

# PERFORMANCE OF AN ENGINEERED COVER SYSTEM FOR A URANIUM MINE WASTE ROCK PILE IN NORTHERN SASKATCHEWAN AFTER SIX YEARS

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## ABSTRACT

The Claude waste rock pile at Cluff Lake uranium mine in northern Saskatchewan’s Athabasca basin contains ~7.2 million tonnes of waste rock, upon which an engineered enhanced store-and-release cover system was constructed. The primary design objectives of the cover system are to reduce percolation of meteoric waters into the waste rock pile, attenuate radiation emanating from stored waste to acceptable levels, and provide a growth medium for development of a sustainable vegetation cover. Instrumentation was installed during construction of the cover system to evaluate cover performance under site-specific climate conditions. Field data collected was input to water balances to quantify the volume of net percolation that occurred during the frost-free periods of 2007 to 2012. Based upon these water balances, the Claude waste rock pile cover system is performing as designed based on field monitoring data and observations collected since 2007.

**Key Words:** Field Performance Monitoring, Water Balance, Net Percolation

## INTRODUCTION

Cluff Lake uranium mine, owned and operated by AREVA Resources Canada Inc. (AREVA), is located in northern Saskatchewan’s Athabasca basin, approximately 75 km south of Lake Athabasca and 15 km east of the provincial border with Alberta. The mine operated from 1980 to 2002, and decommissioning work began in 2004 following an Environmental Assessment. The majority of decommissioning work was complete by the end of 2006. The project is now in the post-decommissioning and follow-up monitoring stage. AREVA is planning to demolish the last buildings on-site including the existing camp, airstrip facilities, and warehouse in 2013 and 2014. AREVA is awaiting regulatory approval to continue its environmental monitoring program through four site visits per year.

Decommissioning of Cluff Lake mine included placement of a multi-layer cover system over a waste rock pile (WRP) known as Claude WRP. The cover system was completed in 2006, and monitoring of its performance has been on-going since then. This paper reviews the design and construction of the cover system for reclamation of the Claude WRP, and focuses on hydrologic performance of the cover system based on six years of field monitoring data.

## BACKGROUND

The Cluff Lake site is situated in a semi-arid environment; the mean annual precipitation and potential evaporation for the region is approximately 450 mm and 600 mm, respectively. Approximately 30% of the annual precipitation occurs as snow. Numerous lakes, swamps and rivers dominate the relatively flat topography of the region.

The Claude WRP was constructed between 1982 and 1989 and contains waste rock from the Claude pit. The pile is approximately 30 m high and covers an area of 26.4 ha to the south of the Claude pit (see Figure 1). It contains approximately 7.23 million tonnes of waste, with an estimated volume of approximately 4.1 Mm<sup>3</sup> based on a dry density of 1,750 kg/m<sup>3</sup>.



*Figure 1. Photo of the Claude waste rock pile in about 2003 prior to pile re-grading and cover system construction (Claude pit being backfilled in the foreground).*

The pile was developed by end-dumping and contains well-developed traffic surfaces between lifts of dumped material. No attempt was made to segregate waste placed in the Claude WRP by chemical composition. The Claude WRP has shown high levels of uranium (200 mg/L) and nickel (43 mg/L) in piezometers around the toe of the pile (COGEMA 2001). This indicates that acid mine drainage is occurring and will continue to occur until the source is depleted. This finding was confirmed and quantified through a detailed waste rock characterization program completed in 1999. AREVA

determined that the Claude WRP would be decommissioned in-place, meaning that an engineered cover system would be required for closure.

## COVER SYSTEM DESIGN AND CONSTRUCTION

Cover system field trials (test plots) were constructed and instrumented in 2001 on the Claude WRP to examine the construction feasibility and hydrologic behaviour of the preferred cover system design alternative. One test plot (TP#1) was constructed on a relatively horizontal surface, while a second (TP#2) was constructed on a 4H:1V sloped surface. Both test covers had the same profile design, consisting of a 10 cm thick (nominal) reduced permeability layer (RPL) overlain by a 100 cm thick (nominal) layer of local silty-sand till. The RPL comprised weathered waste rock material that was compacted *in situ*; field compaction trials were completed in advance to determine the preferred techniques for RPL construction. Field data were collected and interpreted over a 5-year period including net percolation rates, *in situ* volumetric water content (automated and manual measurements), matric suction (negative pore-water pressure), and temperature of the cover and waste materials. The collected field data were used to aid in calibration of a soil-plant-atmosphere (SPA) numerical model as part of the cover system design process for full-scale WRP decommissioning.

Based on the success of cover system field trials, an enhanced store-and-release cover system was selected as the preferred design for closure of the Claude WRP. The final design included a 20 cm thick (nominal) layer of compacted waste rock overlain by 100 cm (nominal) of non-compacted silty-sand till with a grass and legume vegetation cover. The primary design objectives of the cover system are to:

1. reduce percolation of meteoric waters to attenuate peak concentrations for contaminants of concern in natural watercourses, to levels that can be assimilated without adverse effects to the aquatic ecosystem;
2. attenuate radiation emanating from stored waste to acceptable levels; and
3. provide a growth medium for development of a sustainable vegetation cover.

Decommissioning of the Claude WRP was completed between 2005 and 2006 and involved the following primary work activities:

- Re-contouring the side-slopes to a maximum slope angle of 4H:1V;
- Compacting the WRP surface to meet density specifications over a minimum depth of 0.2 m;
- Placing 1 m (nominal) of local silty-sand till material over the compacted waste rock surface;
- Constructing surface water drainage channels to handle the 24-hour, 100-year design storm event; and
- Applying revegetation seed and fertilizer mixture (a drill seeder as opposed to a hydroseeder was used to minimize erosion of grass seeds and maximize availability of fertilizer to the seeds).

Compaction of the waste rock surface was accomplished using a Caterpillar CS583 roller (AREVA 2007). Generally, two passes were required to meet the required minimum dry density of 95% of Standard Proctor Maximum Dry Density. Due to the unseasonably wet weather encountered during the waste rock



compaction effort, moisture conditioning was not required to achieve the specified density. In general, the majority of the re-graded waste rock surface contained sufficient fine-textured materials to produce a relatively smooth surface (see Figure 2). Areas of the WRP that were visually determined to be too open-graded were re-graded to blend in additional fines (with either waste rock or till) and re-compacted. The estimated field saturated hydraulic conductivity of the compacted waste rock layer is  $10^{-5}$  to  $10^{-6}$  cm/s.



Figure 2. Photo of the re-graded Claude WRP being compacted in 2005 prior to till cover placement.

Instrumentation was installed in August 2006 to enable monitoring of the hydrologic performance of the Claude WRP cover system over time under site-specific climate conditions. Field data being collected on the cover system include precipitation, net radiation, runoff, and volumetric water content, matric suction, and temperature of the cover and upper waste rock materials. Figure 3 shows a layout of the instrumentation installed on the Claude WRP cover system. Monitoring stations were located at various slope positions and aspects due to potential differences in cover system performance at these different locations. Also, the monitoring system was automated to the extent possible to avoid missing collection of field response data during key times of the year (e.g., during spring snowmelt and storm events).

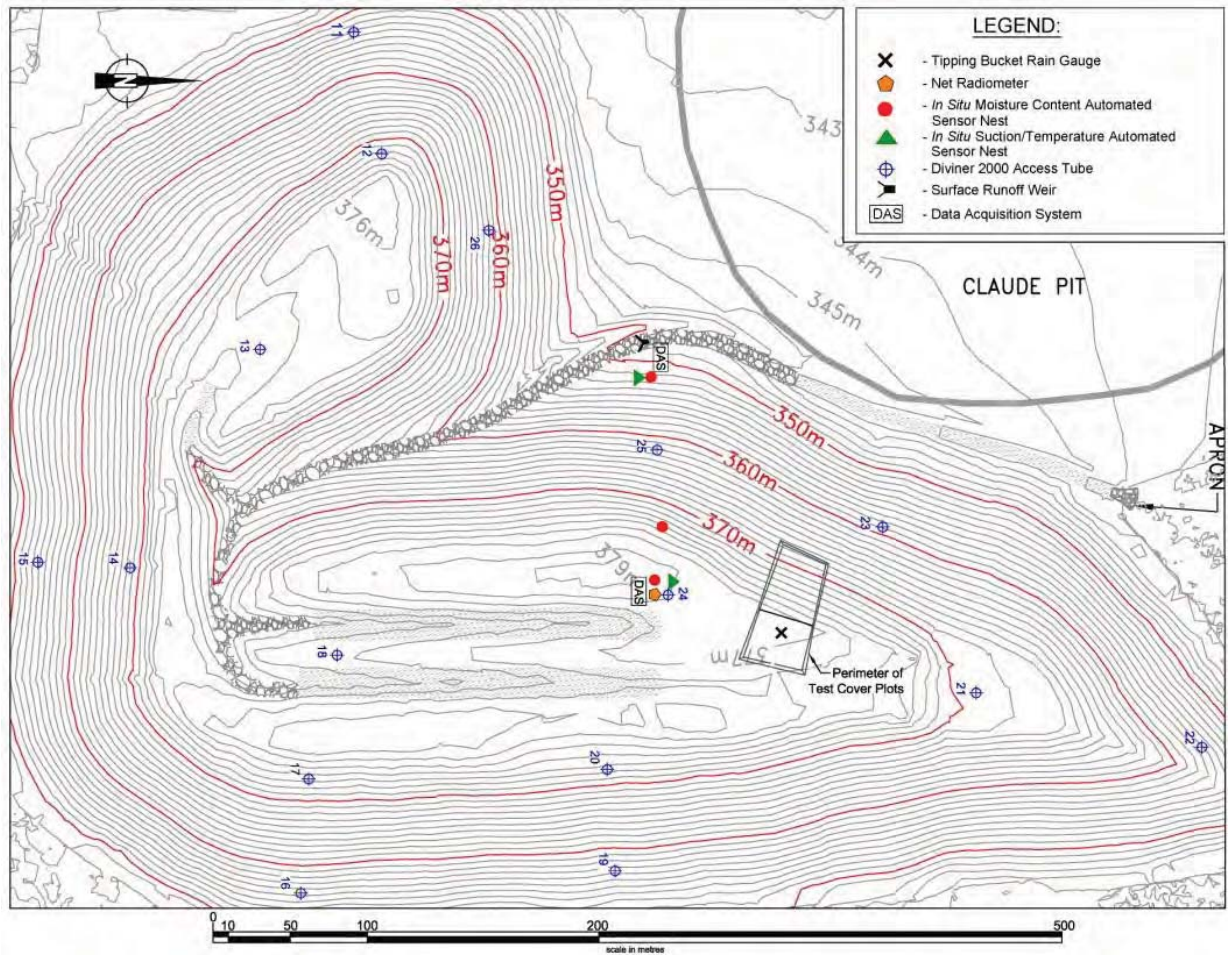


Figure 3. Performance monitoring instrumentation installed on the Claude WRP.

## MONITORING PROGRAM RESULTS

Potential evaporation (PE) at the Claude WRP has been greater than rainfall for all years since the onset of monitoring (Table 1). PE estimates are based on the Penman (1948) method and climate data collected at the site, and represent a theoretical maximum evaporation of a free water surface. When PE is greater than rainfall, the capacity for the cover system to store precipitation and release it back to the atmosphere is greatly improved, thereby improving performance of the cover system by reducing net percolation rates.

Table 1. Annual rainfall accumulation and potential evaporation at the Claude WRP from 2007 to 2012.

	2007 (mm)	2008 (mm)	2009 (mm)	2010 (mm)	2011 (mm)	2012 (mm)
Rainfall	299	183	318	296	215	357
PE	533	581	503	550	596	536

Water storage data (Figure 4) have demonstrated that the water balance of the cover system during the year is largely controlled by storage of snowmelt/rainfall and subsequent release of water through evapotranspiration. There was an increase in storage following snowmelt and after rainfall events in the summer months, after which a slow decline occurred. The presence of vegetation improved the cycling of water storage by increasing evapotranspiration rates, further improving cover performance.

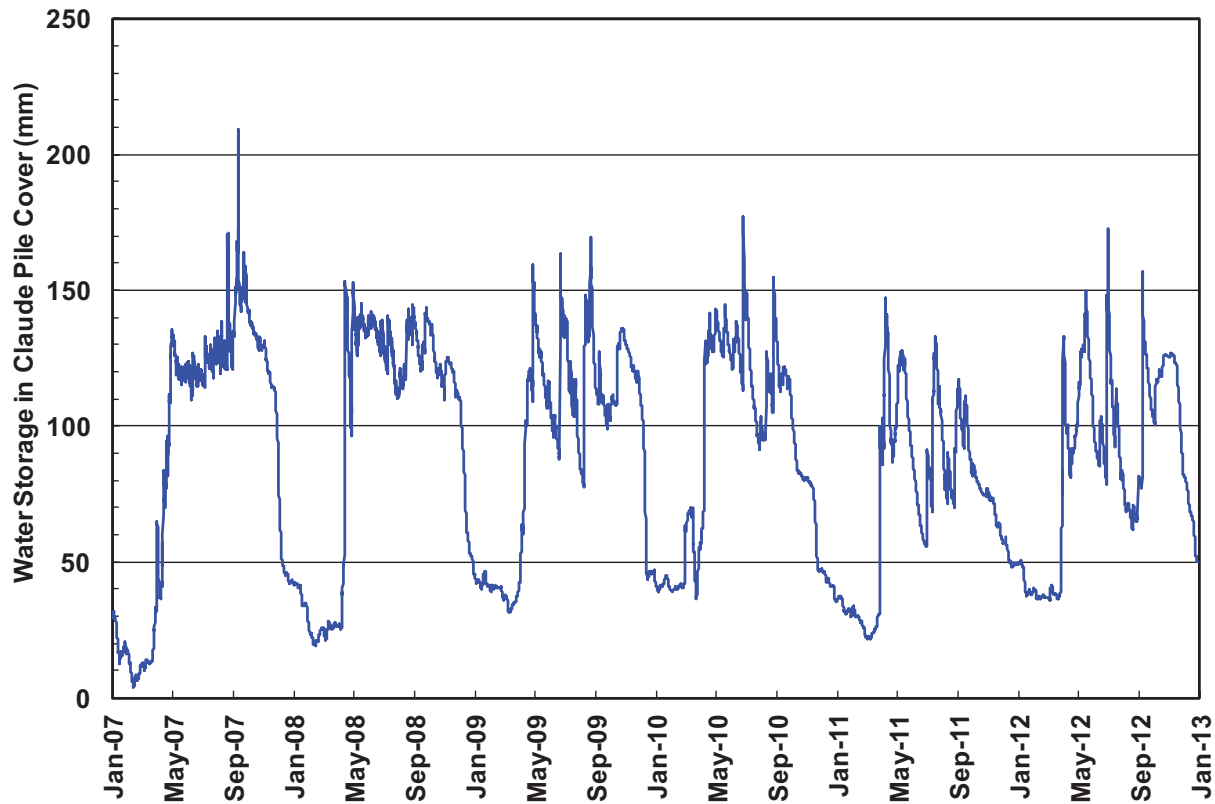


Figure 4. Soil water storage in the till cover profile measured at the upslope monitoring station from 2007 to 2012 (low storage values during the winter seasons reflect frozen ground conditions).

Thermal conductivity (TC) sensors are used to monitor temperatures in the Claude WRP cover and upper waste rock profiles at two different locations. Freeze-thaw cycles in the cover profile are important when interpreting runoff data and understanding when net percolation can be expected throughout the year. The timing and rate of freezing and thawing of the cover profile in the fall and spring depends on several factors including snow cover accumulation, ambient temperatures, and soil water contents. In general, the upper cover profile begins to freeze around the end of October, while complete thaw of the cover profile typically does not occur before mid- to late-May.

Performance of the cover system will evolve over time in response to site-specific physical, chemical, and biological processes (INAP 2003). Substantial growth of the various grass and legume species has occurred between August 2007 and June 2012 on the Claude pile cover system (Figure 5), with only minor observed erosion. A more mature vegetation cover will contribute to lower net percolation / seepage volumes through increased interception and transpiration rates.





(a) August 2007 – Plateau Station

(b) July 2008 – Plateau Station

(c) September 2009 – Plateau Station

(d) June 2012 – Plateau Station

Figure 5. Photos illustrating evolution of vegetation on the Claude WRP cover system.

Field measurement data were used to determine net percolation rates through the cover system by using the water balance method:

$$PPT = R + AET + NP + \Delta S + LD \quad (\text{Eq. 1})$$

Where

- PPT is precipitation (rainfall plus snow-water equivalent),
- R is runoff,
- AET is actual evapotranspiration,
- NP is net percolation, and
- $\Delta S$  is change in moisture storage (all values in mm).

Water balances were estimated on a daily basis during the frost-free period, identified as approximately April 1<sup>st</sup> to October 31<sup>st</sup>. Lateral drainage (LD [mm]) is accounted for in sloping systems through an additional term on the right side of Eq. 1. Water balance fluxes at the top and sloping areas of the Claude WRP cover system since the onset of monitoring are given in Tables 2 and 3.

Table 2. Annual water balance fluxes for the plateau area of the Claude WRP for April to October.

Year	PPT (mm)	Water Balance Fluxes (mm and % of precipitation)			
		AET	$\Delta S$	R	NP
2007	450	231 (51%)	34 (8%)	6 (1%)	179 (40%)
2008	272	297 (109%)	-96 (-35%)	6 (2%)	66 (24%)
2009	387	290 (75%)	31 (8%)	5 (1%)	61 (16%)
2010	358	303 (85%)	12 (3%)	2 (1%)	40 (11%)
2011	271	182 (67%)	9 (3%)	2 (1%)	58 (21%)
2012	430	317 (74%)	33 (8%)	5 (1%)	105 (24%)

Table 3. Annual water balance fluxes for sloping areas of the Claude WRP for April to October.

Year	PPT (mm)	Water Balance Fluxes (mm and % of precipitation)				
		AET	$\Delta S$	R	LD	NP
2007	419	239 (57%)	17 (4%)	58 (14%)	0 (0%)	104 (25%)
2008	261	308 (118%)	-85 (-33%)	50 (19%)	-57 (-22%)	45 (17%)
2009	396	314 (79%)	15 (4%)	41 (10%)	0 (0%)	26 (7%)
2010	371	320 (86%)	4 (1%)	22 (6%)	-21 (-6%)	46 (12%)
2011	295	231 (78%)	3 (1%)	19 (6%)	25 (9%)	44 (15%)
2012	422*	310 (73%)*	51 (12%)*	24 (6%)*	0 (0%)	92 (22%)*

\*Upslope data only.

As was observed when calculating the 2012 water balance, the timing of the precipitation can be of consequence to the amount of net percolation. If storm events occur in September and October, when evapotranspiration is no longer available to remove stored water from the cover system, greater than expected net percolation can occur. In addition, if the entire soil profile does not completely freeze, the water at the base of the cover system can continue to percolate into the underlying waste, further causing conditions for higher than expected net percolation.

In general, net percolation has decreased since construction of the cover system in 2006. This is likely due to an increase in vegetation cover causing an increase in evapotranspiration rates. However, variability in net percolation as a percentage of precipitation did occur during the six years of monitoring, which is to be expected in response to normal cycles in the local climate. General trends on the performance of the system cannot be inferred from a single year of monitoring data; it is only when examining net percolation over the long term and in the overall context of normal climate variability that trends in performance can be determined. Natural climatic variability is to be expected and was accounted for during the design of the Claude WRP cover system.

## CONCLUSIONS

The Claude WRP cover system is a stable landform supporting the growth of productive native plant species and attenuating radiation emanating from stored waste rock to acceptable levels. Percolation of meteoric waters through the WRP has generally decreased since construction of the cover system in 2006. This case study serves to underline the importance of maintaining a long-term perspective when evaluating cover system performance in terms of reducing the net percolation of meteoric waters.

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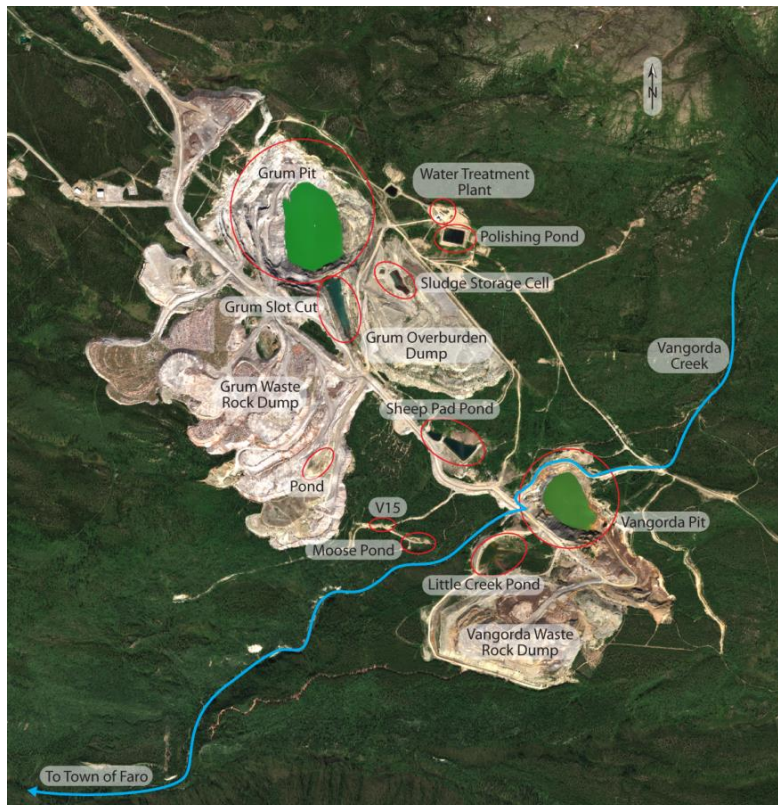
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# Overcoming Northern Challenges

Proceedings of the 2013 Northern Latitudes Mining Reclamation Workshop and  
38<sup>th</sup> Annual Meeting of the Canadian Land Reclamation Association

Whitehorse, Yukon September 9 – 12, 2013



## Table of Contents By Presentation Schedule

Northern Latitudes Mining Reclamation Workshop	iv
Canadian Land Reclamation Association	iv
Acknowledgements	v
Citation	v
Conference Sponsors	vi
 PAPERS 1	

### Tuesday(Below)

### Go To Wednesday

Ayres, O'Kane,Hiller,Helps	Performance of an Engineered Cover
Bromley	Innovative Concepts used during Remediation and Reclamation Planning of a Sulphur Handling Facility
Stewart, Karpenin, and Siciliano	Northern Biochar for Northern Remediation and Restoration
Petelina	Biochar application for revegetation purposes in Northern Saskatchewan
Chang	Bioremediation in Northern Climates
Geddes	Management of Canada's Radium and Uranium Mining Legacies on the Historic Northern Transportation Route
Hewitt, McPherson and Tokarek	Bioengineering Techniques for Re-vegetation of Riparian Areas at Colomac Mine, Northwest Territories
Bossy, Kwong, Beauchemin, Thibault	Potential As <sub>2</sub> O <sub>3</sub> Dust conversion at Giant Mine (paper not included)
Waddell, Spiller and Davison,	The use of ChemOx to overcome the challenges of PHC contaminated soil and groundwater at contaminated sites
Douheret,	Physico-Chemical treatment with Geotube® filtration: Underground Mine Desludging in winter TTS, Iron (Fe) and Zinc treatment
Coulombe, Cote, Paridis, Straub	Field Assessment of Sulphide Oxidation Rate - Raglan Mine
Smirnova et al	Results of vegetation survey as a part of neutralizing lime sludge valorization assessment
Baker, Humbert, Boyd	Dominion Gurney Minesite Rehabilitation (paper not included)
Martínez, Borstad, Brown, Ersahin, Henley	Remote sensing in reclamation monitoring: What can it do for you?

**Wednesday:**

Eary, Russell, Johnson,  
Davidson and Harrington

Knight

Polster

Dustin

Kempenaar, Marques  
and McClure

Smreciu, Gould, and  
Wood

Keefer

Pedlar-Hobbs, Ludgate and  
Luchinski

Chang, et.al

Heck

Janin

Stewart and Siciliano

Nadeau and Huggard

Simpson

**Back To Tuesday**

Water Quality Modelling and Development of Receiving  
Environment Water Quality Objectives for the Closure Planning  
in the Keno Hill Silver District (paper not attached)

Galena Hill, Yukon, Ecosystem Mapping Project

Natural Processes: An Effective Model For Mine Reclamation

Implementation of contaminated water management system  
upgrades to allow for dewatering of two open pits at the Vangorda  
Plateau, Faro Mine Complex, Yukon

Tools for Arctic Revegetation: What's in Your Toolbox?

Establishment of Native Boearl Plant Species On Reclaimed Oil Sands  
Mining Disturbances

Twin Sisters Native Plant Nursery

Key Factors in Developing and Implementing a Successful  
Reclamation Plan

Effects of Soil Aggregates Sizes (paper not attached)

Phytoremediation of petroleum hydrocarbon impacted soils at a  
remote abandoned exploration wellsite in the Sahtu Region,  
Northwest Territories

Passive treatment of drainage waters: Promoting metals sorption  
to enhance metal removal efficiency

Biological Soil Crusts and Native Species for Northern Mine Site  
Restoration

Restoration Planning and Application of Ecological Succession Principals

Defining Disturbance and Recovery - the influence of landscape  
specific ecological responses to oil and gas linear disturbances in  
Yukon



POSTERS	244
Practical Field Uses of Remote Sensing	245
Michael Henley <sup>1</sup> , Gary Borstad <sup>1</sup> , Dave Polster <sup>2</sup> , Mar Martinez <sup>1</sup> , Leslie Brown <sup>1</sup> and Eduardo Loos <sup>1</sup>	
Project Case Study – Composite Soil Cover for Sulphide Tailings at Mine Site in Northeastern Ontario, Canada	246
Bruno Herlin, P.Eng.	
Assessment of Sawmill Waste Biochars for the Purpose of Heavy Metal Remediation	255
Tyler Jamieson, Eric Sager and Celine Gueguen	
Determination of Optimal Substrate to Maximize the Revegetation of Cover With Capillary Barrier Effects	256
Sarah Lamothe <sup>1</sup> , Francine Tremblay <sup>2</sup> , Robin Potvin <sup>3</sup> and Evgeniya Smirnova <sup>4</sup>	
Oil Sands Research and Information Network: Creating and Sharing Knowledge to Support Environmental Management of the Mineable Oil Sands	257
C.B. Powter	
Mineralogical and Geochemical Controls on Metal Sequestration in the Keno Hill Silver District	262
Barbara Sherriff <sup>1</sup> , Andrew Gault <sup>2</sup> , Heather Jamieson <sup>2</sup> , Brent Johnson <sup>3</sup> , Scott Davidson <sup>4</sup> and Jim Harrington <sup>5</sup>	
Oil Sands Vegetation Cooperative – A Coordinated Effort to Harvest and Bank Seeds for Reclamation in Northeastern Alberta	263
Ann Smreciu and Kimberly Gould	
Ratroot ( <i>Acorus americanus</i> ) Propagation and Establishment on Created Wetlands in the Oil Sands Region of Alberta	264
Ann Smreciu, Stephanie Wood and Kimberly Gould	

## **NORTHERN LATITUDES MINING RECLAMATION WORKSHOP**

The Northern Latitudes Mining Reclamation Workshop is an international workshop on mining, land and urban reclamation and restoration methods. The objective of the workshop is to share information and experiences among governments, industry, consultants, Alaska Natives, northern First Nations and Inuit groups which undertake reclamation and restoration projects, or are involved in land management in the north or in comparable environments.

The first Workshop was held in Whitehorse, Yukon Territory, Canada in 2001 and it has been held every two years since, alternating between Canada and Alaska. The primary sponsors of the Workshop include the Yukon Geological Survey, Indian and Northern Affairs Canada, Natural Resources Canada, US Department of the Interior Bureau of Land Management, and the State of Alaska Department of Natural Resources.

## **CANADIAN LAND RECLAMATION ASSOCIATION**

The CLRA/ACRSD is a non-profit organization incorporated in Canada with corresponding members throughout North America and other countries. The main objectives of CLRA/ACRSD are:

- To further knowledge and encourage investigation of problems and solutions in land reclamation.
- To provide opportunities for those interested in and concerned with land reclamation to meet and exchange information, ideas and experience.
- To incorporate the advances from research and practical experience into land reclamation planning and practice.
- To collect information relating to land reclamation and publish periodicals, books and leaflets which the Association may think desirable.
- To encourage education in the field of land reclamation.
- To provide awards for noteworthy achievements in the field of land reclamation.

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- The Conference Papers and Posters Committee: Andy Etmanski, Bill Price, Chris Powter, David Polster, Diane Lister and Scott Davidson
- The Conference Sponsors (see next page)
- The Conference paper and poster presenters
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