directed to contaminated sumps for water treatment
- Equipment will be drained of oils and coolants etc. and these will be disposed of as required in the correct disposal areas
- Propane lines will be purged with an inert gas and disconnected
- Electrical circuitry that is not required in the decommissioning process will be physically disconnected
- Equipment that has the capacity for energy storage will be physically disconnected
- Fireguards will be employed when there is a possible chance of inadvertent combustion i.e. fuel tank reduction
- Guards will be employed when overhead structures are being toppled or brought down to prevent inadvertent access into the fall zone
- During times when decommissioning is not active, all buildings will be closed and locked to prevent inadvertent entry
- Open excavations will be marked and entrances barricaded
- Culverts will be removed from roads and natural flow paths will be re-established
- Materials removed from site will be verified as non-radiologically contaminated through a "green tag" procedure as per current practice at the McClean Lake Operation in Saskatchewan

4.2.3 Decommissioning Logistics

Due to the high cost of mobilization and demobilization of heavy equipment and logistics of starting and lack of road transport into site the work has been scheduled to continue throughout the entire year. The scope of work for each stage may change depending on the project status and schedule.

Similar to the construction phase, the decommissioning phase will involve the use of the winter road from the site to a staging area at the Baker Lake dock facility during the winter months to ship salvageable materials in preparation for marine shipping south in the spring. Wherever possible, shipping containers will be used for ease of handling and durability. If the all-season road is built, consideration will be given to continuing to use it during the initial portion of the decommissioning period.

The Project includes facilities that are not directly involved in the mining and milling of uranium, such as the accommodation complex, acid plant, airstrip buildings, water supply pumphouses, and power house.These buildings and their contents are not expected to contain radioactive materials and for the most part should be salvageable. Salvageable buildings, surface structures, and equipment will be dismantled and demobilized from the site. Non-salvageable buildings and structures will be dismantled or demolished and disposed of in a TMF or the Andrew Lake pit.

4.2.4 Winter Road Construction

Winter roads are known to be a cost-effective means of accessing the tundra with minimal impact to the sensitive underlying vegetation community (Brumbelow et al. 2011). The vegetative growth medium remains intact, thereby allowing for proliferation and regeneration of vegetative species. While some damage to the underlying vegetation may occur during winter road use due to rutting, these impacted areas are anticipated to be localized. Reclamation will be progressive throughout the duration of the Project. Re-vegetation measures are discussed in Section 4.2.10.

The following is a typical schedule for the development, preparation and use of the winter road:

- early December Initial profiling and pioneering of the ice crossings
- mid December Achieve ice thickness for plough trucks and clear full road width
- early January Achieve ice thickness for partially loaded transport trucks
- late January Achieve ice thickness for fully loaded transport trucks
- early February Achieve maximum ice thickness
- end April Suspend ice crossing operations

4.2.5 Water and Contaminant Control

During all stages of the work, clean water will be utilized to reduce dust levels and wet down contaminated materials prior to dismantling, demolition, and transport for disposal. The plan will be to utilize the existing contaminated sumps and water collection areas as much as possible for water collection purposes.

For the purpose of the waste water management plan contact water is defined as any water that may have been physically or chemically affected by site activities. Contact water will include:

- Surface runoff from the milling areas resulting from direct precipitation (rainfall and snowfall), drifting snow and un-intercepted runoff water,
- surface runoff from lined ore stockpile,
- surface runoff from lined special waste stockpile,
- surface runoff and shallow drainage from unlined clean rock piles,

- water expulsed during tailings consolidation, and
- groundwater inflows into open pits.

All contact water will be intercepted, contained, analyzed and treated when required. All water released to the environment will meet the discharge quality criteria and there will be no significant physical or chemical effects associated with the release of water.

Non-contact water will be limited to runoff originating from areas unaffected by site activities and that will not come into contact with mining and milling areas. Non-contact water will be diverted from the site activities to the surrounding surface water system.

All ore haul roads will be radiologically monitored and remediated as necessary during operations, minimizing the need for final reclamation during the decommissioning phase of the mine life.

4.2.6 Concrete Foundations and Pads

Concrete will be broken mechanically or with explosives on a maximum grid spacing of 3 m to prevent water ponding and to allow for root penetration.

4.2.7 Site Roads

All roadways and general grounds around the mill area will be graded to remove surface contamination and the contaminated materials deposited in the Main Zone TMF. Following subsequent radiological surveys, any residual contamination will be removed or covered with clean till to a depth to meet the final radiological clearance criteria. Culverts will be removed and replaced with cross ditches. Roadways will be scarified before abandonment to promote revegetation

The following criteria will be applied:

- All culverts will be removed and replaced with drive - through cross ditches;
- All slopes that exceed a 3:1 ratio will be re-contoured;
- All road berms that impede natural drainage flows will be breached at regular intervals;
- All ramps will be cross-ditched at no more than 30 m intervals or removed where practical; and,
- All driving surfaces of travelways will be scarified to promote natural revegetation.

4.2.8 Area Regrading

The decommissioned areas will be regraded to a stable and aesthetic configuration. Regrading work will include the areas of out buildings/structures that will be removed such as the fuel storage areas. All remaining exposed concrete will be cracked to allow drainage and root penetration prior to leaving it in place and will be covered by a minimum of 0.3 m of till material graded to link with current undisturbed areas. All excavations that require no special treatment will be re-contoured so that they present minimal hazard to wildlife or personnel and so that the re-contouring conforms to the general area topography. Contouring of till covers will be done so that it does not interfere with the natural drainage of the immediate surrounding areas.

4.2.8.1 Quarries and Borrow Pits

Reclamation of quarries and borrow pits will be performed according to best practices and guidelines as outlined in the Northern Land Use Guidelines for Pits and Quarries (INAC 2008). Based on AREVA's experience to date this would include:

- flattening of any slopes greater than 3:1 to maintain land stability and prevent erosion,
- borrow pits and quarries would be recontoured to blend in to the local terrain, and
- the areas would be re-vegetated using the best practices developed from the research that will occur during the operational period.

Further details on closure and reclamation of quarries and borrow pits is provided in Technical Appendix 2N.

4.2.9 Storm Water Management

The removal of constructed facilities will return the area to near pre-construction drainage patterns. The covering of the fractured concrete bases of these facilities will be done in a manner so as not to interfere with the original drainage pattern of the area. The covering of the fractured bases will also be done in a manner such that water will not pool over the former building sites.

4.2.9.1 Diversion Ditches and Berms

Diversion ditches will be backfilled with the previously excavated berm materials and graded to blend in with the surrounding landscape. Pre-mining drainage will be restored and re-vegetated as required.

4.2.10 Revegetation

Revegetation at the Kiggavik Project will be progressive throughout the duration of the Project phases, as mined out open pits used as TMFs are closed and backfilled, and as mine rock stockpiles are constructed to their desired end-state. Other disturbed areas will also be revegetated as they become available, such as areas where infrastructure is removed, where site roads are no longer needed, and where former drill sites exist. It is important to note that this text provides a general overview of expected revegetation activities that will be required for the Kiggavik Project. Revegetation plans will evolve over time, and will become more detailed closer to the time that revegetation activities commence.

Field observations at former drill sites at the Kiggavik exploration project has indicated that a small number of native plants tend to dominate during natural revegetation (Hounjet, 2009). These plants include Polar Grass (Arctagrostis latifolia), Dwarf birch (Betula glandulosa), Bigelow's sedge (Carex bigelowii), Arctic willow (Salix arctica), and Tea leaf willow (Salix planifolia). A number of other Carex grasses were also identified in 5 of 11 plots that were assessed by Hounjet (2009) but they could not be identified to species. Seed mixtures will be created, taking into consideration the above listed plants. If willow species are selected to be planted, cuttings would have to be collected locally and grown commercially for later planting. Existing vendors that were used at the Cluff Lake Project could be contracted for such services. Test plots will be constructed as early as possible during the operational phase, as disturbed areas become eligible for revegetation. Test plots will be used to determine an optimal seed/planting mix and optimal use of fertilizers in terms of rapid, sustainable vegetation establishment that will increase the rate of natural succession.

AREVA has gained valuable revegetation experience from its Cluff Lake Project, located in north-western Saskatchewan. This experience suggests that drill seeding, with subsequent broadcast fertilization would be a successful planting method. Drill seeding ensures that the seed penetrates into the soil cover, resulting in more successful germination, compared to broadcast seeding, where the seed is left exposed to wind, rain, and scavenging from local wildlife. Drill seeding is also much faster, more efficient, and less labour intensive than hydroseeding methods. However, hydroseeding methods should be considered for seeding areas where poor germination exists after the initial drill seeding is completed, and for areas that are too small or soil conditions insufficient to justify using drill seeding equipment.

It will likely be advantageous to fertilize the revegetated areas for one to two years after the initial seeding has been completed. This will provide the necessary nutrients for rapid, healthy plant growth. The exact fertilizer blend to be used will be determined prior to any revegetation activities, based on nutrient deficiencies in the cover material. Soil samples will be collected from the cover material and will be sent to an accredited laboratory for nutrient analysis. These results will be used in conjunction with the nutrient requirements of the species to be planted to determine an appropriate fertilizer blend.

As the various disturbed areas become available for revegetation, it is expected that additional reclamation work (compaction of waste rock, re-contouring / re-sloping, and covering) will be required prior to revegetation. Guidance for these activities will be provided by this PDP document, the experience gained from the Cluff Lake Project and the McClean Lake Operation, as well as by the following documents:

- The Nunavut Tunngavik Incorporated Reclamation Policy (NTI 2008) and the
- Environmental Guideline for Contaminated Site Remediation (GN 2009), prepared by the Environmental Protection Service, Department of Sustainable Development, Government of Nunavut.

Radiological clearance will also be attained before revegetation proceeds. This will involve gamma radiation surveys, and the development of ALARA objectives for clearance protocols. These can be established using the same criteria as that used for the Cluff Lake Project (AREVA 2013) and are discussed further in Section 6.2.2.

4.2.11 Institutional Controls

Institutional controls may be required after the close-out of a mine/mill complex to prevent intrusion into the waste repository; to prevent removal of or interference with the waste; to ensure that the performance of the repository continues to meet the design criteria; and to ensure that necessary remedial actions are carried out (IAEA 1994). The decommissioning objective is to minimize or eliminate the need for institutional control.

Passive controls are to be maximized where possible. Examples of these include proper design for natural drainage, landform stability, and long-term security of contaminated waste material. The institutional controls will not generate significant cost for the operator conducting the decommissioning or for the government or landholder after acceptance of the decommissioned property. This is due to the stringent criteria to be adopted for the decommissioning work, the long-term stability of the reclaimed site and the limited future development potential of the site due to its remote location. It is expected that an institutional control framework similar to that in place in Saskatchewan, where the operator provides the funding for long-term institutional control, will be developed in Nunavut.

4.3 Planning Envelope 1: Kiggavik Site

4.3.1 East and Centre TMF's

Closure activities will be conducted with the objectives of:

- Stabilizing the surface of the tailings and prevent wind and water erosion;
- controlling the release of contaminants over the long-term; and,
- developing an aesthetically pleasing appearance.

The proposed Kiggavik site includes three deposits: East Zone, Center Zone and Main Zone. The proposed mine plan at the Kiggavik site is to:

- Excavate East Zone and stockpile the ore until completion of the open pit. Once this initial ore body has been mined out the pit will be converted into an in-pit tailings management facility (TMF).
- Excavate Center Zone and process the ore; the tailings produced will be disposed of in East Zone TMF. Once Centre Zone has been mined out the pit will be converted to a second TMF.Excavate Main Zone and process the ore; the tailings produced will be disposed of in Center TMF. Once Main Zone has been mined out the pit will be converted to a third TMF to accommodate the tailings produced from the processing of Sissons ore and potential other deposits.

For East Zone and Centre Zone TMFs the conceptual decommissioning plan consists of fully back filling the TMFs above the tailings mass with mine rock and installing a compacted till cover.

A four stage progressive decommissioning plan is envisaged for East Zone and Centre Zone TMFs, commencing during operation. Tailings in these TMFs are expected to consolidate within a 10-year period for East Zone TMF and within a 15-year period for Centre Zone TMF with the lowest predicted hydraulic conductivity and no additional engineering features to promote accelerated consolidation (Technical Appendix 5J, Table 5.5-1). A water cover would be kept on top of them to prevent freezing of the thin rock cover from blocking expulsion of consolidation water.

Stage 1

Placement of tailings will be controlled to achieve a level to slightly mounded tailings surface. At the same time, the water cover will be progressively reduced to achieve a uniform water cover of sufficient depth to facilitate tailings placement. The surface water pond will be pumped through the treatment plant and any sludge recovered will be discharged to the TMF. When the tailings have been levelled and distributed, and the water cover reduced, placement of the soil and rock cover will commence.

Stage 2

Experience in Northern Saskatchewan has demonstrated that waste rock can be placed directly on the tailings surface if care is exercised. The surface of the tailings can be expected to be unconsolidated and relatively soft, allowing the rock fill to sink into the tailings and displace them. This is an undesirable effect since continued placement will cause a wave of unconsolidated tailings to run ahead of the rock fill. To prevent this, it is proposed that a 2-m layer of sand fill, approximately, will be placed over the tailings surface to act as a support filter. A 2-m thick layer of rock will be placed over the sand layer. If there is standing water over the sand support layer, the rock will be placed in a uniform layer onto the ice cover during the winter. The rock will settle uniformly onto the sand surface during the following summer thaw.

A leachate collection system will also be constructed during the summer thaw to allow consolidation flows related to pore fluid seepage to be recovered and treated. The leachate collection system will consist of simple corrugated metal wells installed in a granular blanket within the fill material. HDPE pipe would be considered due to its resistance to corrosion and ability to accommodate large differential movement. Temperature and pore pressure sensors will be installed within the tailings to allow pore water pressure dissipation and temperature to be monitored during and after cover construction.

Stage 3

When the temperature sensors indicate that the tailings are thawed, the third stage of cover placement will commence. The third stage of decommissioning will consist of placement of a clean rock cover. Using the mine fleet sufficient rock will be placed in a mounded configuration to accommodate this amount of consolidation settlement. Consolidation will expel pore fluid, which will be collected in the leachate collection system at the surface of the tailings. All water from the leachate collection system will be treated before discharge and any recovered sludges disposed of by burial in a designated area on the upgradient side of the TMF.

With ongoing settlement, recontouring of the Stage 3 rock cover will be performed as required to maintain a well-drained surface. Ideally placing the clean rock cover would take place in warm weather to prevent freezing the upper layer of the tailings, once the pond had been pumped down to a minimum level.

Stage 4

When pore pressure monitoring indicates that consolidation is complete (following Stage 3 cover placement), the final cover will be placed and revegetated. The final cover for the TMF will consist of clean waste rock with a compacted till cover. The tailings would be covered in one season to prevent freezing. At the same time, the water treatment plant sludge disposal area will be decommissioned, covered using till material, and revegetated.

4.3.2 Post Operational Monitoring

As mentioned above, instrumentation will be installed at various locations within the tailings to monitor the rate of dissipation of induced pore water pressures during consolidation. Once pore-water pressures have reduced to normal levels (hydrostatic), the majority of the pore-water will have been expelled and the tailings mass will be consolidated to the desired endpoint.

Monitoring of pore-water chemistry will continue through the post closure period to assess the concentration of various contaminants in the tailings pore water. Pore-water will be sampled through the same vertical monitoring wells which were utilized during the operational period. Additionally, the leachate collection system installed in the top drain will be monitored for water chemistry and for volume of water removed by pumping.

4.3.3 Main Zone Tailings Management Facility

Based on existing resources and milling schedule, the Main Zone TMF would only be partially filled with tailings upon termination of the milling activities. However, it is considered likely that additional resource will be found over the life of the project and that the Main Zone TMF will eventually be fully filled with tailings. Therefore, the base case for the decommissioning of Main Zone assumes that Main Zone TMF will be fully filled with tailings in a manner similar to East Zone and Centre Zone TMFs. The conceptual decommissioning plan consists of fully backfilling the TMF above the tailings mass with first Type 3 mine rock then Type 2 mine rock and installing a compacted till cover. The Type 3 mine rock is expected to be associated with some acid generation and/or metal leaching potential and/or uranium solid content greater than 250 ppm U.

In the unlikely case where no additional resources are found over the life of the Project. Main Zone TMF would be partially filled with tailings. In that case the conceptual decommissioning plan consists of fully backfilling Main Zone TMF above the tailings mass with first Type 3 mine rock then Type 2 mine rock and installing a compacted till cover. As an alternative, the TMF would be only partially backfilled with mine rock then a compacted till cover would be installed, above which a pond would be allowed to develop. If this alternative were to be pursued in the future, further detailed design, and analysis of long-term pit water quality, would be conducted to support a decommissioning license application.

Experience gained during decommissioning of the East Zone and Centre Zone TMFs will benefit the decommissioning of Main Zone TMF. In particular, this experience will lead to an improved estimate of the time required to complete tailings consolidation. Engineering features can be utilized if needed to achieve a 10-year period (Technical Appendix 5J Tailings Characterization and Management, Section 5 Geotechnical Behaviour and Consolidation).

4.3.4 Permanent Mine Rock Stockpiles

Mine rock not utilized for construction and deemed acceptable from the perspective of acid rock drainage and metal leaching (i.e. surplus Type 1, Type 2 mine rock) will be permanently stockpiled at the Kiggavik site. AREVA is proposing to construct two permanent mine rock stockpiles to accommodate the material excavated during the mining of the Kiggavik deposits. Approximately 30 million m^3 (bcm) of mine rock will be excavated.

Stockpile A will be located to the north of the Kiggavik pits. Stockpile B will be located to the south of the pits. Both stockpiles will be surrounded by perimeter ditches designed to collect runoff water from the stockpiles. Drainage water from the Kiggavik stockpiles will largely consist of direct precipitation (i.e. rainfall and snowfall), with minor amounts of blowing snow. Berms will be constructed along the outer edge of each ditch. These berms will prevent surface runoff from surrounding undeveloped areas from flowing into the perimeter ditch and mixing with runoff water from the stockpiles.

Stockpiles will be constructed in order to meet appropriate physical stability criteria. A layered approach to stockpile construction is proposed to increase overall stockpile stability. Layered placement creates a high uniform density while minimizing segregation to create a stockpile with minimal permeability to air and water penetration. The method also reduces settlement and therefore further enhances overall stockpile stability. It is expected that the stockpiles will be 40 m to 50 m high and constructed in approximately 10 - 20 m lifts with 10 - 20 m wide catchments remaining at the completion of each lift. Experience to date has indicated that this configuration will result in a stable stockpile face with an approximate overall slope of 3:1. The catchments will also act as a slope break and minimize erosion caused by surface runoff.The Type 1/Type 2 mine rock stockpiles will be recontoured to slopes of 3:1 or less, and a cover layer of till added. The stockpiles will then be revegetated to suppress dust emissions and minimize erosion.

4.3.5 Mill/Camp/Maintenance Complex

All facilities comprising the mill/camp/maintenance complex, with the exception of facilities required for future decommissioning and water treatment, are planned for removal during the initial phase of physical decommissioning. Availability of knowledgeable staff and the potential for reducing environmental effects are relevant in choosing this approach.

Prior to mill demolition, all reagents and hazardous materials will be consumed or returned to vendors. Any remaining loose contaminated materials inside the mill complex will be removed and transported to a TMF for disposal. Any materials which are determined to be salvageable will be monitored to ensure they meet all applicable requirements for release from the site, and then transported from the site to the Baker Lake dock site. These requirements will vary depending on future use. For example, materials with some residual contamination could be transported, with suitable packaging, to another uranium production site, but could not be released for unrestricted use. All equipment and building materials which are not salvageable will be disposed of in a TMF. Contaminated soil in the mill area will be removed and deposited in a TMF.

The general concept for mill demolition will be to reduce the building to the ground, then load and haul the material as soon as possible to one of the TMF's. Equipment and process tanks in the mill will be decontaminated and salvaged to the extent possible. Non-salvageable equipment and tanks, including remnants from demolition of the mill buildings, will be disposed of in one of the TMF's.

- All physical and electrical energy sources will be eliminated.
- The exterior cladding of the buildings will be the first component to be removed to provide natural light for interior component visibility and safety; provide better air circulation thus reducing or eliminating radon progeny concerns and allow more efficient access and egress.
- Lines which previously conveyed hazardous materials, such as sulfuric acid, will be flushed and resulting waters will be treated at the WTP.
- Remaining equipment oils will be drained and recycled prior to final demolition. Re-usable uncontaminated and/or decontaminated equipment will be removed and sold, where possible. Due to the high cost of decontamination and the limited resale value, the majority of equipment will be disposed of in the TMF.
- As the boilers and generators are taken out of service, they will likely be sold as they are not contaminated and have reasonable re-sale value. If a buyer cannot be found, they will be disposed of in the TMF.
- Elevated structures will be left in a stable condition as long as possible with completion of each structure expedited once it is weakened beyond a stable condition. The area will be barricaded and guarded during the pulling down of these structures.
- Water will be used at structures being dismantled/demolished to control generation of contaminated dust and resulting potential exposure to workers.
- After the buildings have been demolished, concrete pads will be decommissioned.

The outside electrical distribution system on the mill terrace will be dismantled with non-contaminated materials being salvaged. Any materials which are contaminated, or are from a contaminated area, will be disposed of in the Main Zone TMF. Transformers will be drained of any oils and the oils shipped offsite for appropriate recycling or disposal. All transformers on site will be of modern design and will not contain PCBs. Oils will be removed from the electrical equipment before burial. It is not expected that the equipment will pose a significant risk and, as such, no special containment or risk assessment has been considered for this material.

Materials within the warehouse will be sold for surplus and any remaining materials will be disposed of in a TMF.

4.3.6 Concrete Foundations and Pads

Concrete that extends above the local ground surface will be removed to the surrounding ground surface level and disposed of in the TMF. This will be accomplished using a combination of the following methods: blasting, which will be conducted consistent with past practices and in full compliance with Nunavut regulations using a hydraulic ram mounted on a backhoe; or a wrecking ball.Concrete pads will be cracked and covered or broken up and removed depending on the thickness, amount of rebar and contamination. The concrete floors will be thick (1 m or more in some places) and heavily reinforced with rebar. Based on the location, thickness and amount of rebar this concrete may be impractical to remove. The floors will be drilled and blasted on a maximum 3 m grid to fracture the concrete or cracked on a similar pattern by use of a hydraulic ram or wrecking ball. This will promote drainage and aid establishment of vegetation. The fractured concrete will be covered with a minimum of 0.3 m of till and revegetated, as applicable. Concrete Batch Plant Area

Typically the concrete batch plant is owned and operated by an independent contractor and will be removed by the contractor at the end of the construction phase or at the time of decommissioning. It is typically a mobile batch plant and, as such, is easily removable.

4.3.7 Ore and Temporary Mine Rock Pads

Any remaining ore will be processed through the mill. Alternatively, ore not processed will be placed into the TMF as well as any potentially problematic mine rock and the protective cover over the stockpile liners. The liners and their protective covers from both areas will be cut into manageable pieces and disposed of in the TMF. The ground below the liners will be checked for contamination, and contaminated soils removed to a TMF. After radiological clearance, the area will be scarified and revegetated.

4.3.8 Overburden Stockpile

It is estimated that approximately 8 million m^3 (in-situ volume) of overburden material will be excavated during open pit mining at the Kiggavik site. This stockpile will be used to backfill any surface areas that require large fills. The industrial landfill will be covered with a minimum of 1 m of clean overburden material during the re-contouring operation. Ultimately, slopes of any remaining overburden stockpilies will be less than 3:1, and the stockpiles revegetated.

As noted in Section 4.4.1.3 of Volume 2 Project Description, the thin layer of organic topsoil will be separately stripped during construction activities and stockpiled for use during revegetation of disturbed areas. This stockpile will be entirely used during decommissioning.

4.3.9 Kiggavik Effluent Treatment System

The Kiggavik Water Treatment Plant (KWTP) includes the treatment plant, four lined monitoring ponds and related pumps, piping, ditching, and culverts. These facilities will continue to operate throughout the physical decommissioning phase for as long as required to achieve agreed upon water quality discharge objectives. The KWTP will treat consolidation pore fluids from the East, Main and Centre Zone TMF's until the decommissioning criteria are met. It is acknowledged that although specific time spans of operation have been selected for the purpose of costing, that the cessation of treatment will ultimately be determined by effluent quality as opposed to an arbitrary length of time. Treated effluent from the KWTP will be discharged to Judge Sissons Lake and sludge generated from the treatment process disposed of in a TMF.

Any accumulated sludge from the four monitoring ponds will be placed into a TMF. The liner material will be cut into manageable pieces and transported to a TMF for final disposal. Material underneath the liner will be checked for possible radiological contamination and removed to a TMF if contaminated. Contouring of the sedimentation ponds will be done in order to ensure the topography blends into the general surroundings. Slopes will generally be maintained at less than 3:1. Any berm material surrounding the liner will also be recontoured and revegetated.

There is no special preparation planned for the area which will contain the KWTP sludges. The critical design parameter is not ground preparation, but rather, the location of the sludge disposal area. The area is upgradient to the tailings mass and is situated relatively near the surface of the final contoured surface, just below the soil cover. As a consequence, groundwater in the sludge will be subject to a strong downward hydraulic gradient. If for some reason the total volume of tailings in the TMF is significantly less than the current planned volume at the time of decommissioning, backfill would be placed such that the sludge placement location would remain unchanged. Water from sludges will mix with the water in contact with the tailings mass. The effect of this small volume of material relative to the large volume of tailings would not be discernible from the overall effects of the tailings mass in the groundwater model or solute transport analysis.

4.3.10 Fuel & Waste Oil Tanks

The fuel and waste oil tanks will be emptied and any excess fuel will be transferred to the site diesel tanks remaining in service to support decommissioning activities. The tanks and distribution equipment will then be cleaned prior to cutting up for disposal in the TMF. Waste products from cleaning will be transferred by vacuum truck and disposed of by packaging and shipping offsite as per the protocols noted in Technical Appendix 2U Hazardous Materials Management Plan. The concrete pad(s) will be broken up on maximum 3 m spacing and covered with a minimum of 0.3 m of clean till. Soil samples will be collected and, if required, hydrocarbon contaminated soil will be taken to the onsite hydrocarbon landfarm or disposed of in a TMF.

4.3.11 Explosive Plant and Magazines

Typically the explosive plant and magazines are owned by the explosives contractor. The blasting contract makes provision for the contractor to demobilize their facilities upon completion of their usage. The site will then be graded to a stable configuration and revegetated. The concrete pads will be decommissioned as described above.

4.3.12 Core Storage Areas

Given the valuable technical information associated with the core, it is usually required that the existing core storage areas remain in place. Nonetheless, costs have being included to decommission and reclaim these areas as per the following steps:

- Both mineralized and barren core stored at the Kiggavik and/or Sissons sites will be removed and processed through the mill or disposed of in the TMF depending upon the timing of approval from the territory to dispose of these materials.
- Core shacks and wooden core racks will be burned or landfilled. Any remaining materials will be disposed of in the a TMF.

4.3.13 Airstrip and Associated Buildings

Airstrip reclamation will involve removing culverts, re-contouring fill slopes for wildlife access, and scarifying the gravel surface to facilitate natural revegetation. However, the airstrip may be left for others to use if requested by government agencies or by a third party willing to assume responsibility.

Air strip facilities will be demolished and the debris transported and disposed of in one of the TMF's. The remaining surface soils will be assessed for radiological or othercontamination and once determined clean, scarified and revegetated.

Attachment E provides information on the successful revegetation of large graveled surface areas in a comparable climate.

4.3.14 Solid Waste Disposal Areas and Storage Facilities

Information on the design and operation of waste management facilities is found in Technical Appendix 2S, Waste Management Plan, Technical Appendix 2U Hazardous Materials Management Plan, and Technical Appendix 10B, Spill Contingency and Landfarm Management Plan. The various types of solid waste disposal areas and storage facilities will continue to be operated until generation of each waste stream ceases.

Hazardous Materials

Materials in the Hazardous Materials Storage Area will be sent off site to appropriate recycling or disposal facilities. Any remaining items will be placed into a TMF. Any chemically or radiologically contaminated wastes which cannot be recycled, cleaned or salvaged will be disposed of in a TMF. Contaminated granular and liner material will also be disposed of in a TMF. The area will then be graded to stable contours and revegetated.

Sewage

The majority of sewage solids in the Solid Sewage Management Area at the time of decommissioning may be composted and utilized in reclamation of the permanent mine rock stockpiles. The anticipated volume of these materials is expected to be minimal due to the nature of the sewage treatment process.

Incinerator

During the decommissioning period, the incinerator and building will be dismantled and shipped offsite, if salvageable, or demolished and disposed of in a TMF. A small incinerator, comparable to that currently used at the exploration camp, will be used for the duration of time that a small number of staff remain onsite through to the end of the post-decommissioning monitoring period. All ashes will be shipped offsite for disposal. This incinerator will also be shipped offsite for salvage or disposal.

Industrial Landfills

The industrial landfills will be decommissioned in-situ by constructing a minimum 1 m compacted till cover over the landfill site. The cover will be contoured for drainage consistent with any recontouring of Type 1/Type 2 mine rock stockpiles, and then revegetated.

Contaminated Landfill

The contaminated landfill will be located on the brow of a TMF. The chemically/radiologically contaminated waste interred during operations will be transferred to and disposed of in the TMF. This area will be backfilled as part of the decommissioning of the TMF.

Landfarm

Remediated soils from the hydrocarbon contaminated landfarm will be used in conjunction with revegetation efforts. Fertilizer may be added to contaminated soil to expedite the remediation process if necessary. Any unremediated stockpiled materials remaining at the landfarm at the time of decommissioning, such as large rocks or materials not amenable to landfarming, will be disposed of in a TMF.

4.4 Planning Envelope 2: Sissons Site

4.4.1 Andrew Lake Open Pit

The Andrew Lake open pit will be flooded after operation to permanently store, underwater, the Type 3 Andrew Lake rock material that will be temporarily stored near the pit during operation. There are two possible scenarios for flooding after closure:

- One scenario is to allow flooding to occur naturally as a result of the accumulation of rain and snow melt and the small amount of seepage that may be expected to occur in the active layer near ground surface. At the expected natural filling rate, complete flooding is expected to require approximately 480 years.
- Alternatively, natural filling of the pit can be complemented by flow from a larger water body, such as Andrew Lake or Judge Sissons Lake, during periods of high flow in order to shorten the flooding period.

Experience has shown that while leaching of metals and other constituents can occur while rock and pit walls are exposed to the atmosphere and natural weathering processes, such leaching tends to be insignificant to non-measurable when the same rock is submerged below water. This difference in behaviour suggests that rapid flooding may have some advantages for maintaining good water quality within and downstream of the decommissioned pit.

The Andrew Lake pit water quality was assessed by evaluating constituent loadings originating from the pit walls, rock rubble on pit floor and benches, pore water concentrations from the temporarily stored material, and the leaching of the relocated Type 3 material as the pit fills under natural conditions, as well as under accelerated pit filling conditions (see Technical Appendix 5F). These loadings were assessed to estimate the concentrations of constituents of potential concern (COPCs) in the pit water after the pit is filled.

The calculated Andrew Lake concentrations of COPCs for the enhanced pit filling conditions were compared to CCME guidelines for the protection of freshwater aquatic life. This evaluation suggested that under this pit flooding scenario, the pit water will not represent a risk to aquatic life and pit water could discharge to surrounding surface water bodies without concern after closure.

Thus, the preferred method of decommissioning of the Andrew Lake pit is as follows:

- Andrew Lake pit would be backfilled with the Sissons problematic mine rock and covered with till. This will result in the pit being only partially filled.
- A water diversion structure would be constructed within the Andrew Lake berm to allow accelerated flooding of the pit.
- The water in the pit lake would be monitored and treated as required until water quality objectives are met.

The alternatives assessed regarding backfilling and flooding scenarios for the Andrew Lake pit, potential decommissioning design considerations and effects of accelerated pit flooding, and predicted pit water quality are discussed in Attachment A – Andrew Lake Pit Flooding. It is noted that the time for pit flooding (about 6 years for the proposed method) is less than the time considered for the enhanced pit filling conditions (approximately 10 years) in the analyses of COPC concentrations in the water filled pit (see Technical Appendix 5F).

4.4.2 Buildings

Due to loss of integrity of structures over time, all buildings and facilities not needed to support decommissioning activities, such as the water treatment and utilities facilities, will be dismantled/demolished. Services such as electricity and water will be disconnected and purged as necessary prior to demolition. Oils and other lubricants will be removed from all equipment and storage facilities and disposed of or recycled in accordance with applicable regulations.

All buildings and the oil storage area will be demolished and hauled to a TMF for disposal. Exterior cladding will be removed prior to dismantling and/or demolishing the internal components. The concrete floors will be fractured on a maximum 3 m grid and covered with a minimum of 0.3 m of clean till. The used oil tank will have its contents transferred to appropriate containers for shipping this material offsite prior to the tank being cut up and disposed of in a TMF.

4.4.3 Sissons Water Treatment Plant

The Sissons Water Treatment Plant (SWTP) will be reclaimed in the following manner: dismantling of the main buildling and associated equipment and disposal of any non-salvageable, non-combustible material into the Andrew Lake pit. The concrete foundation and slab will be broken and buried in the uncontaminated water retention pond.

4.4.4 Permanent Mine Rock Stockpiles

At Andrew Lake it is proposed to manage the Type 1/Type 2 mine rock in one stockpile, a volume of approximately 33 million m^3 (bcm).To ensure long-term slope stability, recontouring and re-vegetation will be a progressive and ongoing reclamation activity to ultimately meet a slope of 3:1. At the time of final decommissioning, slopes that require further reduction to meet the 3:1 objective will be recontoured and re-vegetated.

At End Grid it is proposed to stockpile mine rock from ramp construction with the Andrew Lake mine rock permanent stockpile. Any Type 3 mine rock will be segregated and stored on the temporary Type 3 mine rock stockpile. Some mine rock from End Grid will be stockpiled and crushed to be used in mine backfill.

4.4.5 Temporary Mine Rock Stockpiles

It is proposed to manage potentially problematic mine rock (Type 3) from the Andrew Lake pit during operation in a temporary surface stockpile with drainage collection and treatment. This material will then be placed at the bottom of the Andrew Lake pit during the decommissioning phase as described in Attachment A. The temporary storage pad will then be decommissioned as described in Section 4.3.7 for the Kiggavik site.

4.4.6 Ore Pads

After all remaining ore is processed or disposed of in a TMF; all contaminated liner material will be removed from the ore pad and placed in a TMF at the Kiggavik site.

4.4.7 End Grid Underground Mine

Any salvageable materials or hazardous wastes will be removed from the underground mine and transported offsite for salvage, recycling, or disposal. Underground openings including the portal, ventilation raises, and shafts (if constructed) will then be sealed with concrete plugs. The underground mine will then be allowed to flood. The surface disturbed area will be regraded and/or recontoured with the addition of till and subsequently revegetated.

4.4.8 Solid Waste Disposal Areas and Storage Facilities

Solid waste disposal areas and storage facilities including the industrial landfill, and the sewage solids management area will be located at the Kiggavik site. Decommissioning of these areas is described in Section 4.3.15.

4.5 Planning Envelope # 3 Baker Lake Dock and Staging Facilities and Project Access Roads

4.5.1 Port Facilities

All remaining equipment, reagents and supply inventories remaining in lay-down areas will be removed and either returned to the vendors or returned to a uranium mine in Saskatchewan. Radiological clearance of the area will be conducted as described in Attachment C and subsequently revegetated where appropriate.

Any buildings will be offered to the community. If the community is not interested in taking ownership they will be dismantled and placed in the Baker Lake Landfill.

The dock facility and related equipment will also be offered to the community. If the community has no need for it, the dock and landing will be demolished and all non-hazardous waste disposed of in the Baker Lake landfill. Any hazardous wastes will be removed and safely shipped back to an appropriate disposal facilty.

Upon completion of all decommissioning activities in this area AREVA will proceed with decommissioning the main entrance road to the Baker Lake Port. In addition natural drainage will be re-stored to pre-mining status. Should there be any future use for the port road AREVA will co-operate with the party who is to become responsible, so that they may obtain all appropriate approvals for the future use of the road prior to AREVA completing the decommissioning program.

4.5.2 Roads

AREVA will work with the landowner, local community, and the government to determine if there may be alternative uses for the roads after operations cease; however, the current plan is to decommission all roads. Should there be any future use for the roads AREVA will co-operate with the party who is to become responsible such that they may acquire all appropriate approvals for the future use of the roads prior to completion of the decommissioning program by AREVA.

4.5.2.1 Site Roads

All mine site roads for Kiggavik will be decommissioned in the following manner:

- Culverts will be removed to re-establish natural flow paths and replaced with drive - through cross ditches, safe for snowmobile or ATV use in winter;

- Wildlife access will be provided at suitable intervals along the haul roads by regrading the embankment shoulders to flatter slopes;
- Radiological surveys of road surfaces will be conducted;
- All road berms that impede natural drainage flows will be breached at regular intervals;
- All ramps will be cross-ditched at no more than 30 metre intervals or removed where practical;
- All driving surfaces of travelways will be scarified to promote natural revegetation.

If any areas are found to have been locally contaminated, the contaminated material will be removed and disposed of in a TMF.

4.5.2.2 All-Season Road

The all-season road, if constructed, will similarily be decommissioned and include the following:

- Culverts will be removed to re-establish natural flow paths and replaced with drive - through cross ditches, safe for snowmobile or ATV use in winter;
- Wildlife access will be provided at suitable intervals along the road by regrading the embankment shoulders to flatter slopes;
- The cable ferry crossing at the Thelon River will be dismantled and shoreline features restored;
- Radiological surveys of the road surface will be conducted;
- All road berms that impede natural drainage flows will be breached at regular intervals;
- All ramps will be cross-ditched at no more than 30 metre intervals or removed where practical;
- All driving surfaces of travelways will be scarified to promote natural revegetation.

4.5.2.3 Winter Road

Aggregate material may be used to protect lake shorelines where transport trucks accessed the winter road. Reclamation of these access areas will include grading the aggregate to resemble adjacent shoreline features and ensuring all slopes will be stable and safe for human and wildlife access.

4.6 Temporary Closure

In order to temporarily close the Kiggavik Project (i.e. enter a period of care and maintenance), a detailed plan will be developed for approval by regulators prior to the period of temporary closure. AREVA will maintain sufficient full-time staff to operate and monitor critical functions, secure the facilities for the protection of the public and the environment, and facilitate resumption of operations. The Care and Maintenance Plan will be accomplished using the following framework:

Introduction

In the event of a temporary closure the following general measures and procedures will be adhered to in order to prepare for and maintain the temporary non-operational phase.

Organization and Management

Any changes to organization and management as it relates to operations will maintain numbers and qualifications required for operational needs, services and health and safety and environmental programs.

Maintenance of Essential Programs

Details of the extent and duration of a temporary closure will be documented and provided to regulators. Facilities undergoing shutdown and any changes to processes or programs are highly dependent on the extent and duration of the temporary closure. Essential programs that are maintained regardless of temporary closure include the following: Safety, Health, Environment and Quality Programs: Environmental Monitoring Program (EMP), Environmental Code of Practice (ECOP), Radiation Code of Practice and Radiation Protection and Monitoring Programs. .Any adjustments to programs will be identified and communicated to applicable regulators.

Emergency response capability (equipment and manpower), including spill response and industrial fire team(s) will be maintained during a cessation of production activities.

Effluent Treatment

The Kiggavik and Sissons water treatment plants will continue to treat any contaminated water from the dewatering of active open pits, pit tailings facilities, and water storage ponds to prevent potential surface or groundwater contamination. Appropriate freeboard will be maintained on any water holding structures to prevent potential spills. Treated effluent will continue to be discharged to Judge Sissons Lake.

The potable water and sewage treatment plants will be maintained as per operational procedures.

Waste Management

All hazardous wastes and mill reagents will continue to be managed in accordance with hazardous material protocols for operation. Should the mine subsequently move to decommissioning, hazardous materials will be managed in accordance with the approved decommissioning plan.

Extended care and maintenance periods may warrant removal of certain hazardous material from site.

Conventional Safety

Safety management systems involving the protection of workers and property will continue as conducted during operations. In addition the following actions will be taken to minimize the risk of injury or fire:

- Unnecessary propane lines will be purged with an inert gas and disconnected
- Electrical circuitry that is not required in the temporary shutdown will be physically
- disconnected
- Equipment that has the capacity for energy storage will be physically disconnected
- Mill circuits will be cleaned of residual ore materials and chemicals as much as practical and these substances will either be deposited in the appropriate disposal location, or suitably stored for reuse
- Lock-out procedures for non-operational equipment will be employed and all buildings not required will be locked and signed to prevent entry

Radiation Safety

All buildings, vessels and potential confined spaces, not required during the cessation of operations, but contain radioactive materials that could potentially result in unsafe radioactive atmospheres will either be ventilated as per normal operating requirements or locked and signed to prevent inadvertent and/or unnecessary radiation exposure to workers. All area and personal radiation dosimetry programs will continue as per site operating requirements.

Dams, Dikes and Other Containment Structures

Stability monitoring programs will be maintained for berms, dams and/or other containment structures where appropriate.

Site Access and Security, Pubic Safety

Appropriate measures will be implemented to control site access, to prevent unauthorized removal of materials and to ensure the identity of all persons on site will be maintained in a manner similar to that during the operating phase of the mine. In addition, the procedures and associated work instructions established in the Integrated Management System (IMS).

An example of the plan for a temporary production shutdown for AREVA's McClean Lake Operation is provided in the following section.

4.6.1 McClean Lake Operation Temporary Production Shutdown

4.6.1.1 Introduction

In March 2010 AREVA provided formal notification to the regulatory agencies that milling operations at the McClean Lake Operation would be suspended in June 2010 due to lack of ore supply. At the time, this temporary production shutdown was expected to last approximately two years. It has subsequently been extended with mill restart now expected in the fourth quarter of 2014.

Operations at the Kiggavik Project will be substantially the same as those at the McClean Lake Operation. Information on the McClean Lake Operation temporary closure is provided to illustrate the changes to activities and programs that would be implemented in the event of a temporary closure at the Kiggavik Project.

4.6.1.2 Regulatory Notification

The text of the formal letter of notification to regulatory agencies of the McClean Lake Operation temporary production shutdown is provided in Attachment D. Some of the details for a comparable letter of notification for a temporary shutdown of the Kiggavik Project would be different, however, the scope and content would be virtually identical.

4.6.1.3 Regulatory Review and Approval

The normal process of regulatory review and response by AREVA to regulatory agencies comments and questions was followed. Approval to proceed with the temporary closure was received upon resolution of all comments and questions.

4.7 Premature Closure

The Preliminary Decommissioning Plan (PDP) and Financial Assurance (FA) will be progressively updated as successive stages of the Project acquire regulatory approvals. For example, at the construction licensing stage, the PDP and FA need to consider removal of the facilities to be constructed, and restoration of the disturbed areas, but there is no need to increase the FA to that which will be required subsequently for the operational stage. The PDP and FA will also be periodically updated through the operational phase. There will be no fundamental changes to the methods approved for tailings disposal, waste rock storage and disposal, or pit backfilling and other decommissioning activities; however the specific quantities of the materials involved in decommissioning activities will change with time. For example, the number of TMFs will increase, and the volume of backfill will change with time. In addition to updating the PDP and FA to recognize these changes in material requirements associated with the regulatory approval being requested, any changes which would result from premature permanent closure during the time period covered by the approval will need to be included.

This approach is based on the fundamental requirement of the Financial Assurance. This is to ensure that the owner of the lands can satisfactorily decommission the facilities and reclaim all affected lands, in the unlikely event that the licensed operator (AREVA) cannot do so. The approved PDP and FA will thus reflect changes in both the scope of the work for decommissioning, and the associated liability as the Project progresses. This will extend to any changes resulting from premature closure during the time period of each successive approval.

5 Supporting Programs for Decommissioning

5.1 Integrated Management System

The Kiggavik Project will develop an Integrated Management System (IMS), based on AREVA's approach to quality management at the McClean Lake Operation, which provides an overall structure for all site controlled aspects of product quality, processes, and support services. In addition, the Kiggavik Project will target ISO 14001 certification within the first few years of operation. The ISO 14001 registration ensures that Environmental Management Systems used by AREVA conform to rigorous international standards and continually strive to improve environmental protection. To avoid duplication, the IMS has been designed to address all of the requirements for products, processes and support services as well as those of environmental management.

The IMS developed for the Kiggavik Project, including procedures and work instructions shall apply during all phases of decommissioning and reclamation in accordance with the future Kiggavik quality assurance management system. Because the IMS will be dynamic, changes and/or additions required specifically for decommissioning will be integrated as necessary, to ensure appropriate quality control over all critical activities.

During the review process for the DEIS, AREVA committed to provide a list of critical sites/facilities for regular visual inspection, as of the end of the operations phase. This list is provided below in Table 5.1-1.

Table 5.1-1 List of Critical Sites/Facilities Requiring Regular Visual Inspection at Start of Decommissioning

Site/Facility	Inspection Responsibility	Inspection Parameters
Kiggavik Site		
Mill Complex	Operations, Safety	Pumps/tanks/piping - general condition, containment integrity, spills, leaks Utilities/equipment - general condition Spill supplies and fire protection systems - inventory, condition General housekeeping
Tailings Management Facilities	Operations, Environment	Pond - level, depth Pipelines - general condition, containment integrity, spills, leaks
Type 1/Type 2 Mine Rock and Overburden Stockpiles	Environment	Runoff drainage and diversion - general condition Sedimentation ponds - general condition
Ore and Type 3 Mine Rock Storage Pads	Environment	Drainage and diversion - general condition, containment integrity Collection ponds - liner integrity and freeboard
Water Treatment Plant and Effluent Discharge Pipeline	Operations, Environment	Pumps/tanks/piping/pipeline - general condition, containment integrity, spills, leaks Utilities/equipment - general condition General housekeeping
Fuel and Waste Oil Tanks	Environment	Containment integrity, tank levels, general condition Spill and fire protection supplies - inventory, condition
Airstrip and Buildings	Operations, Safety	Runway surface integrity, lighting, and drainage Spill and fire protection supplies - inventory, condition
Solid Waste Disposal Areas and Storage Facilities	Environment	Drainage and diversion - general condition, containment integrity General housekeeping
Site Roads	Operations, Environment	Roadway surface integrity and drainage Dust monitoring and mitigation
Sissons Site		
Andrew Lake Open Pit	Operations, Environment	Pit wall and access ramp stability, safety, and controlled access Pumps/tanks/piping - general condition, containment integrity, spills, leaks
Andrew Lake Dewatering Structure	Environment	General condition and stability

Table 5.1-1 List of Critical Sites/Facilities Requiring Regular Visual Inspection at Start of Decommissioning

Site/Facility	Inspection Responsibility	Inspection Parameters
		Seepage, erosion
Buildings (Heavy Duty Shop and Mine Dry)	Operations, Safety	Pumps/tanks/piping - general condition, containment integrity, spills, leaks Utilities/equipment - general condition Spill supplies and fire protection systems - inventory, condition General housekeeping
Water Treatment Plant and Effluent Discharge Pipeline	Operations, Environment	Pumps/tanks/piping/pipeline - general condition, containment integrity, spills, leaks Utilities/equipment - general condition General housekeeping
Type 1/Type 2 Mine Rock and Overburden Stockpiles	Environment	Runoff drainage and diversion - general condition Sedimentation ponds - general condition
Ore and Type 3 Mine Rock Storage Pads	Environment	Drainage and diversion - general condition, containment integrity Collection ponds - liner integrity and freeboard
End Grid Underground Mine	Operations, Safety	Underground access control
Solid Waste Disposal Areas and Storage Facilities	Environment	Drainage and diversion - general condition, containment integrity General housekeeping
Site Roads	Operations, Environment	Roadway surface integrity and drainage Dust monitoring and mitigation
Baker Lake Dock and Storage Facility		
Dock	Operations, Environment	Structure - general condition Utilities/equipment - general condition Spill supplies and fire protection systems - inventory, condition
Storage Facility	Operations, Environment	Controlled access and security Spill and fire protection supplies - inventory, condition Drainage and diversion - general condition, containment integrity General housekeeping
Oil Handling Facility	Operations, Environment	Pumps/tanks/piping - general condition, containment integrity, spills, leaks Utilities/equipment - general condition Spill supplies and fire protection systems - inventory, condition

Table 5.1-1 List of Critical Sites/Facilities Requiring Regular Visual Inspection at Start of Decommissioning

Site/Facility	Inspection Responsibility	Inspection Parameters
		General housekeeping
Baker Lake - Kiggavik Access Road		
Winter Road	Operations, Environment	Roadway surface integrity and ice conditions Wildlife monitoring
All-season Road (if constructed)	Operations, Environment	Roadway surface integrity and drainage Dust monitoring and mitigation Wildlife monitoring

5.2 Environmental Protection

The decommissioning environmental protection program will be based on the Kiggavik Project operational environmental protection program in place prior to decommissioning. Following the end of operations, the operational program will continue until commencement of decommissioning activities. It is expected that the extent of the program will generally reflect the state of completion of site decommissioning, with reduced environmental protection program activities as decommissioning activities are completed.

Kiggavik Project staff will update and implement the IMS and Environmental Code of Practice (ECoP) to protect both worker safety and the environment during decommissioning. In addition, procedures and associated work instructions will be updated and revised as appropriate from the operational documents.

The IMS will apply during all phases of decommissioning and reclamation. This includes standard methods for sampling, monitoring and environmental data management. Specific sampling and monitoring locations, parameters and frequencies to be used during decommissioning and post-decommissioning periods would be based on review of the operational data and future discussion with the regulatory agencies.

The Environmental Monitoring Program (EMP) will be maintained throughout the decommissioning period to ensure compliance with regulatory requirements and to assess environmental performance during and after decommissioning. There will also be a Follow-up Program (FUP) to verify the assumptions made in the environmental assessment and to ensure that the decommissioning objectives have, or will likely be achieved.

The post-decommissioning EMP (i.e. monitoring stations and frequency) will depend on the results of the decommissioning EMP. It is anticipated that the post-decommissioning EMP will be substantially reduced over time, with the focus being on surface and groundwater quality and performance of critical facilities.

The FUP will be conducted concurrently with the EMP and specifically focus on the assumptions and uncertainties utilized in the prediction of long-term environmental performance. It will continue until these uncertainties are resolved and refinements to the long-term modeling demonstrate acceptable performance for the future.

Satisfactory completion of the above will lead to an application to the CNSC, NWB, and KIA to terminate the licences and leases held by AREVA. This will require development of a long-term institutional control framework similar to that which now exists for decommissioned mine sites in Saskatchewan.

5.3 Radiation Protection

AREVA envisions that the same system for radiation protection (RP) developed at the McClean Lake Operation and at the Cluff Lake Project in Saskatchewan would apply to the Kiggavik Project based on the good success of those programs historically. The procedures and work instructions established under the future IMS for the RP Program, Kiggavik Project would apply during all mine-life phases at the Kiggavik site. These procedures and work instructions would be established to control worker radiation exposure doses using standardized methods and will be updated as required to cover decommissioning activities.

The requirement to keep radiation exposures As Low As Reasonably Achievable (ALARA), social and economic factors taken into account, will be respected as an overall guiding principle.

In association with a future application for a decommissioning license, a revised RP Code of Practice will be prepared to complement the Detailed Decommissioning Plan. It will detail appropriate Administration and Action Levels. Post-closure radiological safety and radiological clearance of the decommissioned site are described in Section 6.2.3.

5.4 Health and Safety

Conventional health and safety activities during decommissioning will be conducted in a manner similar to operational activities. As with the operational phase of the Kiggavik Project, protection of the health and safety of workers will remain paramount throughout all phases of decommissioning. All other considerations will remain secondary.

The procedures and work instructions established under the future IMS for Health and Safety shall apply during all phases of decommissioning and reclamation. Because of changing manpower levels and activity types through different phases of decommissioning, it is recognized that the services provided by the Health and Safety group will change to remain appropriate during each phase.

The Kiggavik Project will target certification under OHSAS 18001 (Health and Safety) to enhance workplace safety. Certification and ongoing compliance require that hazard identification and risk assessments are conducted on all aspects of the operations. This management system will also apply during decommissioning. For each planning envelope during decommissioning, a Hazard Identification Checklist will be completed to identify what types of hazards workers are expected to encounter. This will be followed by a risk assessment of each of those hazards to determine what controls are necessary. Upon completion of the risk assessment auditing will be conducted to ensure that the necessary controls are being used and whether or not there are any other hazards that were missed during the risk assessments.

5.5 Emergency Response

A comprehensive emergency response system will be in place for earlier phases of the Kiggavik Project. The Emergency Response, Environmental Emergency Response and Environmental Monitoring Field Safety procedures, the Water Quality Contingency Plan (potable water) and the ARC Emergency Response Assistance Manual, Version 1 (AREVA 2010a) will continue to apply during all phases of decommissioning and reclamation. The Emergency Response Assistance Manual provides guidance to senior management and direction to emergency response personnel for off-site transportation incidents.

5.6 Site Security

Appropriate measures required to control site access, to prevent unauthorized removal of materials and to ensure the identity of all persons on site will be maintained in a manner similar to that during the operating phase of the mine. The procedures and associated work instructions established under the IMS for site security shall apply during all phases of decommissioning and reclamation.

5.7 Training

The procedures and work instructions established under the IMS for training shall apply during all phases of decommissioning and reclamation. Several tasks and circumstances associated with the decommissioning phase of the mine site will be unique to that phase. It is therefore recognized that training requirements will require updating at that time for specific activities as appropriate.

6 Post-Decommissioning Performance Predictions and Monitoring

6.1 Post-Decommissioning Performance Predictions

The assessment of mine rock materials produced during operation and its influence on post-decommissioning air and water quality suggests that, if properly managed, these materials will not pose a risk to the environment. Predictions of long-term performance of tailings and mine rock and associated effects on the environment have been assessed in Volume 4 Atmospheric Environment and Volume 5 Aquatic Environment and are summarized here. Post-remediation exposure levels and risks have been considered in Volume 8 Human Health and are discussed below.

An assessment was completed to characterize the physical and geochemical properties of the

tailings expected from the development of the Kiggavik Project as they relate to long term environmental management of the site and surrounding area. Groundwater flow and solute transport models confirmed the performance of the tailings containment system and the limited interaction between tailings and natural surface water bodies. Pointer Lake was identified as the main receptor with the potential to be affected over the long term (i.e., after several hundred years) by tailings management activities. Predicted long-term water concentrations of solutes in Pointer Lake were compared to baseline and to the applicable surface water quality objectives. All predicted concentrations were found to be well below applicable water quality objectives and for most constituents incremental concentrations calculated for both the current permafrost and no-permafrost conditions were found to be negligible in relation to baseline concentrations. A detailed discussion regarding long term effects of tailings management activities is provided in Technical Appendix 5J Tailings Characterization and Management.

An assessment of the physical and geochemical properties of the mine rock materials was also conducted. The use of Type 1 waste rock for construction purposes will not present a risk of acid generation or substantial metal leaching and the permanently stored Type 2 mine rock will not present an acid generating issue post-closure. At closure, the Type 3 Kiggavik and Andrew Lake rock materials will be placed in their respective mined out pits and managed underwater. A discussion on the post-closure effects of mine rock materials is provided in Technical Appendix 5F Mine Rock Characterization and Management.

The predicted recovery of Judge Sissons Lake water quality after effluent releases cease is discussed in Section 8.2 of Volume 5. Modelling indicates the system responds quickly and returns to baseline/pre-operation conditions, and that the Project does not have long-term effects on the water quality of Judge Sissons Lake. Post-decommissioning water quality is discussed in detail in Volume 5 Aquatic Environment.

An assessment of post-closure atmospheric emissions indicates that passive radon emissions are predicted to occur from the Type 2 mine rock stockpiles and the fully decommissioned TMFs, however, the predicted incremental radon concentrations are well below the annual threshold of 60 Bq/m^3 within the local assessment area (LAA) and regional assessment area (RAA). Decommissioning objectives are established to ensure that post-closure radiation exposures will not exceed the dose limit for the general public. No further assessment is conducted of the post-closure conditions as the site end-state must meet public dose limits, which are established for the protection of public health. Table 7.5-1 in Volume 8 Human Health summarizes the residual environmental effects identified for members of the public and indicates no residual impacts post-closure of the site.

6.2 Post-Decommissioning Monitoring

6.2.1 Post-Closure Monitoring

AREVA's key decommissioning objective is to remove, minimize, and control potential contaminant sources and thereby minimize the potential for adverse environmental effects associated with the decommissioned property. The PDP is designed to achieve an end-state of the properties that will be safe for human and non-human biota, chemically and physically stable, allow utilization for traditional purposes, and that minimizes potential constraints on future land use planning decisions. AREVA believes that by progressively reclaiming the site as various mining areas are completed and addressing any environmental issues that arise within those areas during the operational phase, that the need for care and maintenance activities, and long-term institutional control can be minimized.

Where relevant, specific water, air, or soil objectives are defined in relation to existing federal and territorial regulations or guidelines, taking into consideration site-specific conditions. For identified COPCs, where federal or territorial guidelines are not available, information obtained from the scientific literature and site specific conditions will be evaluated to derive benchmarks for inclusion as decommissioning objectives.

The operational monitoring plans both minimize the risk of environmental impact and provide a basis for the closure and post-closure monitoring programs. Following the completion of decommissioning activities, a post-closure monitoring program will be implemented. The objectives of the post-closure monitoring program will be to:

- Monitor designated environmental parameters on an on-going basis to ensure that they conform to licence requirements with respect to environmental protection;
- Verify the success of the decommissioning activities;
- Demonstrate compliance with regulatory requirements and decommissioning objectives; and,
- Quantify any residual environmental effects.

Routine inspections of all areas and critical facilities will continue to be conducted during the post-closure monitoring period to ensure decommissioning efforts are successful and that the Kiggavik Project sites are environmentally secure. An on-site workforce will be responsible for implementing the program.

Attachment B provides the Post-Decommissioning Monitoring Plan for AREVA's Cluff Lake Project as an example. Although the specific components of the Kiggavik Project post-decommissioning monitoring plan will be different in detail, the basic approach and scope will remain the same.

During the review process for the DEIS, AREVA committed to provide a list of facilities requiring post closure physical stability monitoring. The facilities, and the physical stability considerations for each, are provided below in Table 6.2-1.

Table 6.2-1 Facilities Requiring Physical Stability Monitoring

Facility	Physical Stability Considerations
Tailings Management Facilities[1]	Cover subsidence or differential settlement, causing poor drainage from the surface and/or water ponding on the surface Erosion or development of significant fissures in the cover, causing an increased rate of infiltration of precipitation
Permanent Mine Rock Stockpiles[2]	Deterioration of slope stability, causing a potential safety hazard for humans or wildlife accessing the stockpiles
End Grid Underground Mine	Ground subsidence above the surface footprint of the underground workings, causing a potential safety hazard for humans or wildlife accessing the area

Table 6.2-1 Facilities Requiring Physical Stability Monitoring

Facility	Physical Stability Considerations
	Deterioration of sealed openings (portal, ventilation raises) to the mine, causing a potential safety hazard to humans or wildlife accessing the area
Quarries and Borrow Pits	Deterioration of slope stability, causing a potential safety hazard for humans or wildlife accessing quarries or borrow pits

1. The breach of the tailings containment dam which occurred on August 4, 2014 at the Mt. Polley mine in B.C. has increased the focus on the need to maintain secure physical containment of tailings. AREVA notes that the conversion of mined out pits to the TMFs for the Kiggavik Project eliminates any need to rely on dams for tailings confinement. In-pit TMFs also provide secure long-term tailings containment, should climate change cause loss of permafrost at the Kiggavik site.
2. AREVA notes that only Type 1 and Type 2 mine rock will permanently remain on surface. Mine rock characterization and analyses of environmental impacts from precipitation infiltrating through these stockpiles, discussed in Technical Appendix 5F, Mine Rock Characterization and Management, shows that long-term environmental protection is achieved without the need for a cover designed to limit infiltration. Monitoring of cover integrity for deterioration, which would increase infiltration, is thus not required.

The data from the post-closure monitoring period will be evaluated prior to the end of the monitoring period to confirm decommissioning objectives are achieved and mitigative measures are performing as designed. Once the data indicates the decommissioning objectives are achieved, the Long-Term Monitoring Program (LTMP) will be initiated.

6.2.2 Radiological Clearance

AREVA commits to achieve a safe state of closure, which meets regulatory criteria at the time of closure, and demonstrates a radiological end-state that is As Low As Reasonably Achievable (ALARA), social and economic factors considered. Radiological release criteria for decommissioning will be developed based on the results of a formal future land use assessment involving local stakeholders in the region. The approach is consistent with decommissioning objectives described in international guidance, and used in other uranium mining jurisdictions. Pre-development background radiation dose rates inform the development of site-specific decommissioning criteria along with considerations of the future use of the site, societal expectations, and economic factors.

Incremental dose rate objectives are used to practically guide decommissioning activities to achieve dose based criteria with the application of the ALARA principle to ensure that decommissioning expenditures result in a corresponding increase in benefit to persons, the environment, or society. Regulatory limits are designed to protect the public and the environment; meeting these dose-based criteria ensure that residual effects are not significantly adverse. The inclusion of the ALARA concept within the decommissioning objectives acknowledges the desire to minimize impacts and to return the land to traditional uses, while considering social and economic factors.

Surveys are required to identify any surficial soils which have been affected by spillage of small amounts of ore or Type 2 or Type 3 mine rock, during hauling or temporary stockpiling of these materials. Any areas requiring remediation are readily identified by gamma radiation emitted from the uranium decay products present in these materials. Equipment and protocols for detailing surface radiological clearance surveys by AREVA, remediation if needed, and independent verification by the CNSC have been developed and implemented for decommissioning of AREVA's Cluff Lake Project. These will be established for the Kiggavik Project using the same approach.

For the Cluff Lake Project, a gamma radiation clearance process was developed and implemented which considered future use of the site and the ALARA principle to ensure no member of the general public would receive radiation exposure exceeding the public dose limit of 1 milliSievert (mSv) per year after decommissioning was complete. In addition, the analysis demonstrated application of the ALARA principle based on a dose constraint of 0.3 mSv/year to ensure the public dose limit is not exceeded. Site-wide comprehensive gamma surveys in major work areas were completed using the Surface Gamma Clearance Procedure approved by the CNSC (AREVA 2013). Surveys were conducted to ensure that residual radiation levels associated with the operation of the Cluff Lake mines and mill met criteria derived on the basis of achieving a safe, stable property that would allow utilization of the area for traditional purposes or occasional access. The Cluff Lake Project Surface Gamma Clearance Work Instruction is included for reference as Attachment C.

6.2.3 Follow-Up Program

The post-closure monitoring program will focus on key environmental indicators from the potential contaminant sources through to the atmospheric, terrestrial, and aquatic environment. In addition, a follow-up program (FUP) will be implemented to confirm that specific mitigative measures and processes are adequate and effective in achieving decommissioning objectives.

The FUP will have several components. A wildlife post-operation baseline will be required as a benchmark for assessing the success of reclamation activities. An aquatic decommissioning baseline will also be required, with a focus on Judge Sissons Lake. It is anticipated that other key components of the follow-up program will include the Tailings and Mine Rock Optimization and Validation Programs (TOVP/MROVP) and updates of the post-decommissioning source terms and contaminant transport models. Observations related to climate change over the life of the project will be incorporated in the updated models. Completion of the FUP will be gradual, as individual components will conclude at different times.

6.3 Transition to Institutional Control

It is anticipated that an Institutional Control Program (ICP) for the decommissioned site will be formally established, similar to the program which now exists in Saskatchewan for decommissioned mines. A long-term monitoring program (LTMP) will be implemented at the end of the post-closure monitoring period. It will continue until AREVA has advanced to the point where application can be made to enter the site into the ICP. Transition from the post-closure environmental monitoring to the long-term monitoring program is expected to be gradual. The objective of the program will be to confirm that mitigation measures will remain effective in the long term. The focus of the LTMP will be to ensure that all information, all collection and analysis of data, and compilation of records is organized towards supporting a future application to transfer the Kiggavik site to the ICP.

Site activities will continue to be regulated until AREVA has advanced the information sufficiently to successfully apply for release from the long-term monitoring phase and transfer of the site back to the landholders under the ICP. The application will include a recommended scope for any on-going monitoring and/or land use controls which will continue after transfer of the site into the ICP. AREVA expects that the ICP framework will also include requirements for estimating future costs for ongoing care of the site and for funding of those future costs by AREVA as a condition for entry of the site into the ICP.

7 Financial Assurance

7.1 Preliminary Estimate of Decommissioning Cost

The preliminary cost estimate for decommissioning is $158,624,608 (CAD). The following table breaks out the key areas for the Kiggavik Project decommissioning cost estimate.

Table 7.1-1 Preliminary Decommissioning Cost Estimate

Component	Estimated Decommissioning Cost (CAD)
Mill Complex	$10,848,351
TMFs	$25,264,201
Effluent Treatment	$7,662,600
Kiggavik Camp Area	$724,393
Kiggavik Ancilliary Infrastructure	$7,214,198
Judge Sissons Discharge Area	$32,816
Sissons Mining Area	$1,102,466
Sissons Ancilliary Infrastructure	$20,865,662
Air Strip	$1,940,609
Baker Lake Port Infrastructure	$267,960
Camp Operating Costs	$25,281,948
Project Management	$14,373,067
Fees and Monitoring	$22,719,749
Heavy Equipment Mobilization/Demobilization	$2,800,000
Pads and Liner removal	$17,526,588
Total	$158,624,608

7.2 Future Financial Assurance Considerations

AREVA has significant experience with the decommissioning of the Cluff Lake mine in Northern Saskatchewan and with the progressive decommissioning of its operating McClean Lake uranium mine; therefore, the approach to third party cost estimation and the level of the contingency rates used in this preliminary plan are based on that experience. In addition, the Kiggavik Project PDP is a dynamic but preliminary document and the level of detail will increase as the project progresses in terms of the detailed engineering and feasibility phases.

The items noted in Table 7.2-1 are representative of an advanced project design entering the licensing phase for construction and operation, rather than a preliminary conceptual approach to decommissioning. The preliminary Kiggavik Project decommissioning cost estimate (Table 7.1-1) includes most of the items referenced in Table 7.2-1. These items will be further refined at the licensing stage during revision of the Kiggavik Project PDP.

Table 7.2-1 Future Financial Assurance Considerations

Element	Description	Present (Y/N)	Reference
Third Party Estimation	The preliminary Kiggavik decommissioning cost estimate is based on third party rates	Y	Cluff Lake Project and McClean Lake Operation Decommissioning Plans as well as actual contract work done at the current Kiggavik Exploration Project
Contingency	Contingency rates based on the relatively high level of confidence in the cost estimates based on the use of actual decommissioning contract rates at AREVA’s Cluff Lake Uranium Mine in Northern Saskatchewan and from progressive reclamation contracts at AREVA’s McClean Lake Operation	Y	All cost components contain independent contingency rates which are based on the certainty of the estimate
Mobilization/Demobilization	Estimated costs for contractor mobilization and demobilization to and from the Project site. This cost assumes that the equipment would remain on-site until completion of the active decommissioning program	Y	Under “Heavy Equipment Mobilization/Demobilization”
Inflation	Annual escalation of costs due to inflation is not included in this preliminary plan as there is no definitive date at this time when construction will begin, however, this would be added at the licensing stage for construction and operation	N	N/A
Contractor Overhead/Profit	Contractor overhead is included in the preliminary decommissioning plan	Y	“Camp Operating Costs”, “Project Management” and “Fees and Monitoring”

Agency Administration	The project management and regulatory costs are third party rates and can be applied to either the regulatory agencies or to contractors depending on who is administering the project	Y	"Project Management" section
Engineering Redesign	AREVA believes that the contingency amount should represent all potential uncertainties including engineering redesign	Y	All cost components have a contingency provision
Indirect Costs	All remaining indirect surcharges or costs have been included in the preliminary decommissioning cost estimate. They include camp operation and maintenance, flights in and out of the site, support services such as environment, safety and radiation protection as well as regulatory fees	Y	"Camp Operating Costs", "Project Management" and "Fees and Monitoring"

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Attachment A Andrew Lake Pit Flooding

Alternatives Assessment for Andrew Lake Pit Flooding

Long-term management of Type 3 (potentially acid generating) mine rock is best accomplished by placing it under water. This prevents access to the mine rock by atmospheric oxygen, and hence prevents further oxidation reactions leading to acid generation. The plan proposed (Volume 2, Project Description and Assessment Basis, Section 13.4.2) is to temporarily store the Type 3 mine rock from the Andrew Lake open pit and the End Grid underground mine, then to place it at the bottom of the mined out Andrew Lake pit prior to reflooding. An alternative location for Type 3 mine rock long-term management would be to deposit it in a natural water body. Given the availability of the mined out Andrew Lake pit, deposition of the Type 3 mine rock in a natural water body has not been pursued.

The plan proposed is to partially fill the mined out pit with problematic (Type 3) mine rock, place a till cap, and then accelerate flooding of the partially filled pit. The only alternative to flooding would be to completely backfill the pit with additional non-problematic (Type 1/Type 2) mine rock. The fundamental requirement of the decommissioned Andrew Lake pit is long term protection of the environment. Water quality in the flooded pit has been previously evaluated. (See Volume 5, Section 7.2.2.4 and Technical Appendix 5F, Section 10). This evaluation suggests that the pit water will not represent a risk to aquatic life and can be discharged to surrounding surface water bodies without concern after closure. Flooding of the partially backfilled pit is then the preferred alternative, given the large additional cost to fully backfill the pit with waste rock.

Flooding could be left to occur naturally over an extended period (hundreds of years), or could be accelerated by transfer of water from one or more nearby surface water bodies. Additionally, the berm separating the dewatered part of Andrew Lake from the remaining natural part of the lake could either be permanently left in place, or partially or fully removed subsequent to completion of flooding and confirmation of satisfactory water quality in the flooded pit.

In order to confirm satisfactory water quality in the flooded pit within a reasonable time period, natural flooding would take too long, and accelerated flooding will be required. Furthermore, the initial concentrations of various COPC and other constituents in the water in the flooded pit are likely to be lower after accelerated flooding. (See Volume 5, Section 7.2.2.4 and Technical Appendix 5F, Section 10).

Two potential sources of water for accelerated pit flooding are to divert water from the remaining natural part of Andrew Lake, or to pump water from Judge Sissons Lake (utilizing road and pipeline previously used for treated effluent release during operations). A passive system for diversion of water from Andrew Lake is the preferred alternative. The berm installed to dewater part of Andrew Lake in order to mine the open pit, would be breached allowing the Andrew Lake pit to fill passively. Further details are provided below.

Preferred Decommissioning Strategy

Design Summary

Type 3 mine rock from Andrew Lake open pit and End Grid Underground mine will be backhauled as soon as practical after completion of Andrew Lake open pit mining. The estimated volume is approximately 1 million loose cubic meters (Volume 2, Table 6.5-1). The Type 3 material will be covered with a layer of till. The volume of water required for flooding has conservatively not been reduced by the volume of this layer which will not be finalized until the detailed design stage.

The volume of water required for flooding is then taken to be the pit volume of 38.4 million m^3 (Volume 2, Table 5.3-1 minus about 1 million m^3 of Type 3 mine rock, equals 37.4 million m^3). This is conservative in that a uniform elevation is assumed around the pit circumference, whereas the actual volume for flooding will be determined by the lowest elevation, where overflow from the flooded pit would first start.

In parallel with backhauling the solid materials, a water diversion structure will be constructed within the berm. A cofferdam will first be installed to isolate that section of the berm. The minimum elevation for water diversion to start from the remaining natural part of Andrew Lake will be above the minimum natural elevation at zero outflow. Specifically, a natural outflow in the order of 0.1 to 0.2 m^3/s will be established during the spring freshet before the Andrew Lake water elevation reaches the elevation where diversion to the pit begins (see details below). The flow cross-section for changing water elevations at the diversion structure will yield a flow vs. elevation relationship similar to that for the Andrew Lake natural outflow (Technical Appendix 5A, Section 5.2.2.1 (LE 8, Andrew Lake)).

A flow control structure will also be constructed at the natural outlet of Andrew Lake. It will incorporate a variable flow outlet feature (valve in pipe, or variable height and/or width weir), which can be adjusted with water elevation to maintain an outlet flow of up to 0.1 to 0.2 m^3/s during all periods of natural discharge from Andrew Lake. This system will allow about 95% of the natural annual inflow to Andrew Lake, occurring primarily during the spring freshet in June and July, to be diverted to the Andrew Lake pit. This corresponds to an average of about 6.3 million m^3 annually (see sections below).

The flooding time for Andrew Lake pit will thus be about 6 years (37.4/6.3), or less given that the total volume has been conservatively estimated.

Andrew Lake Diversion Potential

Daily discharge data were measured for the outflow from Andrew Lake through June, July and August of 2009 and 2010 (Technical Appendix 5A, Attachment VII, Table VII-11). These data were analyzed and showed that over this 2 year period, 96% of the total recorded flow occurred with a stream flow of 0.2 m^3/s or greater, and 97.5% of the recorded flow occurred with a stream flow of 0.1 m^3/s or greater. A water diversion structure to divert flow from the remaining natural part of Andrew Lake to flood the Andrew Lake pit can thus capture most of the annual stream flow while allowing natural flow during low flow periods to be undisturbed. To allow for annual variations, a diversion factor of 95% of the average annual flow volume has been used to estimate the pit flooding time.

The above reference (Table VII-11) also contains estimates of daily discharge flow from Andrew Lake for 2007 and 2008, derived from other surface flows recorded at nearby locations in those years. These data support conclusions from the 2009 and 2010 measured data. In fact, over the four years the annual flow volumes range from 4 to 8 million m^3, and average 6.55 million m^3. It is noted that this average value agrees well with the value of 6.6. million m^3 in Table A1.1-1 in the next section. This latter value is based on the observed correlation between mean annual discharge and drainage area.

Impact on Downstream Lakes

Andrew Lake is within the Lower Lake sub-basin of the Aniguq River basin. The Lower Lake sub-basin water bodies are listed in Volume 5, Table 5.3-1 and shown in Volume 5, Figure 4.5-1. Review of the table and figure shows that the downstream lakes which will be affected by diversion of flow through Andrew Lake for pit flooding are, in sequential order, Shack Lake, Lower Lake and Judge Sissons Lake.

Table A1.1-1: Flow Characteristics – Andrew Lake and Downstream Lakes

Parameter	Andrew Lake	Shack Lake	Lower Lake	Judge Sissons Lake	Reference
Drainage Area (ha)	33.6	47.2	69.0	705	1
Mean Annual Discharge (m^3/s)	0.21	0.29	0.42	4.16	1
Annual Discharge Volume ($m^3 \times 10^6$)	6.6	9.1	13.2	131.2	Calculated(1)
Lake Volume ($m^3 \times 10^6$)	0.0958	0.360	0.196	439	1
Annual Turnovers	69	25	67	0.30	Calculated (2)
Reduced Mean Annual Discharge (m^3/s)	n/a	0.08	0.21	3.95	Calculated (3)
Reduced Annual Discharge Volume (m^3 x	n/a	2.5	6.6	124.6	Calculated (4)

Table A1.1-1: Flow Characteristics – Andrew Lake and Downstream Lakes

Parameter	Andrew Lake	Shack Lake	Lower Lake	Judge Sissons Lake	Reference
10^6)					
Reduced Annual Turnovers	n/a	7	34	0.28	Calculated (5)
Maximum Depth (m)	1.0	1.6	1.4	20.6	2

(1) Mean Annual Discharge in m^3/s times 31.536 x 10^6 s/a

(2) Annual Discharge Volume (m^3) divided by Lake Volume (m^3)

(3) Mean Annual Discharge in m^3/s minus Andrew Lake Mean Annual Discharge in m^3/s

(4) Reduced Mean Annual Discharge in m^3/s times 31.536 x 10^6 s/a

(5) Reduced Annual Discharge Volume divided by Lake Volume

References:

1. Technical Appendix 5A, Hydrogeology Baseline, Attachment III, Table III-1
2. Volume 5, Aquatic Environment, Table 5.3-1

Flow characteristics for these lakes are included above in Table A1.1-1. Shack Lake and Lower Lake have similar characteristics. Both are shallow with maximum depths well below 2 m so may be expected to freeze over the full depth each winter. Both have high ratios of annual discharge volumes from their respective drainage areas to the lake volumes. Lake volumes are thus turned over multiple times during the spring freshet. The effect of removing the Andrew Lake outflow from the current total outflows of each of these lakes is shown in the table. The number of turnover volumes during the spring freshet is reduced but still occurs multiple times. There will be no effect on these lakes during low flow conditions, given the planned design of the Andrew Lake diversion structure, and the Andrew Lake outlet flow control structure. Preservation of multiple turnover volumes during the spring freshet, and of natural low flow conditions, is expected to eliminate any potentially significant environmental impacts on these lakes.

Judge Sissons Lake is much larger and deeper, and removal of the Andrew Lake outflow will reduce the annual flow through this lake by only about 5%. This will be less than year to year variability and not expected to have any significant environmental impacts.

In summary, run off from the large drainage area for Andrew Lake will be used. The annual outflow from Andrew Lake is about 70 times the lake volume. Water will be diverted from Andrew Lake, primarily during the annual freshet, using a diversion structure to breach the berm. The design of the diversion structure, and of a flow control structure at the outlet of Andrew Lake, will maintain Andrew Lake elevations within their natural range. A basic design will be done to finalize the preliminary decommissioning plan and financial assurance at the licensing phase prior to operations. Final optimization will be done as part of the detailed decommissioning plan.

The nominal schedule for pit flooding will be six years, at an average annual diversion flow of 6.3 million m^3. Consideration will be given at the time the detailed decommissioning plan is developed, as to whether to further accelerate the schedule by pumping from Judge Sissons Lake. As shown (Volume 5, Section 6.2.1.5), Judge Sissons Lake could sustain a withdrawal rate of 1 m^3/s over a 4 month summer period, but no evaluation has been made of the pumping system required.

Flooded Pit Water Quality

Accelerated Flooding

Technical Appendix 5F, Table 10.2-2 has been amended to include the predicted chemistry of the pit water for the natural filling (long term) and accelerated filling (10 years) scenarios. The amended Table 10.2-2 in Technical Appendix 5F is provided here as Table A1.2-1. The predicted chemistry was taken from the modeling results that were available but had not been reported fully.

The predicted chemistry for the accelerated pit filling scenario shows that only aluminum exceeds the CCME guideline value for the protection of aquatic life. Aluminum may be predicted to be conservatively high because it is based only on loadings from the rock and mixing. No other geochemical reactions were considered for aluminum and a reaction that is likely to occur and to limit aluminum concentrations is the precipitation of aluminum hydroxide [$Al(OH)_3$] that is known to form in nature at neutral pH values that are expected in the pit water. The solubility of aluminum hydroxide solids can be lower than 0.005 mg/L at a pH of 7 (Stumm and Morgan, 1981). Therefore, it is likely that aluminum will not exceed the CCME value after accelerated or natural pit filling.

Contingency Measure for Treatment if Required

With accelerated pit filling, there will be time to monitor and assess the pit water chemistry during the decommissioning period. This will allow verification of the predicted chemistry and time to develop mitigation strategies if the concentrations of some COPCs exceed the CCME guideline values. There are potential options for mitigation should there be concern for concentrations of some metals.

One technology that has been used in Canada to manage pit water quality is pH adjustment by batch treatment in the pit. The concept of pH adjustment is used in water treatment plants to remove metals from mine water routinely across Canada and globally. This concept has been applied in-situ in pits to remove metals as well. This has been successfully completed in a pit with more than 25 Mm^3 of water (R. Nicholson, personal communication, 2012) and therefore it should be also possible to treat water in the Andrew Lake pit.

Alternatively, pit water could be treated in a water treatment plant specifically constructed for that purpose and that can be operated in campaigns during ice-free periods. The water balance for the pit shows that the inflows are about 90,000 m^3/year. This is a relatively small flow that can easily be treated in a short period of time each year or more likely can be managed by treating several hundred thousand cubic metres in one season by pumping the pit down and then allowing several years for filling before needing to treat excess water from the pit. In any case, water treatment represents standard and best practice technology and by keeping the pit water level below the water levels in surrounding water bodies, the water can be safely contained with no risk to the environment. The low inflow and large pit volume provide management options that could be implemented to assure environmental protection if concentrations of COPCs exceed guideline values in the future.

Nitrogen Concentrations in the Pit Water

Nitrogen compounds related to mining activities include nitrate and ammonia. These compounds originate from explosives that are typically used for blasting of rock. A common chemical used in explosives is ammonium nitrate (NH_3NO_3). The components of this compound get into water as a result of leaching of unexploded material either before or after blasting. Mining operations typically have ammonia management programs in place to minimize the amounts of ammonia in mine water. Technical Appendix 2C Explosives Management Plan discusses proposed measures to effectively manage ammonia. In open pit operations the residual nitrogen explosives are continually washed from the benches and pit floor and dissolve to be pumped out of the pit during normal dewatering operations. The mine waters at the Kiggavik operation will be treated prior to being discharged to the environment. Therefore, the dissolved nitrogen compounds will be continually removed from the pits during operations and the only nitrogen compounds that will remain in the pit at the end of operations will be the relatively small quantities that were used near the end of the operations.

The concentrations of dissolved nitrogen compounds in open pit waters are typically less than 100 mg/L (as N) for ammonia and nitrate. At the end of the operation, the amount of water in the bottom of the pit will be relatively small. The bottom of the Andrew Lake pit will be about 200 m in diameter with an area of about 30,000 m^2. If the amount of water is 1 m deep, then the volume of water left in the pit will be 30,000 m^3. When the pit fills with fresh precipitation (or Andrew Lake water for the accelerated pit filling scenario), there will be about 40 Mm^3 of water in the pit, representing a mixing ratio of 1,300:1 for the original concentrations. This means that an original concentration of 100 mg/L will translate to a final concentration of 0.075 mg/L. This concentration is well below the guideline values for ammonia of 10.3 mg/L at a pH of 7 and a temperature of 10 ^{o}C and for nitrate of 13 mg/L (CEQG, 2003). In reality, there will be other chemical reactions such as oxidation of ammonia and denitrification that can remove ammonia and nitrate, respectively, from the pit water over time.

Proposed Objectives for Release of Andrew Pit Water to Andrew Lake

The proposed water quality objectives to allow release of Andrew Lake pit water to Andrew Lake are the CCME guidelines listed in Table A1.2-1 which is adopted from Table 10.2-2 in Technical

Appendix 5F Mine Rock Characterization and Management. Accelerated filling is predicted to result in all COPC concentrations meeting these guidelines.

Table A1.2-1: Summary of Calculated Andrew Lake Pit Water Concentrations after Flooding

COPC	Units	CCME Guideline for Protection of Aquatic Life	Andrew Lake Pit Water Concentrations after Natural Filling	Andrew Lake Pit Water Concentrations after Accelerated Filling (10Years)[4]	Steady-State Pit Water Concentrations from Exposed Pit Walls
pH	pH units	6.5 – 9.0	6 – 7	6 – 7	6.5 – 7.5
Hardness (as $CaCO_3$)	mg/L	NR[2]	28	18	Less than 10
Sulphate (SO_4^{2-})	mg/L	NR	9.7	7.0	0.026
Aluminum (Al)	mg/L	0.005 – 0.100	0.178	0.019	0.00047
Arsenic (As)	mg/L	0.005	0.00088	0.00009	2.36E-06
Cadmium (Cd)[1]	mg/L	0.000017	0.000045	0.000005	1.20E-07
Chloride	mg/L	120	170	0.4	1.7
Chromium (Cr)	mg/L	0.0089	0.00067	0.00007	1.80E-06
Cobalt (Co)	mg/L	NR	0.00047	0.00005	1.25E-06
Copper (Cu)[1]	mg/L	0.002	0.00236	0.00025	6.31E-06
Manganese (Mn)	mg/L	NR	0.0040	0.0004	1.07E-05
Mercury	mg/L	0.000026	TBD[3]	TBD	TBD
Molybdenum (Mo)	mg/L	0.073	0.00074	0.00008	1.98E-06
Nickel (Ni)[1]	mg/L	0.025	0.00235	0.00025	6.30E-06
Lead (Pb)[1]	mg/L	0.001	0.00031	0.00003	8.41E-07
Antimony (Sb)	mg/L	NR	0.00045	0.00005	1.20E-06
Selenium (Se)	mg/L	0.001	0.00045	0.00005	1.20E-06
Strontium (Sr)	mg/L	NR	0.034	0.004	9.02E-05

Table A1.2-1: Summary of Calculated Andrew Lake Pit Water Concentrations after Flooding

COPC	Units	CCME Guideline for Protection of Aquatic Life	Andrew Lake Pit Water Concentrations after Natural Filling	Andrew Lake Pit Water Concentrations after Accelerated Filling (10Years)[4]	Steady-State Pit Water Concentrations from Exposed Pit Walls
Uranium (U)	mg/L	0.015	0.016	0.012	4.33E-05
Vanadium (V)	mg/L	NR	0.0045	0.0005	1.20E-05
Zinc (Zn)	mg/L	0.03	0.0148	0.0016	3.97E-05

1-Hardness after pit flooding will be applied to these elements that are hardness dependent. The minimum values are shown in this table.

2- NR – no recommended value

3- TBD – Mercury values will be determined when the proposed humidity cell tests are completed for licensing4- Results are conservative for the estimated flooding time of 6 years (see Section A1.1.1)

Attachment B Cluff Lake Project Post-Decommissioning Monitoring Plan Example

Purpose:

The Cluff Lake Project operates under the operating license UMDL-MINEMILL-CLUFF.00/2019, issued by the Canadian Nuclear Safety Commission (CNSC), which has an expiry date of July 31, 2019. Furthermore, the Cluff Lake Project operates under the Saskatchewan Ministry of Environment (SMOE) issued "Approval to Operate Pollutant Control Facilities," Approval IO-191, which expires on October 31, 2016 a "Permit to Operate Waterworks," permit # Shield7-01-00, which expires November 30, 2013.

In fulfilling the requirements of federal and provincial licenses and regulations, and consistent with AREVA Resources Canada Inc.'s (AREVA) commitment to minimize the environmental impact of its operations, an environmental management program was developed and implemented at the Cluff Lake Project. The Environmental Management Program includes a series of key documents which include the Environmental Protection Procedures, this Environmental Monitoring Locations and Schedule (EMLS), the Follow-up Program, the Environment Protection Code of Practice. The entire Environmental Management Program is further described in the current Cluff Lake Project – Integrated Quality Management System Manual.

This document is Version 4 of the EMLS. This version incorporates modifications to the monitoring program resulting from the move to campaign monitoring. The frequency of monitoring has been reduced and certain locations that were included in EMLS Version 3 have been removed. For more details on changes to the monitoring program presented in EMLS Version 4 and associated figures please refer to AREVA 2011.

There will be a small number of staff on-site throughout the year as required to maintain a secure and safe site; however, the majority of environmental sampling will be conducted on a campaign basis by AREVA staff, and additional work will be conducted by environmental consultants. A separate document entitled "Cluff Lake Project - Code of Practice - Environmental Protection", describes administrative levels and action levels for environmental protection. An overview of how campaign monitoring will proceed is presented below:

Who:	On-site:	EMLS monitoring to be completed:
Site Services Staff – AREVA and long-term contractors (as needed)	Year-round presence	Inspections, manual meteorological readings, sanitary sewage works and potable water monitoring (until other arrangements are made – i.e. potable water system decommissioned and bottled water provided for drinking)
AREVA campaign monitoring EH&S staff	Year-round presence	Sample surface water and groundwater, change radon track etch cups, download meteorological data
External consultants	On-site as required for inspections or data collection	Geotechnical inspections; data collection for 2015 Status of the Environment report

Scope:

This document includes the routine operational and compliance monitoring locations and schedule for the post-decommissioning environmental protection program at the Cluff Lake Project. Special investigations and research programs, outside of the bounds of the routine monitoring, are not within the scope of this document.

Applicable To:

The Environment Health and Safety (EH&S) Coordinator is responsible for ensuring the monitoring requirements specified in this document are completed in accordance with the specified schedule.

With the move to campaign monitoring, a small site presence will be maintained for safety, security and monitoring purposes throughout the year and will likely consist of two to three people per shift. Components of the EMLS related to camp facilities (e.g. routine inspections [Table 1], manual meteorological monitoring [Table 2], sanitary sewage works monitoring [Table 6], and potable water monitoring [Table 7]) will be conducted by these individuals.

The majority of environmental sampling will be conducted on an ongoing basis by site EH&S staff, consistent with the frequencies outlined in this EMLS. The routine environmental monitoring will include downloading meteorological data (Table 2), changing radon track etch cups (Table 3) and collecting groundwater and surface water samples (Table 5). Data collection for the Status of the Environment (SOE) report (Tables 9-13) will to be conducted by environmental consultants on a campaign basis and geotechnical inspections will be conducted annually by a qualified engineer (Table 1).

Procedure:

The following sections describe the various components of the environmental monitoring activities at the Cluff Lake Project. Each section references the appropriate tables, which identify the various types of sampling (i.e. air, soil, water, etc.) and frequencies (monthly, semi-annually, etc.) for all sampling locations at the Cluff Lake Project.

1. Site Inspections

The site has been under careful surveillance since the decommissioning license was granted in 2004 and the majority of physical decommissioning has been completed. All physical structures are performing as expected; vegetation is now well established and risk of serious erosion has significantly diminished.

Water management and erosion evaluation and control inspection components (e.g. flooded pits, DP Fresh Air Raise, TMA, main dam, freshwater diversion ditches etc.) will be conducted during an annual geotechnical inspection conducted by a qualified engineer, with quarterly checks being completed by site personnel. Sanitary sewage and potable water inspections will be conducted daily while staff remains at site and the systems are in use. With the move to campaign monitoring, these systems may be decommissioned and no longer used and therefore, inspections will cease. Landfill inspections will be conducted weekly by site staff. Fuel storage inspections will continue on a daily basis by site staff. If the Secondary Treatment System (STS) is operating, routine daily inspections of effluent discharge, settling ponds and pumping systems will be completed.

Routine inspection frequencies are outlined in Table 1.

2. List of Parameter Classes

In order to simplify sampling, the use of parameter classes has been discontinued at the Cluff Lake Project.

3. Meteorological Monitoring

The weather database for the Cluff Lake project has been accumulating since 1981, and will continue as part of this EMLS. Weather data for the Cluff Lake Project are gathered using standard “Atmospheric Environment Service” procedures at the five weather monitoring stations listed as follows:

- The automated weather station located at the Cluff Lake airstrip records the temperature, precipitation, relative humidity, wind speed, and wind direction.
- A second automated weather station located at the TMA as part of the soil cover infiltration monitoring system. Temperature, relative humidity, wind speed and direction, net radiation and rainfall are monitored.
- A weather observation station located at Germaine Camp, at the north end of the Iron Crest Building, records temperature, rainfall/snowfall, snow depth, and snow water equivalency (SWE). Data from this manual station can be used as a backup source for weather information in the case where mechanical difficulties are experienced at the Cluff Lake airstrip automated weather station.
- An evaporation station is located at the southeast end of the TMA.
- A snow survey station is situated roughly 500 m south of the main dam.

With respect to manual meteorological monitoring, site personnel will collect daily weather readings. This information has been collected on-site since 1981 and data collection will continue as long as there are staff on site. The weather stations at the TMA and airport would continue to operate to provide continuous meteorological data. The download frequency of data at the automated weather stations will be semiannual.

Table 2 provides the list of meteorological data collection stations and frequencies.

4. Air Quality Monitoring

The track etch cup locations and sampling frequency are outlined in Table 3.

5. Effluent Monitoring Requirements

The final treated effluent discharged to Snake Creek from the Secondary Treatment System (STS) is sampled at one location (TMA6100S). Future effluent treatment appears unlikely and, if utilized at all, will likely be for short periods to treat small batches. However, discharge from this location continues to represent the regulatory approved final point of release to the environment. The effluent is subject to administrative and action levels specified in the Environment Code of Practice.

The sampling frequency and water quality parameters to be analyzed are provided in Table 4.

6. Monitoring of Groundwater and Surface Water Flowpaths

Changes in groundwater and surface water quality were assessed using a flowpath approach. Table 5 lists the locations, frequencies and parameters for groundwater and surface water at the Cluff Lake Project.

7. Sanitary Sewage Works Monitoring

As long as the current camp infrastructure is used at Cluff Lake, the sanitary sewage works monitoring will be conducted. Monitoring is done at the influent to and effluent from the sewage treatment plant, and at two Germaine Lake locations to monitor potential impacts from the sewage treatment plant. As this campaign monitoring program progresses, and where the site presence is minimal, alternate arrangements may be made to handle sewage and grey water.

The sampling locations, water quality parameters and sampling frequency are summarized in Table 6.

Potable Water Monitoring

The domestic water treatment system at Germaine Camp supplies potable water to site staff. Monitoring is done to ensure that water is safe for human use.

The potable water monitoring locations, water quality parameters and schedule, are outlined in Table 7. As campaign monitoring progresses, the Water Treatment Plant may be decommissioned, and an alternate potable water system will be implemented.

8. Soil Cover Monitoring

Soil cover monitoring will consists of quarterly downloads of data from the download stations at the TMA (CN1000L and CS1100L) and CWRP (CWR1000, CWR1000A, CWR1000B, CWR1000C). These stations would be downloaded quarterly, rather than monthly (Table 8). O'Kane Consultants will continue to come to site annually to complete any maintenance and repairs required at the download stations.

Visual observations and photos of the TMA and CWRP (Table 1) will continue to be completed quarterly, during the ice-free season, by the remaining site personnel. Annual photos of these areas will also be taken during the annual geotechnical inspection, which will be completed by a certified engineer.

The soil cover monitoring also includes soil moisture profiles of the Diviner access tubes monthly during ice-free months (CWR1000DV). The remaining EH&S personnel will collect these measurements and upload them to a PC.

9. Status of the Environment Sampling

In addition to surface water sampling, a schedule for sediment, benthic macroinvertebrates, fish, soil, and lichen sampling is required to provide data for the 2015 SOE report.

Details on these sampling programs are presented in Tables 9 to 13 below.

Records:

The Equis database will be used to store environmental data, schedule components of the EMLS, generate laboratory requests for analyses (Chain of Custody forms), identify and analyze trends in the data, and report data.

Results of the environmental monitoring activities will be outlined in two reports per year: a semiannual report and an Annual Report. AREVA produces these reports for SMOE, CNSC and Environment Canada to demonstrate regulatory compliance. Where applicable, results will be discussed relative to federal and provincial water quality objectives, as well as the site specific decommissioning objectives. The 2015 SOE report will involve more detailed statistical analyses of contaminant concentrations relative to predicted (modelled) performance.

Note – This attachment is provided to show the approach to, and the scope of, the post-decommissioning monitoring plan. Detailed tables have not been included since these details would differ for the Kiggavik Project.

Attachment C Cluff Lake Project Surface Gamma Clearance Work Instruction

Purpose:

The document "Process for Radiological Evaluation Following Decommissioning," June 2004, described at a conceptual level the process by which AREVA will demonstrate the project radiological objectives have been met following decommissioning at Cluff Lake. This work instruction describes the detailed activities associated with the process.

Acceptance of this process by the CNSC and SE provides greater certainty in the radiological clearance process. Once tests are passed, brief radiological clearance reports can be prepared in accordance with this work instruction. Provided reports are in compliance with this work instruction and tests are passed, final acceptance will only depend on field confirmation activities by the regulators.

Applicable To:

- Gamma Radiation Clearance of Cluff Lake Project

Work Instruction:

1. Area submitted for radiological clearance.
    - An area is identified for clearance. An area is suitable for clearance when no further earthworks are planned for the area.

2. Gamma Survey is conducted.
    - The gamma survey instrumentation is described in Appendix A.
    - Instrument response and positional calibration checks are performed and documented each day the instrument is used, in accordance with *CLP-170-06, QA/QC for Ludlum Model 2221 Survey Meter with Trimble TSC1*. Calibration factors for the conversion of counts data to exposure rate readings is provided in Appendix B.
    - The gamma radiation survey is conducted in accordance with *CLP-170-03, Operational Guidance for Radiological Clearance* and *CLP-170-04, Operation of Ludlum Model 2221 Survey Meter and Trimble TSC1*. Gamma radiation exposure rate measurements and coordinates are recorded in an electronic file. Electronic files are administered according to *CLP-170-05, Administration of Data using the GPS Pathfinder Software*.

3. Data evaluation and decision.

    The gamma survey data are subjected to a series of tests, which are listed below. The rational for the tests is described in Appendices C and D. Gamma radiation measurements are collected in an automated fashion using data logging equipment connected to both a radiation detector and a global positioning system. The surveyor moves through the survey area with the survey equipment continually logging data. This practice is intended to be consistent, at a minimum, with a 10 m x 10 m grid gamma radiation survey conducted for radiological clearance at other decommissioning sites. The radiation detector is held 1 m above the ground surface. To conduct data analyses, the survey data is fitted to a regular grid pattern electronically using Arcview with Spatial Analyst software tools. In general terms, grid spacing is selected and the grid pattern is overlain on the collected data. A search radius is selected and data points within the circular search pattern centred on each grid point are used to calculate the indicated statistics.

a) Data Density Test
  - The minimum data density required in disturbed areas is 1 gamma reading per 100 m^2. Areas of inadequate data density are identified for further radiation surveys and data is collected and appended to the initial data set before being resubmitted for data density testing. Once the Data Density Test is passed, the file can be subjected to clearance tests.

b) Lower Screening Value Test
  - If recorded values averaged over 10,000 m^2 (1 ha) are less than the lower screening value, the area can be considered cleared and report prepared for inclusion in the Q/A binder, provided data density and point source tests have also been passed. If values exceed the lower screening test, the area is submitted for subsequent tests.
  - The selection of the lower screening value is described in Appendix C.

c) Upper Screening Value Test
  - Individual Value Test: No individual value may exceed 2.5 μSv/h.
  - Dose Limit Test: The gamma radiation level averaged over 10,000 m^2 (1 ha) area may not exceed 1 μSv/h.
  - If either upper screening value is failed, either mitigative measures will be applied or, where mitigative measures are not practicable, a case will be prepared for consideration by AREVA management and regulators.
  - If both tests are passed, submit for ALARA tests.

d) ALARA Tests
  - The selection of ALARA objectives is discussed in Appendix D.
  - ALARA Test #1: The gamma radiation level averaged over 100,000 m^2 (10 ha) area may not exceed 0.3 μSv/h.
  - ALARA Test #2: Where gamma radiation levels averaged over a localized area of 1000 m^2 exceed 1 μSv/h, the area will be investigated to identify individual values exceeding 2.5 μSv/h.
  - ALARA Test #3: The total area exceeding 1 μSv/h within an area of100,000 m^2 may not exceed 10,000 m^2.
  - If an ALARA Test is failed, either mitigative measures will be applied or, where mitigative measures are not practicable, a case will be prepared for consideration by AREVA management and regulators.

- If ALARA test passed, file in the QA binder.

4. Prepare radiological clearance report including the items listed below. An example report is provided as Appendix E.
    - Description of area;
    - Summary of remedial work undertaken;
    - Summary of radiological data collected;
    - A survey drawing of the area showing gamma radiation levels;
    - Comparison of gamma radiation data to data test criteria; and
    - The rational for not mitigating any areas which exceed the cleanup criteria.

5. Obtain internal approval by Cluff Lake Manager, Decommissioning.

6. Insert report in QA binder.

7. At completion of all decommissioning work, consolidate radiological clearance reports for areas into a site end-state report for submission to regulators.

Summary of Data Tests

The table below describes the various tests associated with the Radiological Clearance Protocol.

Test	Purpose	Test Statistic	Criteria (@1 metre)
Data Density	To confirm an adequate number of readings has been collected per unit area.	Minimum data density(1)	1 reading/100 m^2
Lower Screening	To quickly remove areas within the range of local background from further consideration.	Maximum area average(1)	0.063 µSv/h
Upper Screening - Individual Value	To test against cleanup objective for individual readings.	Maximum individual reading	2.5 µSv/h
Upper Screening Value – Dose Limit	To ensure dose limit for members of the public is not exceeded using average values for small areas - 10,000 m^2 (1 ha).	Maximum area average(1)	1 µSv/h
ALARA Objective #1	To ensure exposure rates in large areas - 100,000 m^2 (10 ha) – conform to ALARA assessment.	Maximum large area average(2)	0.3 µSv/h
ALARA Objective #2	To initiate additional investigation in localized areas to identify points exceeding 2.5 µSv/h.	Average gamma in a 1000 m^2 area.	1 µSv/h
ALARA Objective #3	To ensure total area exceeding 1 µSv/h within a 100,000 m^2 area does not exceed 10,000 m^2	Total area which exceeds 1 µSv/h within a 10 ha parcel.	10,000 m^2

1. Search radius = 56.4 m
2. Search radius = 178.5 m

Records:

- Radiological Clearance Report

Reference:

- Process for Radiological Evaluation Following Decommissioning, June 2004
- *CLP-170-03, Operational Guidance for Radiological Clearance*
- *CLP-170-04, Operation of Ludlum Model 2221 Survey Meter and Trimble TSC1*
- *CLP-170-05, Administration of Data using the GPS Pathfinder Software*
- *CLP-170-06, QA/QC for Ludlum Model 2221 Survey Meter with Trimble TSC1*

Approval:

Author:

Safety & Radiation Coordinator	Kristine Stewart	
Print Title	Print Name	Signature

Reviewer:

SHEQ Coordinator	Devin Helps	
Print Title	Print Name	Signature

Approver:

Manager, Decommissioning	Dave Hiller	
Print Title	Print Name	Signature

Appendix A: Gamma Survey Technology

The major components of the Gamma Survey Technology are:

- Ludlum Model 2221 Survey Meter
- Ludlum Model 44-10 2" x 2" sodium iodide (NaI) detector
- Trimble Pathfinder Pro XRS Geographical Positioning System
- Trimble TSC1 Handheld Computer

The Ludlum Model 2221 Survey meter uses a sodium iodide (NaI) detector, Model 44-10, to measure gamma radiation exposure rates. The exposure rates are measured in units of Counts Per Minute (cpm). As NaI is very sensitive to gamma rays, this meter is useful for gamma surveys and measurements in areas where background exposure rates are very low.

The Trimble TSC1 Handheld computer collects data simultaneously from the GPS and the Ludlum Model 2221, storing gamma radiation readings with positional coordinates in an electronic file. Readings are collected each second during the survey, provided the GPS unit has sufficient satellite communication to determine a position. When satellite information is insufficient, no data is collected.

Gamma Survey Equipment

Ludlum Model 2221 with Model 44-10 NaI Probe	***Trimble Pathfinder Pro XRS GPS and TSC1***
	
Backpack Mounted Survey Gear	***ATV Mounted Survey Gear***
	

Appendix B: Instrument Calibration

A Ludlum Model 2221 Scaler with a sodium iodide scintillation probe is used for the gamma radiation surveys. A 2" x 2" sodium iodide probe was selected due to high efficiency in detecting gamma ray emissions. The instrument does not discriminate gamma energies and has an energy sensitive response. The contaminant of concern at Cluff Lake is uranium series radionuclides.

Presently, commercial available calibration services use point source calibration methods to determine detection efficiency. Sources used are typically Cs-137 or Co-60. These radionuclides exhibit a different energy spectrum than the uranium series. Further, commercial available calibration services do not account for the effect of differing source matrices on the energy spectrum. For these reasons, a calibration factor for the instruments used for gamma radiation clearance surveys has been established using a uranium source dispersed through a large volume concrete matrix. The calibration factor has been determined in accordance with a method described by Clement et al and incorporated into procedures developed by the Low-Level Radioactive Waste Management Office of AECL. An example of the calibration document is included at the end of this appendix. The equivalent uranium sensitivity of the NaI probes is 21 cps/μR/h. This is typical for 2" x 2" NaI probes.

The manufacturer's quoted sensitivity is 15 cps/μR/h using a Cs-137 source. Use of the quoted sensitivity for measurements of uranium distributed in soil would result in an over estimation of exposure rates of approximately 25%.

Conversion to Effective Dose Rate

Readings from the survey instrument must be converted from counts per minute to units of effective dose rate in μSv/h. The conversion is conducted as follows:

$$DoseRate(uSv/h) = \mathrm{Re}\,ading(cpm) \times \frac{cps}{60cpm} \times \frac{1}{E} \times \frac{1uSv}{100\,uR}$$

where the efficiency, E = 21 cps / μR/h

$$Dose\,Rate\,(uSv/h) = \frac{\mathrm{Re}\,ading(cpm)}{126{,}000\,(cpm/uSv/h)}$$

A conservative approximation is being used in the conversion from exposure rate in air, measured in microRoentgens per hour, to effective dose rate, measured in microSieverts per hour. It is conservatively assumed that 1 mrad ≈ 1 mrem ≈ 0.01 mSv. For gamma radiation of the energies associated with uranium ore, this assumption is very conservative. The relationship between absorbed dose in air and effective dose to an adult from terrestrial gamma rays of the U-238 series was reported by UNSCEAR (1993) at 0.69 Sv/Gy. The absorbed dose in tissue is approximately 1.14 times the corresponding absorbed dose in air (Cember 1969). Therefore the effective dose from U-238 series radionuclides is approximately 0.6 (i.e. 0.69/1.14) times the reported value. Gamma radiation readings reported for radiological clearance overestimate true dose rate from uranium series radionuclides by a factor of approximately 1.7.

References

Clement C. H. and McCallum, B. A. “Calibration of Non-Discriminating Scintillating Instruments for Sensitivities to Naturally Occurring Gamma Radiation Emitting Radionuclides at Environmental Concentrations”, Journal of Applied Radiation and Isotopes, 1996.

Cember, H. *Introduction to Health Physics.* Pergamon Press, 1969.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). *Sources and Effects of Ionizing Radiation.* Report E.94.IX.2, New York, United Nations, 1993.

PHFSO Detector Calibration Form

Instrument Type	S/N	Probe Type	S/N
Ludlum 2221		Ludlum 44-10	188946

Comments (temperature, humidity, etc.)	High Voltage Setting
15 C, overcast	1100
	Data Collection Location
	Port Hope
Data Collected by	Date
Dale Huffman, Mike Owen	2005-Jan 12

Calibration Pad Readings

	K Pad	U Pad	Th Pad	Bkd Pad
Counts	69845	93683	90842	62608
Time (s)	300	120	120	600
Gross cps	232.8	780.7	757.0	104.3
Error	0.9	2.6	2.5	0.4
Net cps	128.5	676.3	652.7	n/a
Error	1.0	2.6	2.5	n/a

Calibration Pad Concentrations

	K Pad	U Pad	Th Pad	Bkd Pad	Geometry Correction
K (%)	7.98	1.25	1.34	1.34	93.83%
Error	0.18	0.01	0.01	0.01	-
U (ppm)	0.46	53.33	2.31	0.98	93.32%
Error	0.03	0.39	0.04	0.02	-
Th (ppm)	1.82	3.20	110.00	2.28	91.76%
Error	0.06	0.09	1.42	0.07	-

Calibration Pad Net Concentrations

	K Pad	U Pad	Th Pad	Bkd Pad
net K (%)	6.64	-0.09	0.00	n/a
Error	0.18	0.01	0.01	n/a
net U (ppm)	-0.52	52.35	1.33	n/a
Error	0.04	0.39	0.04	n/a
net Th (ppm)	-0.46	0.92	107.72	n/a
Error	0.09	0.11	1.42	n/a

K, U and Th Sensitivities (cps per % or ppm)

Sk	22.13	±	0.64
Su	13.77	±	0.12
Sth	6.43	±	0.09

Exposure Rate Sensitivities (cps per uR/h)

Ek	14.70	±	0.43
Eu	**21.09**	±	0.18
Eth	22.40	±	0.31

Calibration Constants (counts per R)

CCk	5.29E+10	±	1.54E+09
CCu	7.59E+10	±	6.43E+08
CCth	8.07E+10	±	1.12E+09

All errors reported are 1-sigma and absolute
All grey areas should be filled in with the appropriate values

Appendix C: Gamma Radiation Background Determination and Lower Cutoff Determination

Background Survey

A gamma radiation survey was conducted at the Cluff Lake site to evaluate natural background radiation levels in the vicinity of the site. A statistical approach was used to determine the distribution of natural background radioactivity in reference areas unaffected by site activities. A preliminary background study using 13 data points was conducted in October 2004. The mean and standard error of 0.04 μSv/h and 0.012 μSv/h respectively were used to determine the minimum sampling size. By specifying an absolute error of 0.004 μSv/h (10%) and specifying an acceptable probability of exceeding this error of 5%, it was determined that a minimum sample size of 35 measurements would be required (Gilbert, 1987).

Gamma radiation measurements were conducted with a 2" x 2" NaI probe connected to a Ludlum 2221 ratemeter. Background reference locations are shown in the attached drawing RADBKG-1: Background Survey Locations. The reference locations were selected to traverse the general site area in order to be generally representative of the Cluff Lake site and were undisturbed by the mining activities. A total of 76 reference locations were used. Readings were taken off roadways with a measurement height of one meter. Summary statistics are presented in Table C.1.

Table C.1: Cluff Lake Area Background

Statistic	Cluff Lake Area (μSv/h)
Number of Values	76
Minimum	0.020
Maximum	0.080
Mean	0.035
Median	0.033
Standard Deviation	0.012
97.5 Percentile	0.063

The background radiation levels in the Cluff Lake area are typical of the region (Carson, 2002).

Natural gamma radiation exposure rates significantly above the maximum value in the background study have been observed in the vicinity of Cluff Lake. The mining area referred to as D-Pit was discovered from radiometric anomalies on the surface. A boulder train near the D-Pit exhibits gamma radiation exposure rates exceeding 2.5 μSv/h, the individual value limit for radiological clearance.

Lower Screening Value Determination

The lower screening value defines a radiation level below which no action to reduce gamma radiation levels is warranted. The 97.5 percentile value of the background range for the Cluff Lake Area, 0.063 μSv/h, has been selected as the lower cut-off limit. The 97.5 percentile value of the log-normal background distribution, referred to as the upper baseline concentration, is frequently used for this purpose [MOEE 1997]. Areas with gamma radiation exposure rates, averaged over 10,000 m^2, below 0.063 μSv/h will proceed to final reporting for radiological clearance, provided the data density test and the point source test have also been passed. Primarily, the Lower Screening value is expected to fast track areas which have been unaffected, or minimallly affected, by the mining activity to final clearance. It is anticipated that areas such as the ball diamond, Germaine camp, and borrow areas will meet this criteria.

References

Carson. J.M., et al, "Airborne Gamma Ray Spectrocopy Compilation Series, Lake Athabasca," Geological Survey of Canada, 2002.

MOEE, "Guideline for Use at Contaminated Sites in Ontario. Revised February 1997, Ontario Ministry of Environment and Energy, 1997.

Gilbert, R. O., "Statistical Methods for Environmental Pollutant Monitoring," John Wiley & Sons, Inc., 1987.

Appendix D: ALARA Assessment

The objective of an ALARA assessment is to judge whether doses to members of the general public are As Low As Reasonably Achievable, social and economic factors considered, i.e. has enough been done to protect the public from radiation below the relevant dose constraint.

In the case of the decommissioned Cluff Lake site, the site can be considered as a single dominant source of exposure. The application of a source related dose constraint below 1 mSv/year is not viewed as necessary to ensure doses to members of the general public are kept below the given dose limit.

In the judgement of reasonableness, AREVA has used both qualitative and quantitative methods and has engaged stakeholders to broaden its understanding of traditional land uses.

Stakeholder Workshop

An objective of the decommissioning activities is to achieve an end state that will be safe and allow utilization of the site for traditional uses. Traditional users are the primary future users of the site and are the most potentially exposed members of the general public. Protection designed to meet the needs of traditional users will be adequate for protecting less intensive land users.

On February 21 and 22, 2005, AREVA held a workshop on the decommissioning of the Cluff Lake Project with members of the West Side Environmental Quality Committee and the Athabasca Chipewyan First Nation (ACFN) in attendance in order to gain insights into the traditional use of the lands by aboriginal peoples. Representatives from the Canadian Nuclear Safety Commission and Saskatchewan Environment were also in attendance. An aboriginal trapper from the ACFN has seasonally accessed the Cluff Lake area and maintained a trap line in the local study area. He has maintained cabins on both Cluff Lake and Sandy Lake. He, and members of his family, were also in attendance.

The attendees were given a presentation on the basics of radiation and radiation protection and the gamma radiation survey technology was also demonstrated to them. Choropleth maps depicting gamma radiation levels at Cluff Lake were presented to describe the present surficial gamma radiation conditions and the work in progress to mitigate these conditions. The cleanup criteria were explained. The group was asked to discuss the traditional use of the site so that AREVA could gain insight into the future use of the property in order to provide a gamma radiation end state that follows the ALARA principle. As a starting point, attendees were asked to envision having a cabin on Cluff Lake available for year round use (similar to the trapper who has maintained a cabin there for approximately 40 years). They then developed a list of traditional land uses, such as hunting, fishing, berry picking, hiking, collecting traditional medicines, trapping etc., and described the amount of time they would spend conducting these activities throughout the year and identified the probable locations for the various activities.

The following are major outcomes of the discussion which are pertinent to the ALARA assessment:

1. The mining areas were viewed as unattractive areas for most activities, with the exception of gathering blueberries. Discussions regarding the preferential use of different land areas supported the use of a value of 1000 hrs/year as a very conservative value when considering occupancy of impacted areas.
2. The general opinion was, given the choice, they would not set up a cabin at Cluff Lake given that there are better fishing lakes in the region. The location could be used as a base for operation however most activities would be conducted away from this area. Fishing on Cluff Lake would be limited.
3. With the exception of time spent at camp, no individual activity amounted to greater than 1000 hr/year.
4. The vicinity of pit lakes was viewed as very unlikely areas for setting up camp. Traditional users are unlikely to drink water from, or fish on, pit lakes.
5. Traditional uses such as hunting and trapping, which represent the primary purpose for using the site involve travelling over a wide range. A 10,000 m^2 area is considered small relative to the areas used for traditional purposes. With the exception of berry picking, activities were unlikely to be conducted in small localized areas affected by mining.
6. It is unlikely that a cabin in the area, away from home communities, would be occupied year round. The present trapper only uses his cabin periodically.

Preliminary Dose Assessment

A preliminary annual dose estimate was presented to the group based on the discussions. Gamma radiation exposure rates were selected as follows for the estimation:

- 0.035 μSv/h, the average natural background gamma exposure rate, was used for non-impacted areas.
- 0.15 μSv/h, approximately twice the range of natural background was used for minimally impacted areas such as roads. The value is based on preliminary gamma radiation surveys of the roads on site. The value is conservative because most of the road travel would occur on unimpacted roads away from the Cluff Lake site.
- 0.30 μSv/h was used to represent the maximum gamma exposure rate for disturbed areas after decommissioning. The current Cluff Lake land lease constitutes 1,630 hectares, of which approximately 460 ha (30%) have been disturbed by the Cluff Lake Project. Approximately 10% of the total area (~140 ha) exhibits gamma radiation readings above the range of natural background while the remaining disturbed area (320 ha) is within the range of background. The cleanup objectives will ensure the maximum area average over any 1 ha area will be less than 1 μSv/h. Using the extreme limiting case where all 140 ha exhibit average gamma radiation levels of 1 μSv/h, the weighted average gamma radiation exposure rate in the areas disturbed by mining will be approximately 0.3 μSv/h once cleanup objectives are met, i.e. ((140 ha x 1 μSv/h) + (320 ha x 0.035 μSv/h))/ 460 ha = 0.3 μSv/h

The incremental annual gamma radiation dose due to the Cluff Lake site was conservatively estimated to be 194 uSv. The workshop identified that approximately 12% of the site occupancy would be in areas disturbed by the project activities.

Activity	Season (months)	Frequency (Days/week)	Duration (Hours/day)	Total Exposure Period (Hours/year)	Gamma Exposure Rate (μSv/h)	Total Annual Dose (uSv)	Annual Incremental Dose (uSv)
Fishing	6	7	3	548	0.035	19	0
Hunting	4	3	8	417	0.035	15	0
Berry Picking	4	7	3	365 (4%)	0.3	110	97
Firewood	12	2	4	417	0.035	15	0
Trapping	5	3	8	521	0.035	18	0
Harvest medicine	3	7	1	91 (1%)	0.3	27	24
Garden	4	7	2	243	0.035	9	0
Hiking	12	7	2	730	0.035	26	0
Swimming	4	7	1	122	0.035	4	0
Cabin/Camp	12	7	12	4380	0.035	153	0
Road Travel	12	7	1.75	639 (7%)	0.15	96	73
Unaccounted				287	0.035	10	0
Total				**8760 (12%)**		**501**	**194**

Selection of Mitigative Measures

Two options exist for the reduction of surficial gamma radiation exposure rates in the affected areas at Cluff Lake: excavation of contaminated soils for consolidation with other wastes such as in the Claude pit, and covering materials with clean materials to attenuate the gamma radiation. As each area exceeding the cleanup objectives is encountered, a judgement is made based on the estimated material removal, backfill, and cover quantities. Mitigation may involve either or both methods. Excavation and consolidation has the benefit of reducing the land area affected by the radioactive materials but typically incurs additional expense due to the increase in material movement resulting from the need for backfill used in grading the site after excavation. Further, the Claude pit has a limited volume capacity for accepting contaminated materials; once full, consolidation of materials at this location will not be available as an option. Covering areas with clean materials effectively attenuates the gamma radiation and reaches the cleanup objectives at a lower cost. Given the larger areas of the site where radioactive materials are covered, such as the tailings management area and the Claude pit, these smaller areas represent a small fraction of the total area where a cover-in-place attenuation strategy is being used. Either mitigation method provides effective protection to members of the general public.

Cost Estimate for Mitigation

The cost of reducing gamma radiation exposure rates by a factor of 2 is approximately $\$1.50/m^2$ based on a unit placement cost of $\$5/m^3$ and a minimum achievable cover placement of 30 cm of material. Excavation and consolidation is conducted for approximately double the cost of covering materials in place.

Limiting Case: 1000 hrs/a occupancy in 1 hectare

The cost of reducing an individual's annual dose below the dose limit by covering contaminated soils with clean materials is approximately $30,000 to $60,000 per mSv based on the conservative, limiting case of:

- standard area of 10,000 m^2 (1 ha)
- exposure rate reduction from 1 μSv/h to 0.5 μSv/h, and
- occupancy period of 1000 hrs/a.

When a 40 year occupancy is considered, the expense per mSv of individual dose ranges from $750,000 to $1,500,000 per Sv.

In terms of risk, exposure to 20 mSv represents a risk of developing a cancer of approximately 1/800 based on the current risk conversion factor recommended by the International Commission on Radiation Protection (ICRP) of 0.06 per Sievert [Ref. ICRP 60]. For perspective, the Canadian Cancer Society indicates that 42% of Canadians will develop cancer in their lifetime, i.e. the risk of developing cancer is approximately 2/5 (320/800).

Realistic Case

Given the insights from the stakeholder workshop, additional efforts to reduce exposure rates in small areas, i.e. 10,000 m^2, are not expected to further reduce radiation doses in the realistic dose estimation scenario. Reducing the dose rate by 50% in a single 1ha area, i.e. 0.2% of the disturbed area, will result in an inconsequential dose reduction, 194 uSv/a x 0.2% = 0.4 uSv/a or 16 uSv/40 years.

If this realistic case is used to evaluate the cost of an averted dose, the unit cost is approximately $1 Billion per Sv.

Note, in quantitative ALARA analyses for occupational exposures, collective dose for a practice is calculated to determine the overall dose impact that a dose reduction measure will have. For public exposures in a decommissioning scenario individual doses are considered. The use of collective dose is not an appropriate metric for practices which are conducted in perpetuity.

Conclusions and Project ALARA Objectives

The discussion in this section has demonstrated:

- meetings with stakeholders provided valuable insight into future traditional uses of the Cluff Lake area,
- a 10,000 m^2 averaging area is conservative to use in dose estimates,
- a 1000 hour/year occupancy period is conservative to use in dose estimates,
- mitigation by covering in place or excavating and consolidating provides adequate protection to members of the public from gamma radiation,
- the project cleanup objectives are adequate to ensure the dose limit for a member of the general public is not exceeded, and

- additional work to further reduce dose rates below the cleanup objectives results in an inconsequential impact on the dose to a traditional land user and is not justified by the related expense.

The assessment has used an average gamma radiation value for the entire disturbed area (460 ha) of 0.3 μSv/h, based on a conservative end state scenario where the areas impacted by mining (140 ha) meet only the cleanup objective of 1 μSv/h on average. To turn this commitment into an easily applied test, a spatial boundary is needed. To ensure the average for the disturbed areas meets this estimate, an additional area average objective will be established as ALARA Objective #1.

> ***ALARA Objective #1:*** Gamma radiation exposure rates, when averaged over 100,000 m^2 (10 ha) areas will not exceed 0.3 μSv/h.

Where gamma readings exceeding 2.5 μSv/h observed, mitigation measures will be implemented. Given the large areas surveyed and uncertainties associated with gamma radiation measurements and geographical positioning, not all sources exceeding 2.5 μSv/h will be identified. Experience at Cluff Lake indicates that surficial contamination seldomly exists as discrete point sources. Typically, sources exhibiting radiation levels exceeding 2.5 μSv/h are found within larger areas of contamination. To ensure a reasonable effort is taken to identify these sources, an additional test is applied as ALARA Objective #2.

> **ALARA Objective #2:** Where localized areas (1000 m^2) exceed an average of 1 μSv/h, the area will be investigated to provide confidence that point sources which exceed 2.5 μSv/h are identified and mitigated appropriately. A minimum data density of 100 readings in the 1000 m^2 area must be collected to determine the presence of radiation levels above 2.5 μSv/h. In practice, this will result in additional data being collected in the 1000 m^2 area surrounding the identified point or simply mitigating the area to pass the ALARA test.

The cleanup objective of 1 μSv/h averaged over a contiguous 10,000 m^2 area provides adequate protection to ensure the dose limit to the general public is not exceeded. To identify areas of patchy contamination and provide additional protection, an additional test is applied as ALARA Objective #3.

> ***ALARA Objective #3:*** If 10 aggregated localized areas (1000 m^2) exceed 1 μSv/h within a large area (100,000 m^2), mitigation is required.

Appendix E: Example Radiological Clearance Report

Radiological Clearance Report for OP/DP Mining Area

Description of OP/DP Mining Area

Stripping and construction of ramps for the DP mine began in 1983 and production commenced in 1985. Mining was discontinued in 1999, and the DP mine was allowed to flood under natural conditions. Complete flooding of the workings was achieved in August 2002. The OP/DP raises were partially backfilled in 2000 with final backfilling completed during site cleanup operations in 2002. The OP/DP decline was backfilled from approximately 176m down the ramp to the portal opening. Reinforced concrete caps were placed above all backfilled raises and a concrete plug was poured at the OP/DP portal opening.

Following the cessation of DP area mining, several of the buildings became redundant and were removed in 2001. With the site-wide cessation of mining in May 2002, all remaining support facilities were removed in 2002 and 2003.

Excavations to remove the sump and fuel tank were conducted in 2004.

The surface area of the OP/DP mining area comprises approximately 13 Ha of disturbed area.

Mitigative Measures

Initial radiological surveys identified areas of elevated gamma radiation associated with the OP/DP surface facilities. Approximately 16,040 m^3 of contaminated soil was excavated from the area and deposited in the Claude Pit, including the sump materials and soils surrounding. Approximately 11,260 m^3 of clean material was brought to the OP/DP area and used to further reduce gamma radiation levels and to contour the site to a natural grade.

End-State Radiological Conditions

After final grading, surficial gamma radiation surveys were conducted in accordance with *170-04, Operation of the Ludlum Model 2221 Survey Meter with Trimble TSC1*. Data were analyzed in accordance with procedure *170-02, Surface Gamma Clearance*.

The end-state radiological conditions are depicted in the attached drawing, “RADOMP-3”: OP/DP Mining Area End-State Radiological Conditions. In the figure, different colours show ranges of radiation levels. The table below, also shown on the figure, summarizes the outcomes of the various tests applied.

Table E.1: Radiological Clearance Tests for OP/DP Mining Area

Test	Test Statistic	Value	Criteria	Unit	Pass/Fail
Data Density	Minimum data density	1	1	Reading/100 m^2	Pass
Lower Screening Value	Maximum area average (10,000m^2)	0.29	0.063	µSv/h	Fail
Upper Screening Value - Individual Value	Maximum individual reading	1.007	2.5	µSv/h	Pass
Upper Screening Value - Dose Limit	Maximum area average (10,000m^2)	0.29	1	µSv/h	Pass
ALARA Objective #1	Maximum large area average (100,000m^2)	0.21	0.3	µSv/h	Pass
ALARA Objective #2	Number of 1000 m^2 areas exceeding 1 µSv/h	0	NA	Areas	Pass
ALARA Objective #2	Minimum data density in areas exceeding 1 µSv/h	NA	10	Reading/100 m^2	Pass
ALARA Objective #3	Total area which exceeds 1 µSv/h within a 10 ha parcel.	0	10,000	m^2	Pass

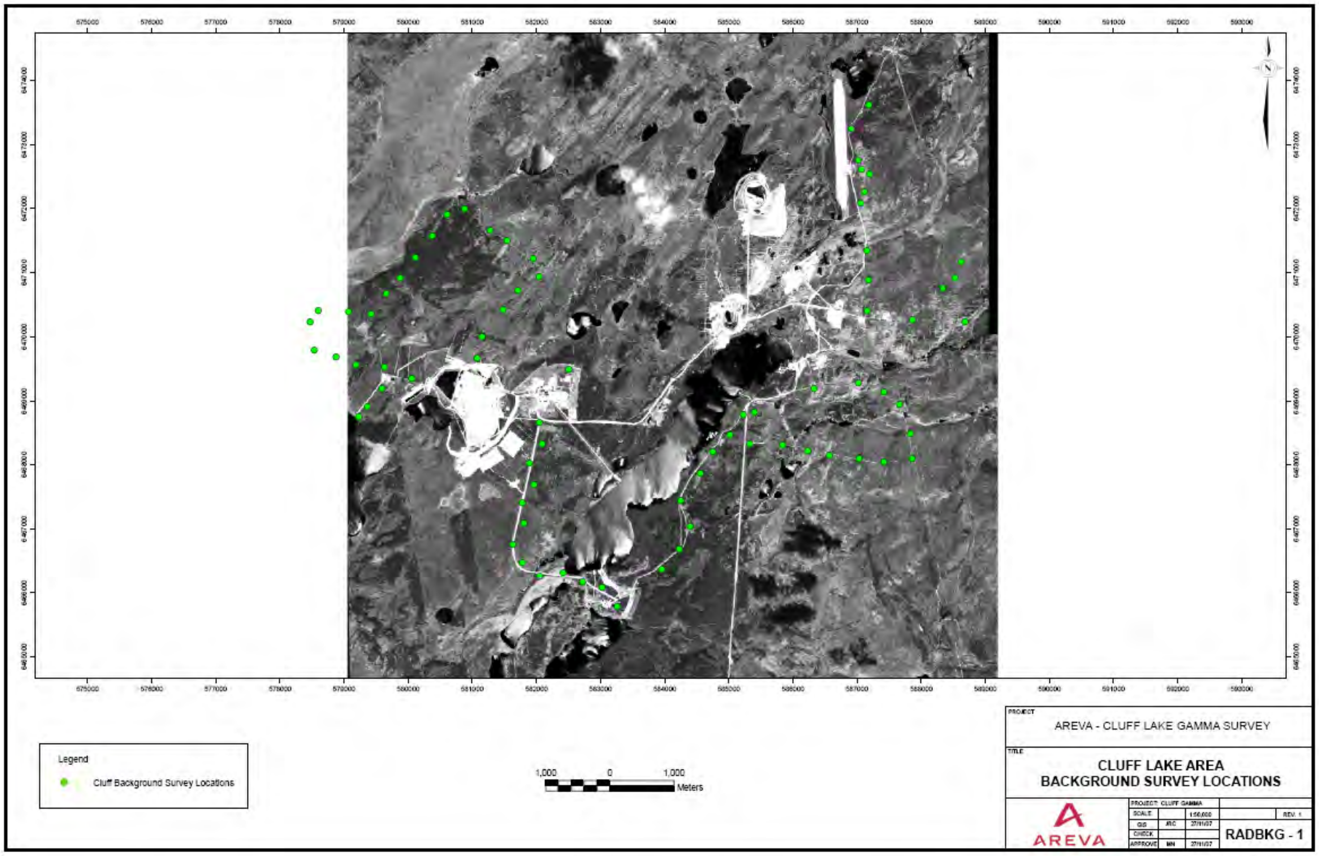
Table E.2: Descriptive Statistics for OP/DP Mining Area

Descriptive Statistics	Value	Unit
Average	0.16	µSv/h
Maximum	1.07	µSv/h
Average data density	8	reading/100 m^2
Total Area	133,618	m^2
Area exceeding 0.063 µSv/h	106,754	m^2
Area exceeding 0.3 µSv/h	7,492	m^2
Area exceeding 1.0 µSv/h	0	m^2

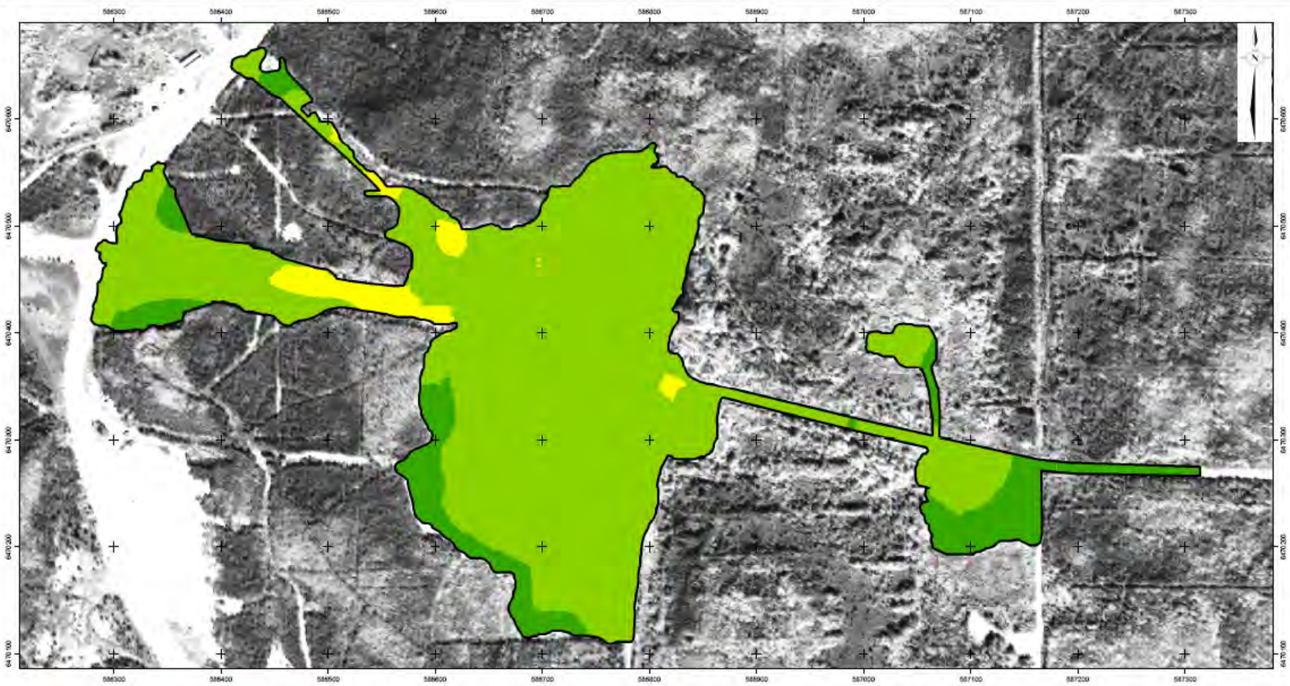
Conclusions

- The OP/DP mining area exhibited gamma radiation levels above the range of background for the Cluff Lake area so did not pass the Lower Screening Value Test.
- The end-state radiological conditions in the OP/DP area meet the approved cleanup objectives for the project.
- The end-state radiological conditions in the OP/DP area meet the ALARA objectives for the project.
- The OP/DP area has achieved the objectives for radiological clearance, subject to satisfactory confirmatory measurements conducted by CNSC staff.

Drawing RADBKG-1



Drawing RADOMP-3



Legend

0.0 - 0.1	
0.1 - 0.3	
0.3 - 1.0	
1.0 - 2.5	
> 2.5	

(uSv/Hr)

1000 m^2 Area Average

Test	Test Statistic	Value	Criteria	Unit	Pass/Fail
Data Density	Minimum data density	1.03	1.0	readings/100 m^2	Pass
Lower Cut-Off	Maximum area average (10,000m^2)	0.286	0.063	uSv/h	Continue
Point Source	Maximum individual reading	1.007	2.5	uSv/h	Pass
Dose Limit	Maximum area average (10,000m^2)	0.286	1.0	uSv/h	Pass
ALARA Objective #1	Maximum large area average (100,000m^2)	0.205	0.3	uSv/h	Pass
ALARA Objective #2	Number of 1000 m^2 areas exceeding 1 uSv/h	0	0	No. of Areas	Pass
ALARA Objective #2	Minimum data density in areas exceeding 1 uSv/h	NA	10.0	readings/100 m^2	Pass
ALARA Objective #3	Total area which exceeds 1 uSv/h within a 10 ha parcel	0	10,000	m^2	Pass

50 0 50 Meters

PROJECT
AREVA - CLUFF LAKE GAMMA SURVEY

TITLE
OPDP AREA
FINAL AVERAGE GAMMA READINGS
ALARA OBJECTIVE #2

AREVA

PROJECT: CLUFF GAMMA			
SCALE		1:3,000	REV. 1
GIS	JRC	27/11/07	RADOPM - 3
CHECK			
APPROVE	MN	27/11/07	

Attachment D McClean Lake Project – Text of Letter of Notification to Regulatory Agencies for Temporary Production Shutdown

Re: McClean Lake Operation – Notification of Temporary Production Shutdown

As you are aware, milling operations at McClean Lake are scheduled to cease at the end of June, 2010 for what is expected to be approximately two years. This letter is submitted as formal notification of the changes to activities and programs at the McClean Lake Operation that will result from the production shutdown. It also contains a description of the processes that will be followed to place the JEB Mill and associated facilities in a safe suspension state.

<u>No Significant Changes to Processes or Programs:</u>

We note that no significant changes will be made to any processes or programs, and therefore there are no updates to the Mining Facility Licensing Manual and the Facilities Description Manual required. Should these documents be modified for other reasons during the production shutdown, they will be edited to note the non-operational status of the mill.

<u>Organization & Management:</u>

The organization and management of the corporate office in Saskatoon will remain unchanged as it relates to McClean Lake Operation. The organization chart for McClean Lake will remain unchanged, although several positions will remain vacant during the shutdown period.

<u>Maintenance of Essential Programs:</u>

During the process of shutting down the mill and throughout the shutdown period, all current essential Safety, Health, Environment and Quality (SHEQ) programs will be maintained. These programs include the Environmental Monitoring Program (EMP), Environmental Code of Practice (ECOP), Radiation Code of Practice, Radiation Protection and Monitoring Programs (RMP), and all Safety programs. Appendices to this letter provide details of specific adjustments to the current programs in each of these areas.

Throughout the shutdown AREVA will maintain sufficient manpower at site to carry out the requirements of these programs at all times. Essential training will be provided on an on-going basis.

During the production shutdown period, work on the Systematic Approach to Training (SAT) will focus on additional program development, with implementation scheduled in preparation for the restart of operations.

The ISO 14001 (Environmental Management System) and OHSAS 18001 (Occupational Health and Safety System) certifications will also be maintained throughout the production shutdown period.

Facilities Shutdown:

Mining:

- Mining operations ceased in 2008 and will therefore be unaffected by the current shutdown[1].
- Mining Equipment Development (MED) program activities in 2010 will also be unaffected by the production shutdown. All activities are expected to be complete by July.

Milling:

- Ore feed to the mill will cease at the end of June.
- Mill circuits will be shut down sequentially.
- Each area will be cleaned once the final materials have cleared the circuit.
- Areas will be isolated at the completion of cleaning, and ventilation will be reduced or stopped completely where appropriate (see Appendix B, Radiation Protection Program). Radiation protection principles will remain unchanged.

[1] Temporary closure of the Kiggavik Project may, or may not, involve a shutdown of mining operations, depending on the status of mining activities at the time. Given sufficient advance time, mining activities would be completed at mines in progress, and not started at mines not already in progress.

JEB Mill Expansion:

- Repair and commissioning work will continue in the slurry receiving area. Further commissioning of the JEB Mill expansion will be conducted in preparation for the receipt and processing of McArthur River ore. Receipt of McArthur ore is subject to a separate licensing action.

Mill Utilities:

Reagents[2]*:*

- Hydrogen peroxide
  - limited supply may be required for treating sludge from the JWTP
  - receiving, storage, and use are expected to follow current procedures
- Sulphuric acid
  - limited supply will be required for water and sludge treatment processes during shutdown
  - acid storage tanks will be filled prior to shutting down the acid plant
  - when the supply is depleted, sulphuric acid will be trucked to site for the remainder of the shutdown
  - sulphuric acid has been trucked to site in the past and receiving/offloading procedures will be maintained
- Kerosene, Amine & Isodecanol
  - will not be required during the shutdown
  - it is currently expected that all organics will be removed from the solvent extraction circuit as it is shut down
  - it is currently expected that the used organic will be exported from the site for resale/storage

[2] There are some differences in the reagents required for the Kiggavik Project. Due to the difficult logistics of supplying reagents to the Kiggavik Project, production of reagents produced onsite would be continued at a reduced rate, rather than switching to importation of those reagents in finished form.

- Sodium carbonate
  - will not be required during the shutdown
  - supplies will be depleted as operations conclude
  - it is currently expected that minimal material will remain on site
- Anhydrous ammonia
  - will not be required during the shutdown
  - supplies will be depleted as operations conclude
  - all material will be removed from site
- Carbon
  - carbon columns will not be required during the shutdown
  - it is currently expected that all carbon will be removed from the columns and stored or disposed of on site
- Sodium hydroxide
  - will not be required during the shutdown
  - supplies will be depleted as operations conclude
  - any remaining product may be held on site for start-up use
- Ferric sulphate
  - limited supply will be required for water and sludge treatment processes
  - after the on-site manufactured product is depleted, material will be trucked to site and stored in the current storage tanks
  - ferric sulphate has been trucked to site in the past and all required equipment and procedures are in place
- Lime, barium chloride, and flocculant
  - limited supplies will be required for water and sludge treatment processes
  - lime slaking will continue throughout the shutdown period at a reduced rate

- $BaCl_2$ and flocculant will be trucked to site and handled as per current procedures

Utility Plants:

- Sulphuric acid plant[3]
  - at this time it is expected that the plant will not be operated during the shut down period
  - only services required to maintain facility insurance will remain in place
- Ferric sulphate plant[3]
  - will be shut down
  - only services required to maintain facility insurance will remain in place
  - any magnetite remaining on site at the cessation of operations will remain in the designated covered storage for the duration of the shutdown

Waste Management:

JEB Water Treatment Plant (JWTP)[4]:

- The JWTP will continue operation during the production shutdown. Waste streams directed to the plant will include:
  - raise water from the JEB TMF
  - reclaim water from the JEB TMF
  - domestic sewage
  - surface runoff
  - contaminated dewatering well water

[3] Limited production may be required, since these reagents will continue to be produced onsite for the Kiggavik Project. Importation in a finished form is impractical.

[4] The Kiggavik water treatment plant is the equivalent water treatment plant to the JEB water treatment plant at the McClean Lake Operation.

- Sludge produced during treatment will be removed from the JWTP as per current practice and treated in the tailings preparation circuit.

Tailings Preparation Circuit:

- JWTP sludge will continue to be neutralized in the current tailings preparation circuit
- Treated sludge will be transferred to the Tailings Management Facility (TMF) from a neutralization tank on a batch process.

JEB TMF[5]:

- The TMF raise well and reclaim systems will be operated throughout the shutdown period.
- TMF pond level will be regulated by the dewatering wells[6] and the reclaim system, as per current operation.
- Clean dewatering well water[6] will be discharged without treatment to Sink Reservoir as per current operation.
- JWTP sludges will be placed subaqueously in the TMF using existing piping, barge and deposition lines.

Sue Water Treatment Plant (SWTP)[7]:

- SWTP will be unaffected by the shutdown and probably remain in suspension for the duration of the shutdown period.

Sink/Vulture Treated Effluent Management System (S/V TEMS):

- S/V TEMS will continue to operate throughout the shutdown as per current practice.

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[5] The JEB TMF utilizes a mined out pit, similar to the proposed use of mined out pits for TMFs at the Kiggavik Project.
[6] Dewatering wells are not required for the Kiggavik Project due to minimal groundwater inflows in a permafrost environment.
[7] The Sissons water treatment plant is the equivalent of the Sue water treatment plant at the McClean Lake Operation.

Air Emissions Control Systems:

- The scrubber systems currently located in four stacks (CX, grinding, yellowcake calciner, and yellowcake packaging) will not be required during the production shutdown.

- Because of the anticipated acid plant shutdown, the in-stack continuous SO_2 analyzer and the ambient SO_2 analzyer will not operate.

- The bag house on the lime silo will continue to be operated and serviced throughout the production shutdown.

Conventional Waste and Temporary Contaminated Landfill:

- All conventional waste management systems and the temporary contaminated landfill will remain in use. Conventional waste management includes:
    - waste segregation
    - hydrocarbon landfarm
    - incineration of green waste
    - landfilling of industrial waste
    - temporary storage and shipment off-site of hazardous waste
    - current recycling programs

Other Considerations:

Registration of pressure vessels will be maintained for the first year of the shutdown. At that time the situation will be reviewed and a decision made to either maintain registration for unused vessels or to allow the registrations to lapse and then be re- registered according to regulatory requirements.

Out buildings will be left cold with all utilities disconnected, where practical, as allowed by AREVA's insurance carrier; the mill proper will have minimal heating as required.

Note that throughout the shutdown period, most circuits and areas will be subject to some maintenance/repair/commissioning activities.

Summary:

The JEB Mill circuits will be shut down and cleaned systematically. This will be optimized through a detailed work plan and a Project Management Plan, which is currently being developed. Ventilation, lighting and heating will be minimized in the main building and halted in out buildings as permitted by AREVA's insurance carrier and radiation monitoring results.

The only reagents consumed on site will be for use in the JWTP and the treatment process for the JWTP sludges. All reagents will be trucked to site. The lime mill, TMF, JWTP, tailings preparation, S/V TEMS, and all conventional waste management systems will remain operational.

All SHEQ programs will be maintained as described in the attached Appendices.

We trust this provides you with the information needed to support this notification. Should you have any further questions, please contact me at (306) 633-2177.

Appendix A - Environment Program Changes

Environmental Monitoring Program	
Program Element	**Discussion/ Explanation**
Air emissions monitoring: Stack Sampling will not be performed after 2010 until operations restart. In-stack continuous SO_2 analyzer will not operate. Ambient SO_2 monitoring will be suspended after the acid plant ceases operation.	No process emissions. All annual stack sampling will be completed during 2010. Sulphuric acid plant not operational; no SO_2 emissions.
Tailings thickener underflow (CM08) sampling will be suspended. Material placed in TMF sampling	Tailings thickener will not be in use. No tailings will be produced. Chemical precipitates will be sampled during placement in TMF. Parameters to be analyzed are to be determined.
Daily & weekly inspections: Suspension of inspection of grinding area for accumulation of fines. Suspension of inspection of batch plant.	Grinding circuit will be shut down; no fines will be present. Batch plant will not be in use.
Environmental Reporting	
Program Element	Discussion/ Explanation
Monthly reporting will be changed to quarterly reporting.	As noted by the CNSC and SMOE, quarterly reporting requirements regarding content, trending timelines, event reporting and format are to be clarified. AREVA will prepare a draft quarterly report for review and approval by both agencies.

Environmental Emergency Regulations Requirements	
Program Element	**Discussion/ Explanation**
Anhydrous ammonia will be removed from the list of substances on file with Environment Canada under these regulations.	The substance will not be stored on site. Annual testing of the Environmental Emergency Response Plan in relation to one of the substances on file with Environment Canada is required. Therefore, the annual mock emergency exercise will test response to propane or hydrogen peroxide releases.

Appendix B - Radiation Protection Program Changes

Routine gamma, radon progeny, long lived radioactive dust, and ventilation monitoring		
Program Element	Discussion/ Application	Practical Application
Dosimetry Monitoring	The Dosimetry Monitoring strategy is designed to assign appropriate dosimetry devices to personnel based on an estimate of their anticipated doses to each source of exposure. As such, no changes are required to the DMS; only a revised Table C.	Estimation of future doses will be used to assign dosimeters. Table C will be revised.
		It is expected that ventilation will not be required, or required only on an occasional basis. No radiation or ventilation monitoring will be performed on a routine basis. Areas will be signposted. RP will determine whether respirators or safe work permits are required for access.
Routine Radiological Monitoring	The RRMS is designed for the monitoring of work places. As areas are closed down, they will no longer be work places and monitoring will be suspended. Access will be restricted.	Closed areas of the mill will be treated as restricted areas requiring RP oversight through task specific monitoring and radiation work permits. Areas which meet workplace nominal exposure rate objectives can remain open as workplaces.
Code of Practice	Admin action levels are applicable under routine conditions. These are not applicable to restricted or unoccupied areas. COP values will continue to be relevant in occupied workplaces. No change to COP needed.	Monitoring results for occupied workplaces will continue to be compared to COP values to determine adequacy of workplace exposure conditions.

Appendix C - Safety Program Changes

Program Element	Discussion/ Application
Safe work permits may be modified to provide more RP information/ requirements	Safe work permits will be used for access to, and work in, areas where ventilation and monitoring has been reduced.
Fire suppression systems may be changed to dry systems in some out buildings that do not have utilities	Will follow requirements of insurance carrier.
Emergency Response Team fire fighting approach may be adjusted	AREVA has been working towards meeting a National Fire Protection Association 600 standard for Industrial Fire Brigades. Decision to train for interior and/or exterior attacks will depend on number of team members available.
Frequency of some Safety checks may change in areas that are not in routine use.	Will follow requirements of insurance carrier.

Attachment E Long Term Gravel Pad Reclamation on Alaska's North Slope

Restoration and Reclamation Review
Student On-Line Journal
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Department of Horticultural Science
University of Minnesota, St.Paul, MN

Long Term Gravel Pad Reclamation on Alaska's North Slope

Daniel Abdon Peterson

Overview

Alaska's arctic North Slope is and has been a heavily debated place, especially when degradation from oil drilling occurs and the land needs to be restored. When oil companies drill for oil in the permafrost they must create stable surfaces for equipment. The surfaces created are used for oil drilling pads, roads, and pipeline routes. A majority of the stable surfaces are made of gravel from local deposits (Jorgenson and Joyce 1994), and the gravel pads are usually three to six feet (one to two meters) in depth (Streever 2001). Once the oil is depleted from the drill site, the equipment is removed, the oil-well is capped, and the gravel pads are abandoned, leaving areas that need to be reclaimed. Alaska's arctic coastal plain is approximately 20 million acres (8.1 million ha), of which 16.6 million acres (6.7 million ha) are considered permafrost wetlands (Fanter and Herlugson 1995). Since the late 1970's, the United States Department of Army has issued permits to allow for more than 21,000 acres (8,500 ha) of wetlands to be filled with gravel (Fanter and Herlugson 1995). Of all the land in the Alaskan Arctic degraded from oil drilling 74% is gravel–filled pads (Jorgenson and Joyce 1994). With federal and state environmental policies now in place for North Slope oil development, companies working there must eventually return the land to a condition as close to the surrounding tundra as possible (Herlugson et al. 1995). In compliance with governmental policies, oil companies have implemented strategies for reclaiming damaged tundra. The main reasons for revegetating the North Slope are to aid in control of soil erosion and degradation, restore wildlife habitat, and improve aesthetics (McKendrick 1999).

Reclamation Strategies

The ultimate goals of most reclamation projects have been to establish plants as quickly as possible and allow for natural succession to occur. Eventually natural succession will lead to similar vegetation of the surrounding tundra (McKendrick et al. 1997). On gravel pads there are two main strategies that have been used to reclaim damaged areas including revegetation of gravel to compensate for lost wildlife habitat, and secondly reclamation of contaminated soils from oil spills (Jorgenson and Joyce 1994).

The first steps taken for reclamation are identifying native plants, experimenting with seeding practices, and manipulating ground fill for better plant establishment (McKendrick et al. 1992). Some of the dominant plant species which have been identified and used in reclamation projects are graminoids – including *Carex aquatilis*, *Eriphorum angustifolium*, *Dupontia fisheri*, *Poa glauca*, and *Festuca rubra*; willows – *Salix ovalifolia*, and *S. reticulata*; and mosses – *Sphagnum* sp. (Shirazi et al. 1998). The establishment of native plants is also important for creating forage and cover for a number of native animals (McKendrick 1999).

There are also strategies for reclamation of oil spills on and near gravel pad sites. One approach to remove the oil is tilling the contaminated soil and applying fertilizers to increase volatilization (McKendrick and Mitchell 1978, Mitchell et al. 1979). The best results occurred when the oil contaminant was left for a period of time before tilling, which allowed for more volatilization. Tilling immediately after a spill incorporated more toxins deeper into the soil structure, which decreased contaminant breakdown (McKendrick and Mitchell 1978a). Burning spilled oil was also used (McKendrick and Mitchell 1978a). The best results occurred when the oil spill was immediately burned; if the oil was allowed even two days to absorb into the soil, burning became difficult, if not impossible (McKendrick and Mitchell 1978a). One negative effect of burning oil was the sterilization of the soil as well as the decrease in organic matter levels, especially during the growing season. Burning during the winter months allowed more plant survival (McKendrick and Mitchell 1978a).

Slow Recovery Potential due to North Slope Climate

Alaska's North Slope is an environment of extreme cold, winds and a very short growing season, all of which make reclamation difficult. The North Slope is all permafrost soil or rock which has remained below 32°F (0°C) for a minimum of two years (Alyeska pipeline website 2000). Permafrost can range from a few inches (several cm) to over 2230 feet (680m) in depth (Alyeska pipeline website 2000). Temperatures along the North Slope can reach a low of -60°F (-51°C) in the winter and have an average annual temperature of 10°F to 21°F (-12°C to -6°C) (Arctic tundra province 1995). The low temperatures result in short growing seasons ranging from seven to ten weeks (Jorgenson and Joyce 1994). Along with the low temperatures and short growing seasons, the North Slope receives two to ten inches (5 to 25 cm) of precipitation per year; approximately one-third falls during the growing season (Jorgenson and Joyce 1994). The yearly snowfall accumulation will melt in three to ten days. Virtually all of the snowmelt is surface flow since the ground only thaws a few centimeters deep (Jorgenson and Joyce 1994).

Revegetation Practices

Revegetation of gravel pads is important for reducing thermokarst reactions. Thermokarst is the collapse of surface from melting of massive ice; in essence the ground sinks and pools form (Walker and Walker 1991). When thermokarst occurs the soil hydrology is drastically affected and can make restoration extremely difficult and even impossible (Walker and Walker 1991). In undisturbed tundra the organic layers of the soil act as an insulator, which reduce thermokarst reactions (Walker and Walker 1991).

A major objective for revegetation is to create a barrier to prevent seed from blowing away and to collect snow to act as thermal protection during the harsh winter months. On undisturbed sites plant litter accumulates snow, but on open gravel sites there is nothing to hold the snow. To compensate for the lack of a windbreak, snow fence has been used as a snow trap (McKendrick et al. 1992). Along with the artificial windbreak hydro-mulch has been used to hold the seed in place (McKendrick et al. 1992). The two to six feet of overburden, which is removed for gravel pad construction, has also been used and shown to aide in moisture retention and increase aeration for seed establishment (McKendrick et al. 1992).

Problems occurred during early revegetation attempts, which either prevented or reduced the establishment of desired communities. Initially when revegetation efforts began in the 1970's erosion was thought to be a major risk for open exposed soils; so fast, dense growing plant species were used as cover crops – *Arctagrostis latifolia*, *Festuca rubra* and *Poa glauca* (McKendrick 1997). These grasses were expected to be short lived and allow for colonization of other tundra species. After 25 years the areas are still dense grass stands, and have not allowed for natural colonization to occur. On the other hand, seedings performed at the same time with other grasses like *Puccinellia arctica* allowed other tundra species to recolonize (McKendrick 1997).

One of the most important things learned in reclamation experiments is the tundra soils are considerably nutrient poor, specifically in nitrogen and phosphorous (Shaver and Chapin 1980, McKendrick 1991, Truett and Kertell 1992). It was also noted that seeded areas failed initially where no fertilizer was used (McKendrick 1997). Nitrogen and phosphorous are naturally occurring in tundra soils, but they are in an organic form. Low temperatures and the frost depth of the soil prevent the decomposition of organic nutrients. Thus very little mineralized nitrogen and phosphorous are available for plant uptake (Truett and Kertell 1992). To compensate for the lack of available nutrients several trials have involved the additions of fertilizers to aid in revegetation (McKendrick 1991, Jorgenson and Joyce 1994). They also learned with large doses of phosphorous and potassium the gravel pads revegetated rapidly with grasses, but succession was decreased because the grasses had increased in longevity (McKendrick 1991).

Some areas had problems with drilling mud (used as a lubricant and waste products of oil drilling), which had seeped from the oil drilling pits into the surrounding tundra (McKendrick 1991). Originally poor plant establishment in the mud was thought to be from heavy metal contamination. Once pH tests were performed it was found to be high, which rendered the heavy metals unavailable. More tests concluded high concentrations of sodium chloride were found to be the cause of the poor plant survival (McKendrick 1991). On one test site seeding failed in 1991 and 1992 due to sodium chloride contamination (Reiley et al. 1995). To attempt a decrease in sodium chloride levels in the soil a calcium nitrate solution was added to the contaminated soil. After the application of calcium nitrate in 1993 and 1994 levels of sodium chloride declined and vegetation was established again (Reiley et al. 1995).

Success of Reclamation Practices

Most reclamation projects include the use of fast growing native vegetation which is important to reduce thermokarst reactions as well as allow for natural succession of plant species (Helm 1997). Estimations made of species diversity and concentrations to reach those of the surrounding tundra range from one hundred to two hundred years (Streever 2001). After completing several long-term projects McKendrick (1997) concluded there is little risk of erosion in the North Slope area. Erosion is reduced for two reasons: one the ground is frozen when snowmelt occurs and secondly the overall slope of the land is relatively flat resulting in very little silt carry. Hence the rapid revegetation which is currently being used may not be the best tactic for establishing communities of flora. As noted earlier from previous reclamation practices some of the revegetative crops used tend to get too dense to allow fast paced natural succession.

Observations of long term success of several projects have been made. Revegetation plots with grasses in the early 1970's, which were heavily fertilized, are still flourishing (McKendrick 1997). Plots seeded at the same time which were not fertilized and the grasses did not fair well have been colonized by native tundra species (McKendrick 1997), which was unexpected to occur in the short period of time. Seedings dominated by *Puccinellia langeana*(alkaligrass) were expected to remain a monoculture, but instead declined and allowed for native tundra to recolonize the site (McKendrick 1999). Areas where oil had been spilled and/or burned in 1973, to test tundra response to oil contamination, had been colonized by native vegetation by 1997 (McKendrick 1999a); although areas of heavier oil spill tests had fewer colonizers compared to light spill sites (McKendrick 1999a). McKendrick (1997) developed a list of priorities for establishing a target community of vegetation. They included the selection of naturally occurring plant species (not just rapidly establishing vegetation), the selection of sexually and vegetatively reproductive plants, three to four years of organic matter build up, standing dead vegetation for wind breaks (to catch snow drift), and creating a moss layer to insulate the ground to prevent thermokarst.

Wildlife habitat has also improved. Caribou have been observed feeding on reclaimed areas; arctic ground squirrels and nesting birds have also moved into the revegetated areas (McKendrick 1999). These observations indicate there is now enough forage and cover to attract and sustain them. The observation of birds indicates there is an adequate amount of plant debris and moss in the revegetated stands to allow nesting. Unexpected wildlife observations occurred indicating they may even prefer the disturbed sites to undisturbed tundra (McKendrick 1991). This is especially evident with the caribou, which have created trails along old gravel roads (McKendrick 1991). Over long term observation McKendrick (1999) found significant improvements had occurred over the span of twenty plus years to allow for native tundra communities to persist.

Technological Advances to Accelerate Restoration

With the increased environmental awareness and public opinion, the oil industry is looking to minimize inputs and maximize output while reducing ecological impacts by using newer concepts to obtain oil. One newer technology being used is a machine called a Rolligon; Rolligon's are designed with large balloon tires to reduce surface pressure, thus they leave minimal ruts in the tundra surface. Along with minimizing pressure of vehicles, some gravel roads are being substituted with ice roads to the drill sites. When these melt in the spring the evidence of traffic soon fades (McKendrick 1991, Hazen 1997). In conjunction with ice roads, ice pads are being experimented with in place of gravel drill pads with the idea when the drill is abandoned virtually no restoration will need to be done (BP website 2000). Another advancement is the gravel pad size. Twenty years ago a twenty-well pad took up 25 plus acres (10 ha) of land, now the same volume drill operation only uses about 12 acres (5 ha) of gravel pad, since the equipment size has decreased (McKendrick 1991). Also, where salt pollution from the drilling process was a problem, newly engineered systems are being used to seal the contaminants in the well itself in hopes to prevent outside contamination (McKendrick 1991). Pipelines are also being installed higher to allow for caribou and other wildlife to roam unhindered (BP website 2000). The pipelines are also being installed the same time the ice roads are being built in order to minimize the amount of stress from vehicles on the tundra surface.

Alaskan North Slope Reclamation

A unique aspect of restoration in Alaska's North Slope is the multifaceted approach to refine revegetation strategies. Their attention to optimizing recovery is critically important in this harsh environment which has very problematic growing conditions. Conditions of low temperatures, extreme wind, and a short growing season make vegetation establishment extremely difficult. The key advancements they've made are identifying the importance of fertilization to maximimize establishment of newly seeded lots and eliminating the use of cover crops, because of their unexpected impacts to their target community. As a result of the reclamation done on the North Slope, successfully revegetated areas and increased use by wildlife have been observed. They have also made strides to reduce environmental impacts (and so minimizing what needs to be restored) by improving construction practices so the area needed for operation is minimized and by implementing new and cleaner technologies such as ice road and pad construction along with low impact vehicles. The use of multi-approach reclamation strategies is especially important since Alaska's North Slope oil will continue to be an important energy resource.

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