# IMPLEMENTATION OF CONTAMINATED WATER MANAGEMENT SYSTEM UPGRADES TO ALLOW FOR DEWATERING OF TWO OPEN PITS AT THE VANGORDA PLATEAU, FARO MINE COMPLEX, YUKON

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## ABSTRACT

The Vangorda Plateau at the Faro Mine Complex contains two open pits that, starting in 2013, will both require dewatering. Since mine abandonment in 1998, water levels in Vangorda pit have been actively maintained below a maximum recommended elevation, whereas Grum pit has been filling at a rate of approximately 3 m per year due to average annual inputs of 400,000 $m^3$. In late 2011, Grum pit levels reached a threshold elevation requiring dewatering to begin in 2013 to prevent exceeding the maximum recommended elevation. Continued filling of Grum pit could allow contaminated pit water to enter groundwater in as little as two years, and reduced pit capacity may prevent its use for contingency surface water storage during extreme flood events. Water from the pits cannot be discharged directly to the environment because it is noncompliant with respect to metals. Zinc (Zn) is one of the main contaminants of concern, with a site discharge limit of 0.5 mg/L.  Vangorda pit water samples have contained up to 235 mg/L Zn (at pH 3 to 5), and Grum pit water samples have contained up to 6 mg/L Zn (at pH 7.5 to 9).

The Vangorda Water Treatment Plant (WTP) was constructed in 1992 to treat acidic and metal-contaminated water from Vangorda pit utilizing a low-density sludge lime treatment process. Contaminated water from Vangorda pit is pumped uphill to the WTP through a 24" HDPE pipeline. Treated water is directed to a polishing pond where sludge is settled, and compliant effluent is decanted for release to the environment. The pond's maximum sludge storage capacity is reached after treatment of 350,000 to 500,000 $m^3$ of Vangorda pit water over a four week summer period. Sludge removal is a laborious process that occurs in mid-winter when frozen sludge is excavated and hauled by truck to a nearby overburden dump. Thus, the current system has no excess sludge management capacity available to allow for treatment of an additional 400,000 $m^3$ of water that will need to be removed annually from Grum pit. To ensure a sustainable water management solution for 2013 and beyond, a pump and 8" HDPE pipeline will be installed to transfer water from Grum pit to Vangorda pit, and a dredging system will be installed over the polishing pond so that sludge removal can occur intermittently during the treatment season. Sludge will be pumped out of the pond and flow by gravity down the 24" influent pipeline to Vangorda pit for subaqueous disposal. These upgrades will allow for seasonal treatment of 750,000 to 900,000 $m^3$ of contaminated water, and will provide excess treatment capacity should extreme storm or flood events necessitate emergency pit dewatering. This paper reviews the upgrade requirements and compares the possible alternatives based on their cost, time required to implement, and site-specific operational parameters.

## INTRODUCTION

This is a case study of a contaminated water management strategy that was developed for mine infrastructure on the Vangorda Plateau at the Faro Mine Complex. The Vangorda Plateau is situated 6 km upstream of the Town of Faro in the Vangorda Creek regional catchment. The importance of Vangorda Creek as a water resource is exemplified by its role in providing recharge to the town's municipal water supply, and in providing fish habitat between its confluence with the Pelly River and Vangorda Creek falls, which are situated on the upstream margin of the town. Thus, protecting Vangorda Creek from mine impacted water is crucial for protecting the environment, and human health & safety.

## BACKGROUND

The Faro Mine Complex (FMC) is an abandoned lead-zinc-silver mine located in mountainous, subarctic Yukon, Canada, at 62°N latitude in a cold climate. The FMC developed around three open pits that are geographically divided into two areas connected by a 14 km haul road (Figure 1). Mining of the Faro pit began in 1968, whereas mining of the Grum and Vangorda pits started in the early 1990s. Operations ceased in 1998 due to owner bankruptcy. The FMC is now managed by the Government of Yukon, with funding provided by the Government of Canada. The site is currently in a state of care and maintenance while engineering and design work is undertaken to support remediation plans.

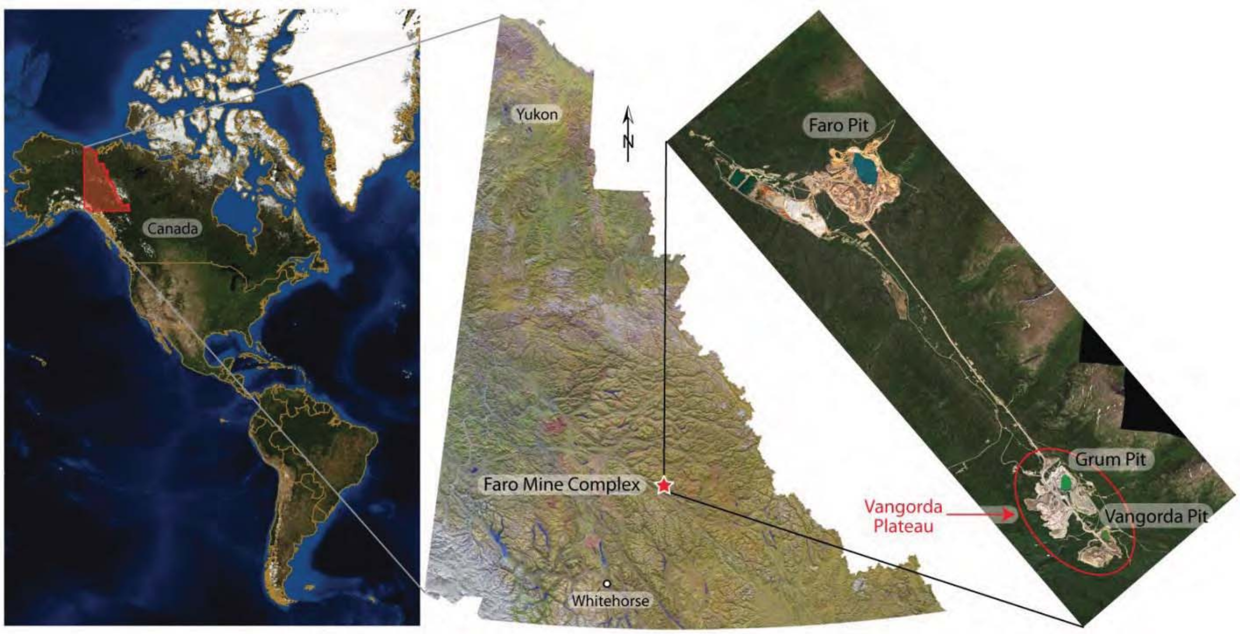


*Figure 1. Location of the Vangorda Plateau at the Faro Mine Complex*

The main ongoing challenge at the FMC is water management. The goal is to prevent contaminated water from entering the receiving environment, and preventing fresh water from mixing with contaminated water. A key component of the contaminated water management strategy is seasonal dewatering and lime-treatment of acidic and/or metal-contaminated water from pits and ponds. This creates ample storage capacity in water containment areas to safely manage natural inputs of atmospheric precipitation and snowmelt, thus preventing noncompliant discharges. Annually, effective water management is most crucial during freshet and occasional extreme precipitation events. It is imperative that excess storage capacity also be maintained to protect against low probability, large magnitude floods and other geohazards that may only occur on a decadal scale or longer.

A subarctic continental climate, where daytime highs remain below freezing for 40% of the year, necessitates that all water management activities be conducted in the short summer season when pits and ponds are ice-free. Mean annual air temperature is approximately -5°C with a range of mean monthly temperatures from -30°C in January to 20°C in July, however, pit lake surfaces commonly remain ice-covered well into June. Despite the region receiving only moderate amounts of precipitation (mean of 300 mm, up to 400 mm in a wet year), rapid snowmelt in May or June regularly creates conditions where excess amounts of surface water must be managed in a short period of time, commonly when variably thawed ground creates difficult working conditions.

## VANGORDA PLATEAU SITE CONDITIONS

Major mine infrastructure features on the Vangorda Plateau that must be considered in a contaminated water management strategy are Vangorda pit (Figure 2A), Grum pit (Figure 2B), the Vangorda Water Treatment Plant (Figure 2C), and the Water Treatment Plant (WTP) polishing pond (Figure 2C). The WTP (1307 metres above sea level (masl)) and polishing pond (1301 masl) are at a higher elevation than Grum pit (maximum recommended elevation 1213.4 masl) and Vangorda pit (maximum recommended elevation 1091.8 masl). In addition to inputs of clean surface water that cannot be diverted, the pits are used as repositories for other sources of contaminated water prior to being processed at the WTP (Figures 3 and 4). In a normal treatment season, Grum and Vangorda pits are respectively anticipated to contribute 400,000 $m^3$ and 350,000 to 500,000 $m^3$ of water to the WTP.

With up to 6 mg/L zinc (at pH 7.5 to 9), Grum pit water is less contaminated than Vangorda pit water (up to 235 mg/L Zn at pH 3 to 5). Water in both pits, however, is above the discharge limit of 0.5 mg/L zinc, necessitating treatment prior to release. The WTP was constructed in 1992 to treat Vangorda pit water, whereas a passive microbiological treatment program was tested on Grum pit. The passive treatment program was discontinued in 2012 when the dewatering trigger elevation was reached and Grum pit water was still noncompliant.

## RISK MITIGATION

Pit dewatering and treatment reduces the risk of noncompliant discharges of contaminated water to the receiving environment. If pit water elevations are allowed to rise unchecked, the pits may cease to be groundwater sinks, thus allowing contaminated pit water to enter groundwater, particularly at the bedrock-overburden contact. At Grum pit, a portion of the north pit wall is mainly formed of unstable till that progressively slumps and fails. A catastrophic failure of this material could create a large wave capable of overtopping the pit, thereby releasing contaminated water and potentially creating a health and safety risk to individuals working downstream.


*Figure 2. Major mine infrastructure at the Vangorda Plateau. A) Vangorda pit looking southeast. B) Grum pit looking southwest. C) Polishing pond at the Vangorda Water Treatment Plant. D) Terminus of the Vangorda Creek Diversion. Vangorda pit visible in upper right.*

To allow for open pit excavations, diversions were constructed during mine development in order to route creeks around the pits and prevent pit flooding. During implementation of the final closure plan, larger, more robust diversions will be constructed in new locations farther away from the pit walls to reduce the probability of failure. Ample storage capacity must be maintained in pits to accommodate flood inflows in the event of diversion failure. The North East Interceptor Ditch prevents a small creek from entering Grum pit, whereas the Vangorda Creek Diversion (VCD) prevents much larger flows from entering Vangorda pit. The Vangorda deposit was the first ore body discovered at the FMC, due to it being incised by, and exposed along Vangorda Creek. The VCD was constructed in 1991 to route Vangorda Creek around the northern edge of the pit (Figures 2D and 3). The VCD was sized for a 1-in-100 year flood event (10 $m^3$/s) and had a design life of 10 to 15 years. It is already 10 years past its intended lifespan and is estimated to have passed three 1-in-100 year flood events since 1998. A complete failure of the VCD near the start of a 1-in-1000 year flood event with sustained flows could cause Vangorda pit to fill and overtop to Vangorda Creek in 7 days, whereas a 1-in-100 year event could causing filling in 16 days. Dilution of Vangorda pit water by flood waters would be unlikely to prevent a noncompliant discharge. The VCD will eventually be reconstructed in a new location to ensure long-term environmental protection. Until a new diversion is constructed, however, the contaminated water management strategy must allow for enough Vangorda pit dewatering capacity to accommodate flows that could result from diversion failure.


*Figure 3. Aerial image of Vangorda Plateau indicating locations of mine components. Important mine components considered in the development of the contaminated water management strategy are circled in red.*

## DESIGN CONSIDERATIONS

Updating the contaminated water management strategy for the Vangorda Plateau for 2013 was driven by two main factors: 1) Grum Pit dewatering (and associated treatment) must commence in 2013, and 2) the WTP could not treat the additional water from Grum Pit because of limited sludge storage capacity in the polishing pond. Based on these considerations, options were developed for Grum Pit dewatering (Table 1) and treatment sludge management (Table 2).

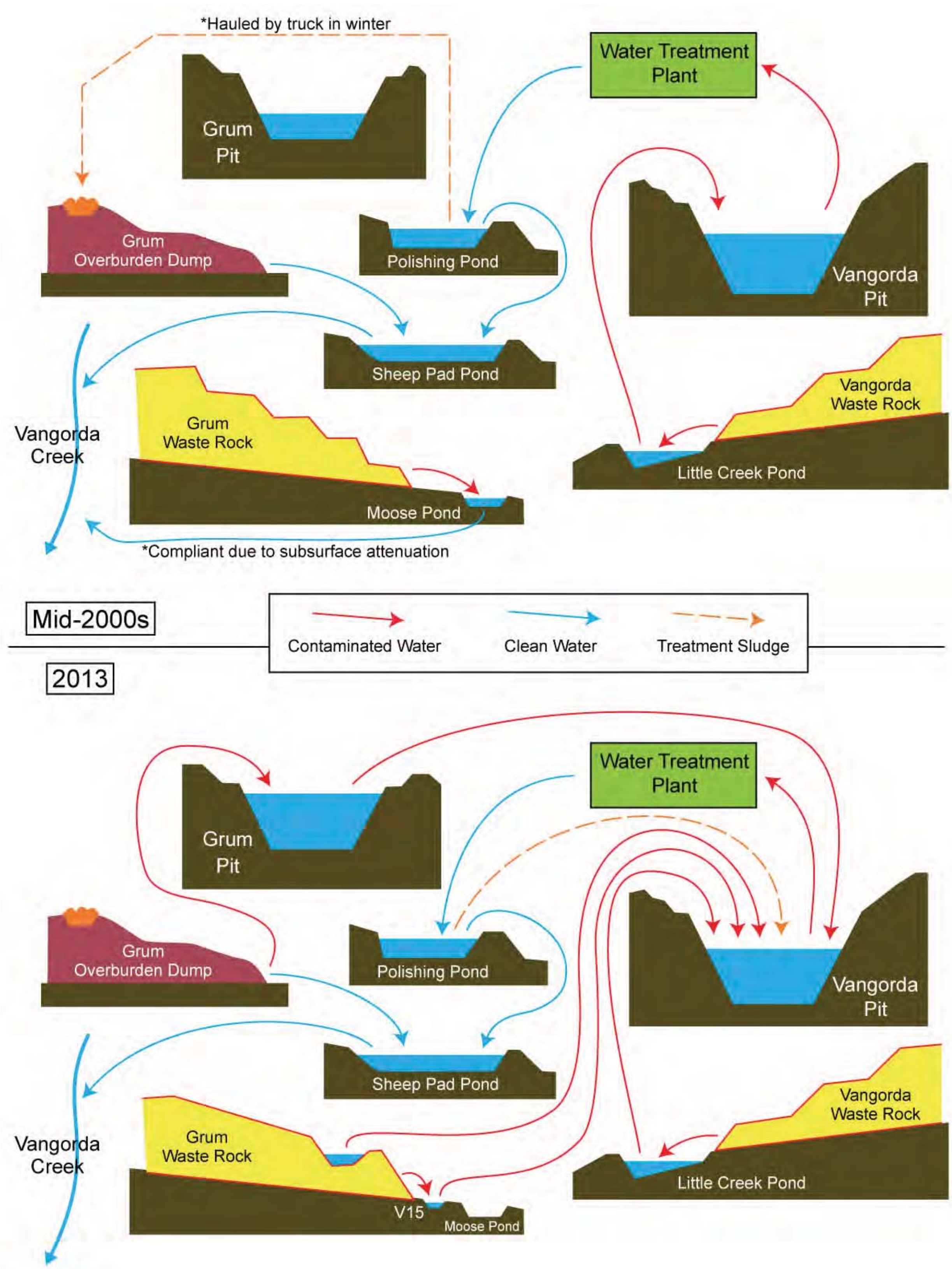


*Figure 4. Schematic showing Vangorda Plateau contaminated water management strategy before the upgrades implemented in 2013 (top) and after (bottom).*

*Table 1. Grum pit dewatering options*

| Option | Description | Advantages | Disadvantages |
|---|---|---|---|
| 1 | Pump directly to WTP | 1) Slightly shorter pipeline distance<br>2) Stainless steel pump not required (cost savings) | 1) High pressure pipeline required<br>2) High head pump required<br>3) Increased lime consumption due to lower metal load in Grum pit water<br>4) Must configure WTP for two geochemically distinct influent sources<br>5) Difficult pipeline routing |
| 2 | Pump to Vangorda pit | 1) Single influent source to WTP simplifies treatment process<br>2) Expensive stainless steel pump not required<br>3) Cheaper, lower head pump than Option 1<br>4) Most of the flow path is downhill, thus high pressure pipeline only required for first 800 m to crest of Grum pit, then low pressure pipeline to Vangorda pit | 1) Slightly longer pipeline distance<br>2) Increased electricity consumption and component/pump wear due to double handling of Grum pit water |
| 3 | Pump Vangorda pit to Grum pit, Grum pit to WTP | 1) Single influent source to WTP<br>2) Allows Vangorda pit water to be pumped to Grum pit for emergency storage<br>3) Compatible with long-term closure option (in 10+ years) to treat all water on the Faro side of the property; allows for staging of Vangorda Plateau contaminated water in Grum pit | 1) Expensive high head stainless steel pump required in Grum pit<br>2) High pressure pipeline required from Grum pit to WTP<br>3) Requires expensive and cumbersome reconfiguration and re-routing of large-diameter pipeline currently in use<br>4) Acceleration of water quality degradation in Grum pit due to input of acidic, highly metal-contaminated Vangorda pit water to circum-neutral pH Grum pit water |

*Table 2. Treatment sludge management options*

| Option | Description | Advantages | Disadvantages |
|---|---|---|---|
| 1 A | Excavate and haul sludge to Grum Overburden Dump | 1) Short haul distance<br>2) No design, procurement, construction, installation or commissioning of equipment required | 1) Sludge cannot be removed from polishing pond in summer<br>2) Contaminant-containing sludge placed in a cell excavated on clean borrow material that will be used for waste cover system construction<br>3) Limited storage capacity in current sludge cell, thus new cell would need to be excavated<br>4) Labour-intensive and time-consuming to bulk sludge in winter with excavator to promote freezing, then haul nearly 1000 dump truck loads<br>5) Sludge must be consolidated after dewatering in summer to maximize storage capacity in sludge cell |
| 1 B | Excavate and haul sludge to Grum pit slot cut | 1) Abundant long-term storage capacity<br>2) No sludge storage on clean borrow source | 1) Sludge cannot be removed from polishing pond in summer<br>2) Labour-intensive and expensive to bulk sludge in winter with excavator to promote freezing, then haul nearly 1000 dump truck loads<br>3) Extensive and expensive preparation work required to dewater Grum slot cut and construct truck access<br>4) Slightly longer haul distance |
| 1 C | Excavate, haul and place sludge on ice-covered pit lake (assume Grum pit due to close proximity to WTP) | 1) Abundant long-term storage capacity<br>2) No sludge storage on clean borrow source<br>3) Rapid implementation possible (less preparation than Option 1B)<br>4) Sludge settles to pit bottom upon melting of pit lake ice cover | 1) Sludge cannot be removed from polishing pond in summer<br>2) Annual design, construction and monitoring of pit lake ice road<br>3) Increased risk to worker health and safety by driving heavy equipment on ice-covered pit lake<br>4) Labour-intensive and expensive to bulk sludge in winter with excavator to promote freezing, then haul nearly 1000 dump truck loads<br>5) Slightly longer haul distance |

| Option | Description | Advantages | Disadvantages |
|---|---|---|---|
| 2 A | Dredge pond + pump sludge to Grum pit | 1) Sludge removal can be completed in summer to increase treatment capacity and extend treatment season<br>2) Once installed, system is less labour-intensive than excavating and hauling<br>3) Abundant long-term storage capacity<br>4) No sludge storage on clean borrow source | 1) Design, procurement, construction, installation and commissioning of dredging equipment required<br>2) Design, procurement and installation of sludge pipeline to pit required |
| 2 B | Dredge pond + pump sludge to Vangorda pit | 1) Sludge removal can be completed in summer to increase treatment capacity and extend treatment season<br>2) Once installed, system is less labour-intensive than excavating and hauling<br>3) With minor modifications, can use existing influent pipeline for directing sludge to Vangorda Pit<br>4) Abundant long-term storage capacity<br>5) No sludge storage on clean borrow source | 1) Design, procurement, construction, installation and commissioning of dredging equipment required<br>2) WTP must be stopped for up to two weeks to allow sludge to be passed through the influent pipeline |
| 3 | Upgrade WTP to High Density Sludge from Low Density Sludge System | 1) Installation of a thickener eliminates the need to remove sludge from the polishing pond<br>2) Provides robust, long-term solution (10+ years) | 1) Most expensive option<br>2) Cannot be implemented in time for 2013 treatment season<br>3) New pipeline required to Grum pit for sludge disposal |

**OPTION SELECTION**

For the Grum pit dewatering project, Option 2 was selected as the best solution because it can be implemented rapidly, has the lowest cost, and is the easiest to integrate with the current contaminated water management systems. For the treatment sludge management project, Option 2 B was selected as the best solution because it could be implemented quickly at a reasonable cost while enabling treatment sludge to be removed from the polishing pond during the treatment season.

## DISCUSSION AND CONCLUSIONS

At the time of writing, the Grum pit dewatering system was complete and had just begun to transfer water to Vangorda pit. The polishing pond dredge system was on site, but had not yet been utilized for transferring sludge to Vangorda pit because maximum sludge storage capacity in the pond had not yet been reached. The effectiveness of the completed Vangorda Plateau contaminated water management system upgrades will be evaluated at the end of the 2013 water treatment season in October.

# Overcoming Northern Challenges

Proceedings of the 2013 Northern Latitudes Mining Reclamation Workshop and

38th Annual Meeting of the Canadian Land Reclamation Association

Whitehorse, Yukon September 9 – 12, 2013

CLRA | ACRSD
Canadian Land Reclamation Association
Association canadienne de réhabilitation des sites dégradés

Northern Latitudes Mining Reclamation Workshop

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**Wednesday:** **Back To Tuesday**

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| Knight | Galena Hill, Yukon, Ecosystem Mapping Project |
| Polster | Natural Processes: An Effective Model For Mine Reclamation |
| Dustin | Implementation of contaminated water management system upgrades to allow for dewatering of two open pits at the Vangorda Plateau, Faro Mine Complex, Yukon |
| Kempenaar, Marques and McClure | Tools for Arctic Revegetation: What's in Your Toolbox? |
| Smreciu, Gould, and Wood | Establishment of Native Boearl Plant Species On Reclaimed Oil Sands Mining Disturbances |
| Keefer | Twin Sisters Native Plant Nursery |
| Pedlar-Hobbs, Ludgate and Luchinski | Key Factors in Developing and Implementing a Successful Reclamation Plan |
| Chang, et.al | Effects of Soil Aggregates Sizes (paper not attached) |
| Heck | Phytoremediation of petroleum hydrocarbon impacted soils at a remote abandoned exploration wellsite in the Sahtu Region, Northwest Territories |
| Janin | Passive treatment of drainage waters: Promoting metals sorption to enhance metal removal efficiency |
| Stewart and Siciliano | Biological Soil Crusts and Native Species for Northern Mine Site Restoration |
| Nadeau and Huggard | Restoration Planning and Application of Ecological Succession Principals |
| Simpson | Defining Disturbance and Recovery - the influence of landscape specific ecological responses to oil and gas linear disturbances in Yukon |

## 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.

## ACKNOWLEDGEMENTS

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- The Conference Organizing Committee: Alissa Sampson, Andrea Granger, Bill Price, David Polster, Diane Lister, Justin Ireys, Linda Jones, Mike Muller, Neil Salvin and Samantha Hudson.
- 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
- Dustin Rainey, Jocelyn Douheret and Brian Geddes for permission to use their photos on the Cover, Papers and Posters pages, respectively

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