



Natural Resources
Canada

Ressources naturelles
Canada



Compendium of Tailings Management

Science and Research Initiatives
at Natural Resources Canada



Canada



Natural Resources
Canada

Ressources naturelles
Canada

Compendium of Tailings Management

Science and Research Initiatives at Natural Resources Canada

Prepared by Natural Resources Canada's
Tailings Management Horizontal Task Team.

Last revised February 2013.

Aerial photo on front cover is a tailings facility
at LaRonde, courtesy of Agnico Eagle Mines Ltd.

Aussi disponible en français sous le titre :
Recueil des initiatives en science et recherche –
La gestion des résidus à Ressources naturelles Canada

Information contained in this publication
or product may be reproduced, in part or in
whole, and by any means, for personal or public
non-commercial purposes, without charge or
further permission, unless otherwise specified.

You are asked to:

- exercise due diligence in ensuring the accuracy
of the materials reproduced;
- indicate the complete title of the materials
reproduced, and the name of the author
organization; and
- indicate that the reproduction is a copy of an
official work that is published by Natural Resources
Canada (NRCan) and that the reproduction has
not been produced in affiliation with, or with the
endorsement of, NRCan.

Commercial reproduction and distribution is
prohibited except with written permission from
NRCan. For more information, contact NRCan at
copyright.droitdauteur@nrcan-rncan.gc.ca.

Cat. No. M34-13/2013E-PDF1 (Online)
ISBN 978-1-100-22551-7

© Natural Resources Canada, 2013

Contents

Introduction.....	3
Initiatives	5
Canadian Forest Service	9
Earth Sciences sector	15
Energy sector.....	19
Innovation and Energy Technology sector.....	21
Minerals and Metals sector and CanmetMINING.....	23
Canadian Nuclear Safety Commission.....	29

Introduction



This compendium consolidates information on current or proposed science and research initiatives by Natural Resources Canada (NRCan) sectors and the Canadian Nuclear Safety Commission.

A multitude of science and research initiatives are currently under way or planned across the sectors. Some initiatives are energy- or mining-sector specific while others are wide-reaching studies that have implications for all natural resource sectors. This collection of initiatives is intended to be an evergreen document and demonstrates a commitment to improving tailings management in Canada.

Initiatives



Tailings Management Science and Research Initiatives	Direct (Y) or indirect (N) focus of research	Completed (X)
Canadian Forest Service		
Boreal Ecosystem Atmosphere Study (BOREAS) 1994–1996	N	X
Dynamics of Vegetation and Soil Changes in Boreal Forest Peatlands – Climate Change and Carbon Project	Y	
Ecosystem Management Emulating Natural Disturbances (EMEND)	N	
Enhancing Microenvironments on Challenging Sites	N	
Ecosite Classification	N	X
Ecosystem Services in Oil Sands Landscapes	N	
Effects of Oil Sands Processing Emissions on the Boreal Forest	N	X
Indicators and Benchmarks for Forest and Wetland Reclamation	N	
Methods and Products Using Remote Sensing for the Provision of National Annual Change Information on Forest Cover and Type of Forest Disturbance	N	
Scientific Advisory Role on Atmospheric Deposition and Terrestrial Effects Monitoring	N	
Screening of Willow Clones for Salt Tolerance for use in Stabilization of Shorelines of End Pit Lakes, Other Riparian Areas and for Reclamation of Mines Areas	Y	
Spatial and Temporal Analysis and Modeling	N	
Studies of Peatland Vegetation and Landform Dynamics in Boreal and Subarctic Regions of Western and Northern Canada, Including Alberta	N	X

continued

Tailings Management Science and Research Initiatives	Direct (Y) or indirect (N) focus of research	Completed (X)
Earth Sciences sector		
Earth Observation Demonstration Projects – Earth Observation Monitoring of the Oil Sands Workshop	N	X
Coal and Oil Resources Environmental Sustainability (CORES)	N	
Optimizing Remediation of Gold Mine Tailings in Nova Scotia	Y	
Geoenvironmental Model for Uranium-Rare Earth Elements Granitic Pegmatite-hosted Deposits of the Grenville Province	Y	
Tools for Environmental Impact Assessment Downstream of Contaminated Mine Sites: The Lac Dasserat Study	N	
Remote Sensing Technologies Applied to Environmental Remediation Projects	Y	X
Energy sector		
No research is being conducted in the Energy sector.		
Innovation and Energy Technology sector		
Mitigation of the Oil Sands Tailings Environmental Footprint	Y	
Water Issues in Oil Sand Processing	Y	
Minerals and Metals sector and CanmetMINING		
Assessment of Mine Waste Management Practices in Canada (Joint With CNSC)	Y	
Biochar for Mine Reclamation	Y	
Bioleaching of Pyrrhotite Tailings	Y	
Critical Review of Environmental Impacts of Submarine Tailings Placement	Y	
Environmental Ore Deposit Models for the Canadian North	N	
Evaluation of the Ecological Risks and Benefit of Revegetation of Thetford Mine – Phase I	Y	
Field Assessment of the Occurrence of Algal Biofilm on Submerged Tailings	Y	X

continued

Initiatives

Tailings Management Science and Research Initiatives	Direct (Y) or indirect (N) focus of research	Completed (X)
Green Mines Green Energy	Y	
Mine Environment Neutral Drainage (MEND) Program – Stratos	Y	
Mine Environment Neutral Drainage (MEND) Program – EcoMetrix	Y	X
Mine Environment Neutral Drainage (MEND) Program – NRCan	Y	X
Mineralogical Characterization and Speciation of Arsenic in Tailings From the Experimental Field Cells at the Delnorte Mine Site	Y	X
Options Review for Tailings and Waste Rock	Y	
Physical and Chemical Characteristics of Leached Mine Backfill	Y	
Quantitative Mineralogy of Processed Kimberlite and Waste Rock Samples From the Diavik Diamond Mines	Y	X
Radium Remobilization From Submerged Uranium Tailings (Joint With CNSC)	Y	
Reprocessing of Asbestos Tailings Phase 1: Tailings Characterization	N	
Sulfide Oxidation and Mobilization of Arsenic in the Ketzar River Mine Tailings	Y	X
A Weight of Evidence Approach to Assess the Cycling of Oil Sands-relevant Metals in Tailings Ponds and the Athabasca River	Y	
Canadian Nuclear Safety Commission		
Assessment of Mine Waste Management Practices in Canada (Joint With CNSC)	Y	
Effects of Chronic Exposure to Alpha-emitting Radionuclides on Health and Reproductive Fitness of Biota	N	
Environmental Investigations at Legacy Sites	N	
Radium Remobilization From Submerged Uranium Tailings (Joint With NRCan CanmetMINING)	Y	

Canadian Forest Service



Boreal Ecosystem Atmosphere Study (BOREAS) 1994–1996

Objectives Assess the role of the boreal forest in the global carbon cycle and climate system and improve its representation in global models. The study involved organizations such as NASA, Environment Canada, Canada Centre for Remote Sensing, Canadian Forest Service and many Canadian and American universities.

Activities The study links to reclamation through its focus on water balance, which controls both the location of the forest/grassland ecotone and the special patterns of vegetation and carbon accrual across the boreal forest mosaic, via topography and drainage.

Focus Indirect focus: provides baseline information about the scale and rate of changes in boreal forests, with a focus on climate change affects on hydrology; carbon dynamics of wetlands and forested peatlands; and forest recession at the forest grassland ecotone

Status Completed

Results: Completed The reports are in the public domain so the data are publicly accessible.

Primary contribution Research results and data assets

Lead researchers Ted Hogg, David Price, Rick Hurdle, Northern Forestry Centre

Dynamics of Vegetation and Soil Changes in Boreal Forest Peatlands – Climate Change and Carbon Project

Objective Assess recent changes in carbon source-sink relationships and greenhouse gas emissions in forest-peatland ecosystems in various regions of Canada.

Activities Field measurements of vegetation, soils, permafrost, hydrology and greenhouse gas emissions in study sites.

Focus Direct focus: provides baseline information about the scale and rate of changes in forested peatlands. The work includes a permanent study site adjacent to an oil sands mining area in the Lower Athabasca region.

Status Scheduled for completion in March 2013

Results: Anticipated Ongoing preparation of peer-reviewed journal articles and technical reports

Primary contribution Research results and data assets

Lead researcher Jagtar Bhatti, Canadian Forestry Service, Northern Forestry Centre

Ecosystem Management Emulating Natural Disturbances (EMEND)

Objective Identify the best forest harvesting and regeneration practices to maintain biotic communities, forest structure and functional ecosystem integrity.

Activities A large-scale research project was established in the boreal forest in northwest Alberta in collaboration with the University of Alberta. The research can be used to guide reclamation activities with the goal of establishing a functional forest ecosystem. Among other information, this project currently provides critical information on boreal biodiversity indices and targets for taxa.

Focus Indirect focus: collective knowledge of

- 1) reaction of biotic communities to disturbance
- 2) what is required for succession pathways to become established following disturbance
- 3) predictability of succession pathways
- 4) foundations for boreal ecosystem design

Status Ongoing. Research programs commenced in 1998 and are continuing.

Results: Anticipated Specific research has been completed that deals with biodiversity monitoring, forest primary productivity, silvicultural systems, forest ecology, soils and nutrient cycling, forest hydrology, forest genetics, and socio-economic impacts.

Primary contribution Research results and data assets

Lead researchers J. Volney (lead), B. Kishchuk, B. Pinno, Northern Forestry Centre

Enhancing Microenvironments on Challenging Sites

Objective Enhance microenvironments on challenging sites to benefit the establishment of desirable crop trees.

Activities

- 1) Prince Albert, Saskatchewan – site preparation techniques to address degraded hardpan soils on jack pine sites compacted by short fire return intervals (established 1987)
- 2) Muskeg River, Northwest Territories – site preparation trials to establish white spruce crop trees on organic alluvial flood plains (established 1994)
- 3) Red Earth, Saskatchewan – mixed wood site preparation trials to establish white spruce on degraded luvisols (established 1997)
- 4) Whitecourt, Alberta – site preparation trials to establish white spruce (established 1993)

Focus Indirect focus: experience and expertise in adopting best applications and technical practices to modify soil horizons to maximize the success of growing desirable crop trees

Status Ongoing

Results: Anticipated Development of best practices for challenging sites

Primary contribution Research results and data assets

Lead researcher Derek Sidders, Canadian Wood Fibre Centre

Ecosite Classification

Objective Create a field guide to ecosites of Northern Alberta.

Activities The field guide is an ecological classification system based on vegetation, soil, site and forest productivity. Ecosites are described by defining ecosite phase and plant communities in the field. A soil type classification system was developed to describe 17 soil types observed in northern Alberta.

Focus Indirect focus: information useful in identifying baseline conditions and ecological targets

Status Completed

Results: Completed The field guide is complete and in operational use by consultants, the forest industry and the provincial government when local site classification is of interest.

Primary contribution Research results and data assets. The field guide is a system to identify and describe field sites in support of research and collecting field data.

Lead researchers Ron Hall, Canadian Forestry Service, Northern Forestry Centre. The field guide was written by J. Beckingham and H. Archibald in collaboration with I.G.W. Corns.

Ecosystem Services in Oil Sands Landscapes

Objective Acquire detailed knowledge of forest conditions before exploitation to understand the impacts of oil sands development. There is a need to characterize landscape patterns and dynamics of geochemistry, soils, biodiversity and forests to qualify and compare natural variation and oil sands activities. Methods and tools for integrating data from field, inventory and geospatial datasets will describe and assess, and monitor changes to, current ecosystem services.

Activities

- 1) Assessment and collection of data about the natural conditions of the oil sands landscapes.
- 2) Identification and sampling of soil, vegetation, biodiversity, etc. of sites typical of the undisturbed and reclaimed conditions, including sites along a spatial transect from reclaimed to undisturbed conditions.

Focus Indirect focus: provide baseline information about the natural occurrence and variation of ecosystem services in the landscapes to help define targets for land reclamation

Status To be implemented, scheduled completion March 2013

Lead researcher Evelyne Thiffault, Canadian Forestry Service, Laurentian Forestry Centre

Effects of Oil Sands Processing Emissions on the Boreal Forest (Information Report NOR-X-284)

Objectives

- 1) Establish a network of permanent monitoring sites to evaluate the effects of airborne pollutants on the forest system near the oil sands operation.
- 2) Select and evaluate various biological variables for use in the biomonitoring of air pollutant impacts.

This study was undertaken between 1975 and 1985.

Focus Indirect focus: The study addressed the effects of airborne pollutants on soils and vegetation.

Status Completed

Results: Completed A summary of this project was published as an Northern Forestry Centre Information Report NOR-X-284 in 1986 by Addison, et al.

Primary contribution Research results and data assets

Lead researcher Doug Maynard, Pacific Forestry Centre

Indicators and Benchmarks for Forest and Wetland Reclamation

Objectives

- 1) Determine, characterize and assess the elements of recovering forests required for reclaiming functional watershed and wetland attributes on industrially and naturally disturbed landscapes by using data analysis, synthesis, modeling and pilot-scale field studies.
- 2) Set ecologically relevant and realistic indicators and benchmarks to optimize land and water reclamation.
- 3) Develop the means to project how and when a recovering forest re-sets ecological function in damaged landscapes for the various options.

Activities

- 1) Using a functional trait approach, explore the ecological processes to optimize the ecosystem recovery.
- 2) Existing methods of ecosystem valuation will be examined to determine how these may be used in determining the value of ecosystem services that have been lost and restored.
- 3) Compare recovering forests across naturally (fire) and industrially disturbed (logging, mining) watersheds and their role in re-establishing functional landscapes and aquatic ecosystems.
- 4) Develop metrics that describe the hydro-chemical regimes and range-of-variation in undisturbed watersheds to set realistic pre-disturbance targets and benchmarks for industrially disturbed watersheds and wetlands.

Focus Indirect focus: knowledge of ecosystem function in natural landscape provides reference targets for the restoration and reclamation of disturbed landscapes

Status To be implemented

Results: Anticipated Completion in 2014–2015

Lead researcher Dave Kreutzweiser, Canadian Forestry Service, Great Lakes Forestry Centre

Methods and Products Using Remote Sensing for the Provision of National Annual Change Information on Forest Cover and Type of Forest Disturbance

Objective Produce a national annual change product and research change detection to derive enhanced information on the change proportion of forest cover and disturbance type that affect the forest landscapes, based on moderate resolution imaging spectroradiometer (MODIS) 250m data.

Activities

- 1) Develop the change detection method by using MODIS imagery.
- 2) Survey changes in Canada's forest landscapes from 2000 to 2013.
- 3) Update the photo-plot for the national change database for planning the Canadian National Forest Inventory.

Focus Indirect focus: provides baseline information about the scale and rate of changes in the forest landscapes caused by natural (fire, insects) and anthropogenic (clear-cut) disturbances. It can also monitor the extent of the areas covered by mining activities and tailings.

Status Ongoing

Lead researcher Luc Guindon, Canadian Forestry Service, Laurentian Forestry Centre

Scientific Advisory Role on Atmospheric Deposition and Terrestrial Effects Monitoring

Objectives

- 1) Provide scientific advice to the Wood Buffalo Environmental Association (WBEA) related to monitoring acid deposition in the oil sands region.
- 2) Review project proposals and reports for WBEA related to acid deposition and monitoring.
- 3) For WBEA, develop a new design for the long-term monitoring of air pollution on terrestrial (jack pine) ecosystems affected by the oil sands development.

Activities

- 1) Perform soil and foliar analysis on their six-year resampling monitoring program in 2011–2012.
- 2) Interpret the findings.

Focus Indirect focus: information useful for the Ecosystems Services in the Oil Sands Landscapes study and providing background information

Status Ongoing. The sites were sampled in 1998, 2004 and 2011.

Results: Anticipated The reports are in the public domain so the data are accessible. Detailed soil surveys of the oil sands are available also. The Canadian Forestry Service was not involved in the previous sampling or the soil survey but the data are available.

Primary contribution Research results and data assets

Lead researcher Doug Maynard, Canadian Forestry Service, Pacific Forestry Centre

Screening of Willow Clones for Salt Tolerance for use in Stabilization of Shorelines of End Pit Lakes, Other Riparian Areas and for Reclamation of Mines Areas

Objectives

- 1) Demonstrate the existence of, and rank, a selection of salt-tolerant willow clones that could be used to stabilize the shoreline of end-pit lakes and to revegetate other areas that may be subject to salt-affected water.
- 2) The longer-term objective is to test the best willow varieties identified in the greenhouse trial in field situations.

Activities

- 1) Assemble a broad selection of willow clones from various sources (local to oil sands sites, regional, national and international (± 40 clones).
- 2) Rank the clones using an aeroponics growth system for tolerance to three salt concentrations – the highest based on field data.

- 3) Test the best and a selection of the worst clones in a greenhouse pot study on two challenging soil types encountered on reclaimed mined areas.
- 4) Design a field study to test material in operational conditions.

Focus Direct focus: Salt tolerant clones would be used not only for reclaimed mined areas around end pit lakes and for seepages, but also for reclaimed tailings ponds. Additional testing is required to determine if direct planting in dewatered tailings is possible.

Status Ongoing. Started February 2011.

Results: Anticipated Anticipate a ranked list of willow clones that are tolerant to two levels of sodium chloride. The ranking is specific to the aeroponics study and the soil study. The ranking will form the basis for a future field study to investigate the performance of the willows under operational conditions and the implications to using willows for restoring ecosystem processes. The results will also stimulate the search for and/or development of, additional salt-tolerant clones.

Primary contribution The ranking of the clones and data from growth rates, salt partitioning and photosynthesis effect are the primary contributions.

Lead researcher Richard Krygier, Canadian Forestry Service, Northern Forestry Centre

Spatial and Temporal Analysis and Modeling

Objective Collect remotely sensed and spatial data and combine them with modeling to inform on previous forest conditions and provide a base to model future conditions. Measurement of historic forest dynamics will inform on regionally appropriate regeneration and forest recovery post-disturbance. Modeling of future conditions can then be informed by measurement of past recovery and through an accurate depiction of current landscape conditions.

Activities

- 1) Monitor land cover dynamics over time and a range of scales.
- 2) Characterize landscape structure and patterns.
- 3) Project forest conditions (scenario-based modeling).

Focus Indirect focus:

- 1) acquire historic and current Landsat data over the oil sands
- 2) research methods to map temporal history of fire disturbance and harvesting over the past 40 years

Status On hold. Some activities are currently ongoing, others are awaiting funding.

Results: Completed and Anticipated Previous work has produced manuscripts in peer review. Similar communication of further findings is anticipated.

Primary contribution Research results and data assets

Lead researcher Mike Wulder, Canadian Forestry Service, Pacific Forestry Centre

Studies of Peatland Vegetation and Landform Dynamics in Boreal and Subarctic Regions of Western and Northern Canada, Including Alberta

Objective Collect baseline information about the scale and rate of change in forested peatlands, including the area in the Lower Athabasca region contained in numerous Canadian Forestry Service reports by S. Zoltai from 1960 to the 1990s.

Activities Information can be related to reclaiming mining areas to wetland ecosystems.

Focus Indirect focus: provides baselines information about the scale and rate of changes

Status Completed

Results: Completed Reports are available in the public domain so that the data are accessible.

Primary contribution Research results and data assets

Lead researcher S. Zoltai, Northern Forestry Centre

Earth Sciences sector



Earth Observation Demonstration Projects – Earth Observation Monitoring of the Oil Sands Workshop

Objective Define Earth Observation demonstration projects in the oil sands as a follow-up to the 2011 Earth Observation Monitoring of the Oil Sands workshop.

Activities Working with the Alberta Energy Conservation and Resource Board to define Earth Observation demonstration projects in the oil sands as a follow-up to the Earth Observation Monitoring of the Oil Sands workshop held in February 2011 in Edmonton, Alberta. The workshop was co-chaired by Alberta Energy Resources and Conservation Board, CCRS and Canada Space Agency.

Focus Indirect focus

Status Completed

Results Reports

Primary contribution Research results and data assets

Lead researchers Dr. Vern Singhroy, Dr. Abdelgadir Abuelgasim, Canada Centre for Remote Sensing

Coal and Oil Resources Environmental Sustainability (CORES)

Objective Develop geochemical tools to differentiate between natural and anthropogenic sources of contaminants (including tailings impoundment) in the oil sands region. The activities use geoscience to fill knowledge gaps about how to improve the efficiency of remediation efforts in the oil sands and develop approaches to quantify and limit contamination from the use of bitumen and coal.

Activities

- 1) Accumulation and attenuation of natural organic compounds: Evaluate new isotopic techniques to differentiate between naturally occurring and anthropogenic sources of organic contaminants to provide an historical perspective on the accumulation of organic contaminants and to contribute to improved environmental targets in northeastern Alberta and northwestern Saskatchewan.
- 2) Biogeochemical cycles of metals: Develop a geoscience strategy to mitigate metal contamination from coal, trace anthropogenic metal inputs and assess the impacts of contaminant input in the aquatic environment.
- 3) Characterization of naphthenic acids in tailings ponds: Assess the level of natural attenuation of hydrocarbon-derived contamination in sediments and in tailings ponds.
- 4) Groundwater transport of organic and metallic contaminants: Identify, quantify and model the flux of oil sands-related chemicals in groundwater along two alignments of wells selected to include open mining sites within the Athabasca oil-sands region.

Focus Indirect focus: This project's results will inform tailings management plans for oil sands surface mining.

Status Activities 1 and 2 are ongoing (2009–2014). Activities 3 and 4 were pilot studies undertaken through the Clean Energy Fund and are completed (2010–2012).

Results: Completed and Anticipated Alberta Environment and Environment Canada are key partners of this project. Results from this project will be used by them and the industry to inform the environmental management of oil sands tailings.

Primary contribution Research results and data assets

Lead researcher Dr. Martine Savard, Geological Survey of Canada (Quebec)

Optimizing Remediation of Gold Mine Tailings in Nova Scotia

Objectives

- 1) Design appropriate remediation strategies for arsenic-rich historical gold mine tailings in Nova Scotia that a) prevent arsenic concentrations from increasing in downstream surface and ground water and b) reduce health risks to local residents and recreational users of these sites.
- 2) Define the geochemical and microbial controls on the stability of arsenic-hosting minerals in weathered gold mine tailings and develop remediation options that can minimize arsenic release.
- 3) Develop general guidelines for optimizing the management and remediation of high-level arsenic mine wastes at active and abandoned gold mines across Canada and at other sites worldwide.

Activities

- 1) Ongoing fieldwork at the Montague and Goldenville abandoned mine sites in Nova Scotia to evaluate tailings solids and pore waters, the role of microbes in controlling arsenic mobility and the effectiveness of geosynthetic clay liners as a tailings cover.
- 2) Field and laboratory experiments to investigate the leaching behaviour of gold mine tailings under various disposal scenarios and the role of colloids in arsenic release and transport.
- 3) Ongoing meetings with supporting organizations and Nova Scotia Environment to ensure project results are used appropriately to inform tailings management plans at historic gold mine sites.

Focus Direct focus: The results will be applicable to modern and historic gold mines.

Status Ongoing. Activity under the ESS Environmental Geoscience Program. Initiated in September 2008; Completion Date: March 31, 2014.

Results: Anticipated Results from this project will be used by the province of Nova Scotia to optimize remediation plans for historic tailings at two sites in Nova Scotia to reduce risks to the ecosystem and human health.

The information will be used to develop general guidelines for management of high-level arsenic gold mine tailings at active and abandoned gold mines across Canada, and at other sites worldwide.

Primary contribution Research results and data assets

Lead researcher Dr. Michael Parsons, Geological Survey of Canada (Atlantic). Parsons is a co-principal investigator on an NSERC strategic grant in support of this work with Queen's University, Trent University, the University of Ottawa, AMEC, SRK Consulting and Nova Scotia Environment.

Geoenvironmental Model for Uranium-Rare Earth Elements Granitic Pegmatite-hosted Deposits of the Grenville Province

Objectives

- 1) Provide a pre-mining baseline to characterize the potential hazards and develop guidelines for assessing risks to human health and ecosystems from uranium and rare earth elements (REE) resource development.
- 2) Characterize the concentrations and mineral hosts for radionuclides, REE and metals in historical mine wastes from granite-hosted uranium deposits near Bancroft, Ontario.
- 3) Assess the geochemical controls on radionuclide and REE mobility in surface waters that drain both mine wastes and naturally mineralized areas.
- 4) Examine the role of secondary minerals and colloids in controlling radionuclide and REE transport in surface waters.
- 5) Determine the concentrations and speciation of radionuclides and REEs in lake sediments downstream of former uranium tailings impoundments at the Bicroft Mine near Cardiff, Ontario, to evaluate the role of sediments as a long-term sink for contaminants.

Activities

- 1) Sample Bicraft surface waters, sediments and mine tailings to examine seasonal effects on water chemistry.
- 2) Detailed laboratory analysis of waters and sediments for metals and radionuclides to assess the mineral hosts for these elements and the role of colloids in uranium release and transport.
- 3) Combine results with concurrent Geographic Survey of Canada studies of groundwater, surficial geochemistry, and soil gas radon to complete a geoscience-based characterization of the environmental risks associated with U-REE granite pegmatite deposits to better inform public policy and regulatory decision making.

Focus Direct focus: The results will be applicable to modern and historic uranium-REE mines.

Status Ongoing. Activity under the ESS Environmental Geoscience Program. Initiated in 2009; Completion date: March 31, 2014.

Results: Anticipated Results from this project will be used by the Canadian Nuclear Safety Commission and provincial environment departments for assessing the ecosystem and human health risks associated with granite-hosted uranium deposits. Comparison of predicted and actual water quality at decommissioned uranium mines can also be used to determine the reliability of predictions from past environmental impact statements and to improve future mitigation measures.

Primary contribution Research results and data assets

Lead researchers Dr. Michael Parsons, Geological Survey of Canada (Atlantic); Dr. Alexandre Desbarats, Geological Survey of Canada (northern Canada)

Tools for Environmental Impact Assessment Downstream of Contaminated Mine Sites: The Lac Dasserat Study

Objectives

- 1) Establish geoscience-based tools for environmental impact assessments (EIAs) and environmental risk characterization.
- 2) Create lake sediment archives.
- 3) Conduct hyperspectral remote sensing, specifically for assessment of cumulative environmental effects, monitoring and follow-up programs downstream of contaminated mine sites.

Activities

- 1) Determine the history and spatial extent of metal contamination by using the distributions of metal concentrations and diatoms.
- 2) Identify the sources of metal contamination to Lac Dasserat and Lac Arnoux, whether industrial or from natural mineralization, by using lake sediment metal profiles and metal and/or isotopic and geochemical surveys.
- 3) Take into account the processes of sequestration and/or remobilization of contaminant metals in lacustrine sediments and surface waters, including the roles of bacteria, sedimentation and sediment type, environmental mineralogy and organic matter.
- 4) Document environmental degradation (e.g. of vegetation) in the Lac Dasserat watershed and its recovery after restoration of the Aldermac site by using time series optical and hyperspectral remote sensing techniques that detect and track surface changes related to contaminant sources.

Focus Indirect focus: The results will be used by Environment Canada (National Metal Mining Environmental Effects Monitoring [EEM] program) and the province of Quebec (ministère des ressources naturelles et, du développement durable, environnement, faune et parcs du Québec).

Status Ongoing. Activity under the ESS Environmental Geoscience Program. Initiated in 2009; Completion date: March 31, 2014.

Results: Anticipated The Lac Dasserat study will establish geoscience-based tools for environmental risk characterization: lake sediment archives, surface water and bottom sediment surveys, sub-bottom acoustic profiling and hyperspectral remote sensing, specifically for assessment of accumulated environmental effects, monitoring, and follow-up programs downstream of contaminated mine sites.

Primary contribution Research results and data assets

Lead researcher Dr. Sam Alpay, Geological Survey of Canada (northern Canada)

Status Completed the activity under the ESS Environmental Geoscience Program.

Results: Completed The guidelines will be released to member states as a supplement to methods of reporting radioactive mining or environmental activities to the UN-IAEA.

Primary contribution Report

Lead researcher Dr. H. Peter White, Canada Centre for Remote Sensing

Remote Sensing Technologies Applied to Environmental Remediation Projects

Objective Consult with the United Nations International Atomic Energy Agency (IAEA) on developing guidelines to member states on the application of remote sensing to support reporting requirements on the remediation management of radioactive mine and waste sites.

Activities

- 1) Three consultation meetings with the IAEA have occurred.
- 2) An internal IAEA review has been completed.
- 3) Documentation is now undergoing final review.

Focus Direct focus: Although directly related to the mining of radioactive material, tailings and waste rock are not necessarily radioactive. Remediation requires that erosion and other environmental transport of tailings do not adversely impact the surrounding environment based on land use. Remote sensing to monitor accumulated environmental impacts or to directly detect tailings contributes to tailings management.

Energy sector



There are currently no research activities identified in the Energy sector. For research related to oil sands tailings, see Innovation and Energy Technology sector.

Innovation and Energy Technology sector



Mitigation of the Oil Sands Tailings Environmental Footprint

Objective Reduce the amount of water used per barrel of bitumen production. This research leads directly to developing technologies that result in dry, stackable tailings.

Activities

- 1) Develop and demonstrate new technologies that improve water recovery.
- 2) Develop and demonstrate the potential for environmentally benign tailings and recycle water containment.
- 3) Develop and demonstrate the merit of integrating coke, sulphur, asphaltenes and other waste streams in tailings deposits rather than storing them in exposed areas.

Focus Direct focus with some indirect but significant components. Some aspects of the program are aimed at bitumen recovery from tailings ponds and tailings process streams and/or the use of other waste streams to enhance the performance of dry, stackable tailings technologies.

Status Ongoing. The Fine Tailings Fundamentals Consortium (1989–1995) led to the development and commercialization of the composite tailings process at Suncor. This in turn has led to the development of rim ditching (2004–2014) and centrifugation (2000–2012). All of these processes will benefit in different ways from bitumen recovery and/or integration with other oil sands wastes such as sulphur, asphaltenes, and coke (2010–2015).

Results: Completed and Anticipated Tailings technology is today where the extraction process was at the start-up of the industry. Many technical challenges have been overcome, but a tremendous amount of work is required to improve the process from both a performance and economic perspective. The IETS tailings program is directed at these gaps.

Primary contribution Research results and technologies

Lead researcher Dr. Kim Kasperski, CanmetENERGY Devon (IETS); funding by the Program of Energy Research and Development

Water Issues in Oil Sands Processing

Objective Understand, predict and reduce the impacts of the changing quality of process water in oil sands operations and reclamation.

Activities

- 1) Design and build water quality models for oil sands mining operations to predict impacts of operational changes such as tailings treatments on water quality and resultant implications for operations and reclamation.
- 2) Measure and model the thermodynamics of partitioning of volatile organic compounds and soluble contaminants in tailings ponds.
- 3) Measure and mitigate as possible fouling reactions in in situ operations to reduce water treatment and waste streams.

Focus Direct focus with some indirect but significant components. In oil sands operations, water chemistry affects everything because all water recovered from the tailings is recycled, so any tailings treatment method will affect water chemistry. It is important to understand what the water chemistry is, how it changes and how this affects oil sands extraction, tailings behaviour and ultimately, reclamation.

Status Ongoing. Water quality modeling has been completed. The remainder of the project is ongoing.

Results: Anticipated Modelling of water chemistry in oil sand mining sites started in 1998 with Suncor. The most recent model was built in 2006 for Canadian Natural Resources Limited. Various projects in this program were started in 2008 and are ongoing. Projects evolve and new ones develop as issues arise as identified by IETS, provincial regulators or industry contacts.

Primary contribution Research results and modeling

Lead researcher Dr. Kim Kasperski, CanmetENERGY Devon (IETS); funding by the Program of Energy Research and Development

Minerals and Metals sector and CanmetMINING



Assessment of Mine Waste Management Practices in Canada (Joint With CNSC)

Objectives

- 1) Survey mine waste management practices in Canada and determine the scientific rationale for selecting certain mine waste management practices.
- 2) Assess the reliability of pre-mining water quality predictions and identify inherent risk factors that may affect water quality.

Activities A joint effort by Environment Canada, the Canadian Nuclear Safety Commission and CanmetMINING in data survey and assessment to

- 1) Identify major metal and uranium mines in Canada and create a database of their information that includes a description of their waste characteristics and waste management practices.
- 2) Gather and evaluate water quality prediction information for the mines from environmental impact statements or other reports.
- 3) Select a representative subset of mines that have sufficient data for in-depth study.
- 4) Identify the most common causes of water quality impact and prediction failures and determine if there were inherent risk factors at mines that may predispose an operation to having water quality problems.

Focus Direct focus

Status To be implemented. Proposed completion date September 2013.

Results: Anticipated A project report and seminar. A journal publication, if warranted.

Lead researchers Michael Rinker, Karina Lange, Richard Goulet, CNSC; John Kwong, Janice Zinck, CanmetMINING

Biochar for Mine Reclamation

Objectives

- 1) Demonstrate the potential usefulness of biochar in mine reclamation.
- 2) Evaluate opportunities for carbon sequestration in mine tailings
- 3) Study the impact of carbon-rich amendments on tailings stability.

Activities

- 1) Laboratory metal sequestration testing.
- 2) Growth trials.
- 3) Field testing.

Focus Direct focus

Status To be implemented. Completion date anticipated March 2016.

Results: Anticipated Demonstration that biochar is a useful amendment for the reclamation of tailings that reduces metal leaching while sorting carbon in the tailings.

Lead researcher Suzanne Beauchemin, CanmetMINING

Bioleaching of Pyrrhotite Tailings

Objective Research using bioleaching to recover nickel from pyrrhotite tailings and reduce the potential for acid generation from these tailings.

Activities Stirred tank bioleaching studies

Focus Direct focus: Technology can be used to recover metals from a waste material and reduce its acid-generating potential.

Status Ongoing. Proposed completion date: March 2014.

Results: Anticipated The results will show the feasibility of recovering nickel from pyrrhotite tailings and generating a waste material that has lower acid generating potential.

Lead researcher Rory Cameron, CanmetMINING

Critical Review of Environmental Impacts of Submarine Tailings Placement

Objectives

- 1) Conduct a critical review of literature on the ecological impacts of deep sea tailings placement (DSTP).
- 2) Prepare review papers on the findings for publication in high-impact scientific journals.

Activities

- 1) Meet with international collaborators in Brisbane, Australia, (December 2011) to define the scope of work.
- 2) The Commonwealth Scientific and Industrial Research Organisation will lead in preparing a review paper on the ecological impacts of DSTP.
- 3) CanmetMINING will lead writing a paper on the viability of DSTP as a method of tailings management.

Focus Direct focus

Status Ongoing. December 2013.

Results: Anticipated Two review papers for publication in high-impact scientific journals and a general discussion paper to be posted on the CSIRO Web site

Lead researchers David Brewer, CSIRO (Australia); John Kwong, CanmetMINING

Environmental Ore Deposit Models for the Canadian North

Objective Develop environmental ore deposit models for selected types of mineral deposits in the Canadian North to facilitate sustainable mining development.

Activities The models elucidate the interconnection between deposit geology, mining and mineral processing methods, and mine waste management alternatives to inform choosing the best combination of methods to minimize the overall cost and environmental impacts of a mining project. Tailings management is a key component of the models.

Focus Indirect focus

Status Near completion. December 2013.

Results: Anticipated A technical report; journal and conference papers; fact sheets and technology transfer workshops

Lead researcher John Kwong, CanmetMINING

Evaluation of the Ecological Risks and Benefit of Revegetation of Thetford Mine – Phase I

Objective Determine the feasibility of establishing a vegetation cover on asbestos tailings through laboratory pot trials and data on the effect of vegetation on the mobility of metals, nutrients and carbon in the soil-plant system.

Activities

- 1) Conduct a literature review.
- 2) Collect tailings samples.
- 3) Conduct laboratory pot trials.
- 4) Produce a report.

Focus Direct focus: Revegetation is one of the end-of-life options for asbestos tailings piles.

Status Completed. Report completed in December 2011

Results: Completed The results assist in determining the feasibility of revegetation with or without soil amendments and the effect of the revegetation on the chemistry of the tailings.

Lead researcher Yonghong Wu, CanmetMINING

Field Assessment of the Occurrence of Algal Biofilm on Submerged Tailings

Objectives

- 1) Determine if photosynthetic biofilms are generally present on submerged mine tailings.
- 2) Identify the physico-chemical conditions favourable for biofilm formation.
- 3) Clarify the effects of biofilm on metal mobilization.

Activities

- 1) Field investigation and sampling at five mine sites across northern Quebec and Ontario that have submerged tailings of different composition.
- 2) Laboratory analysis of water chemistry and mineralogy to support field observations and measurements.

Focus Direct focus

Status Completed. September 2009–November 2010.

Results: Completed MEND Report 2.12.2b officially released in May 2011

Lead researcher John Kwong, CanmetMINING

Green Mines Green Energy

Objectives

- 1) Rehabilitate mine tailings.
- 2) Produce biofuel feedstock from tailings disposal areas.

Activities

- 1) Establish and monitor field test plots to determine the feasibility of establishing agricultural land on mine tailings by using organic waste materials.
- 2) Conduct laboratory leaching column studies.
- 3) Establish three field test locations in Ontario and one in British Columbia.

Focus Direct focus

Status Ongoing. Initial field tests established in 2008. Expanding in 2011. Monitoring to continue to at least 2015.

Results: Completed and Anticipated

Results have demonstrated

- 1) that canola and corn can be grown on organically amended mine tailings
- 2) the seed yield of canola has met the Ontario agricultural average
- 3) the effect on tailings mineralogy and groundwater: to date, no significant uptake of metals into organic cover or crops has occurred

Lead researcher Bryan Tisch, CanmetMINING

Mine Environment Neutral Drainage (MEND) Program – Stratos

Objective Research and predict priority issues that affect mining in Canada, including mine waste management.

Activities Conduct a paper study to examine climate change impacts on water and tailings management activities, including tailing impoundment structures.

Focus Direct focus

Status Completed.

Results: Completed The paper outlines which areas to consider in further projects on climate change.

Lead researcher Stratos Inc.

Mine Environment Neutral Drainage (MEND) Program – EcoMetrix

Objective Research and predict priority issues that affect mining in Canada, including mine waste management.

Activities The Evaluation of the Water Quality Benefits From Encapsulation of Acid-generating Tailings by Acid-consuming Tailings was a laboratory study that investigated the benefits of encapsulating acid-generating tailings by acid-consuming tailings as a strategy for water quality mitigation, including acid neutralization.

Focus Direct focus

Status Completed

Results: Anticipated The field study will apply the results to manage historic acid-generating tailings in Ontario. The results are in progress.

Lead researcher EcoMetrix Incorporated

Mine Environment Neutral Drainage (MEND) Program – NRCan

Objective Research and predict priority issues that affect mining in Canada, including mine waste management.

Activities Produced the *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials*, which provides information for conducting a prediction program to deal with mine site drainage, including the management of tailings.

Focus Direct focus

Status Completed

Results: Completed Information transfer ongoing through workshops and short courses.

Lead researchers NRCan, CanmetMINING

Mineralogical Characterization and Speciation of Arsenic in Tailings From the Experimental Fields Cells at the Delnorte Mine Site

Objectives

- 1) Determine the form and nature of arsenic in the tailings and assess the impact of the organic cover on the stability of arsenic species.
- 2) Evaluate options for long-term management of the tailings.

Activities

- 1) Mineralogical characterization of the tailings, including X-ray diffraction and scanning electron microscopy examinations.
- 2) Arsenic speciation by using synchrotron X-ray absorption near edge spectroscopy (XANES).

Focus Direct focus

Status Completed

Lead researcher Dogan Paktunc, CanmetMINING

Options Review for Tailings and Waste Rock

Objective Summarize the options and screening criteria to help stakeholders select appropriate waste management options.

Activities

- 1) Develop an assessment to screen and select waste management options.
- 2) Submit the document and screening tool to a stakeholder peer review.

Focus Direct focus

Status Ongoing.

Results: Anticipated A review document and screening tool for assessing options.

Lead researchers Janice Zinck, Gilles Tremblay, CanmetMINING

Physical and Chemical Characteristics of Leached Mine Backfill

Objective Investigate and document the effects that leaching has on mine backfill that is made from tailings.

Activities Use laboratory simulations and actual underground mine settings to leach and weather mine backfill made by using conventional Portland cement and alternative binders.

Focus Direct focus

Status Ongoing. Initiated Fall 2008, completion spring 2014.

Results: Anticipated The development of mining practices that will result in backfill that has long-term physical and chemical stability.

Lead researcher Allen Pratt, CanmetMINING

Quantitative Mineralogy of Processed Kimberlite and Waste Rock Samples From the Diavik Diamond Mines

Objectives

- 1) Determine the mineralogical composition and abundance of the minerals.
- 2) Assess the oxidation, weathering and neutralization potentials of the material in the processed kimberlite storage facility.

Activities

- 1) Mineralogical characterization of the tailings, including optical microscopy, X-ray diffraction, scanning electron microscopy examinations and electron microprobe analyses.
- 2) Perform calculations to determine mineralogical acid generating and neutralization potentials.

Focus Direct focus

Status Completed

Lead researcher Dogan Paktunc, CanmetMINING

Radium Remobilization From Submerged Uranium Tailings (Joint With CNSC)

Objectives

- 1) Determine the attenuation and release mechanisms of radium (Ra) at legacy sites.
- 2) Link the identified processes with site characteristics to improve long-term predictability and inform the development of best tailings management strategies to prevent Ra remobilization.

Activities

- 1) Review previous work to identify data gap and uncertainties.
- 2) Conduct supplementary field investigation and sampling to identify probable key parameters that control the release or immobilization of Ra.

- 3) Perform in situ micro analysis to reveal the mechanism of Ra attachment and column tests to differentiate alternative mechanisms of Ra sequestration and release.
- 4) Develop and conduct column tests and compare the result to the field results.
- 5) Analyze how site conditions affect the long-term behaviour of Ra-226 in uranium tailings.
- 6) Identify the appropriate management strategies to prevent remobilization of radium.

Focus Direct focus

Status Project commenced June 1, 2011, and is expected to conclude July 2014.

Results: Anticipated A literature review report, project report and journal publication, as appropriate

Lead researchers Michael Rinker, Karina Lange, Richard Goulet, CNSC; John Kwong, CanmetMINING

Reprocessing of Asbestos Tailings Phase I: Tailings Characterization

Objective Obtain an objective and consistent understanding of the interrelationship between the mineralogical, chemical, structural, textural and morphological properties of tailing materials produced from chrysotile mining activities.

Activities Efforts are made to complement the respective strengths of advanced sample preparation and analytical techniques such as micro-X-ray diffraction, field-emission scanning electron microscopy, electron probe X-ray microanalysis and synchrotron-based characterization methods to obtain a powerful integrated approach for the characterization of this complex waste material.

Focus Indirect focus: provide pertinent information on the nature of the tailing materials that could subsequently be used for developing an economically viable and environmentally responsible transformation of the waste

Status Completed. Completion date: December 2011.

Results: Completed Final report and publication

Lead researcher Yves Thibault, CanmetMINING

Sulfide Oxidation and Mobilization of Arsenic in the Ketz River Mine Tailings

Objective Determine the mineralogical changes related to depth, including the microbiological effects on the release of arsenic from the tailings.

Activities Mineralogical characterization of the tailings including optical microscopy, X-ray diffraction and scanning electron microscopy examinations; chemical extraction tests; arsenic speciation molecular-scale characterization using synchrotron-based XANES and EXAFS (X-ray absorption fine structure spectroscopy).

Focus Direct focus

Status Completed

Lead researcher Dogan Paktunc, CanmetMINING

A Weight of Evidence Approach to Assess the Cycling of Oil Sands-relevant Metals in Tailings Ponds and the Athabasca River

Objective Determine the fate and effect of metals in oil sands tailings ponds and the adjacent Athabasca River.

Activities

- 1) Collect Athabasca River and tailings ponds samples.
- 2) Conduct chemical analysis and toxicity testing of samples.
- 3) Produce a report.

Focus Direct focus: More information is required on metal cycling within oil sands tailings ponds for proper management.

Status Completed. Implementation in October 2010; report was produced in March 2012.

Results: Anticipated Results help indicate if there are metals of concern in the tailings ponds and river and the potential effects of these metals on the environment.

Lead researchers Carrie Rickwood, Philippa Huntsman-Mapila, CanmetMINING

Canadian Nuclear Safety Commission



Assessment of Mine Waste Management Practices in Canada (Joint With CNSC)

Objectives

- 1) Survey mine waste management practices in Canada and determine the scientific rationale for selecting certain mine waste management practices.
- 2) Assess the reliability of pre-mining water quality predictions and identify inherent risk factors that may affect water quality.

Activities A joint effort by Environment Canada, the Canadian Nuclear Safety Commission and CanmetMINING in data survey and assessment to

- 1) Identify major metal and uranium mines in Canada and create a database of their information that includes a description of their waste characteristics and waste management practices.
- 2) Gather and evaluate water quality prediction information for the mines from environmental impact statements or other reports.
- 3) Select a representative subset of mines that have sufficient data for in-depth study.
- 4) Identify the most common causes of water quality impact and prediction failures and determine if there were inherent risk factors at mines that may predispose an operation to having water quality problems.

Focus Direct focus

Status To be implemented. Proposed completion date September 2013.

Results: Anticipated A project report and seminar. A journal publication, if warranted.

Lead researchers Michael Rinker, Karina Lange, Richard Goulet, CNSC; John Kwong, Janice Zinck, CanmetMINING

Effects of Chronic Exposure to Alpha-emitting Radionuclides on Health and Reproductive Fitness of Biota

Objectives

- 1) Evaluate the long-term effects of chronic internal exposure on non-human biota to low doses of alpha-emitting radionuclides.
- 2) Contribute to national and international efforts to develop ecologically relevant toxicity benchmarks for chronic exposure to alpha-emitters.

Activities

- 1) Select wild animals so that results may be extrapolated to natural settings at uranium mines and mills.
- 2) Conduct experimental studies of chronic internal exposure of more sophisticated animal models to low doses of alpha-emitting radionuclides.
- 3) Interpret the data to derive toxicity benchmarks for several biological endpoints relevant to population and individual survival.

Focus Indirect focus: Research is being conducted on the alpha radiation effects on health and reproductive fitness for two U-238 decay chain alpha emitters for biota that is representative of uranium mining sites in Saskatchewan. This data will be used to develop toxicity benchmarks needed for risk assessment of uranium mining projects in northern Saskatchewan.

Status Ongoing. Research project timeline is June 2009 to May 2013.

Results: Anticipated Progress reports; a project summary and report; and publications, as appropriate

Primary contribution toxicity benchmarks, research data and reports

Lead researchers Michael Rinker, CNSC; Carmel Mothersill, McMaster University

Environmental Investigations at Legacy Sites

Objective Research the long-term effects of radiation on biota at nuclear legacy sites in contrasting environments.

Activities Scope future directions for environmental research at uranium mining and similar legacy sites in Canada and the former Soviet Union.

Focus Indirect focus: identify environmental risks to biota posed by uranium and other radioactive and non-radioactive contaminants associated with uranium mine tailings

Status Preliminary scope completed. The project description is under development.

Results: Completed A scoping workshop was completed in May 2011. A scoping report has been completed.

Lead researchers Michael Rinker, Steve Mihok, CNSC

- 4) Develop and conduct column tests and compare the results to field results.
- 5) Analyze how site conditions affect the long-term behaviour of Ra-226 in uranium tailings.
- 6) Identify the appropriate management strategies to prevent remobilization of radium.

Focus Direct focus

Status Project commenced June 2011 and is expected to conclude September 2013.

Results: Anticipated A literature review report; a project report; and journal publication, as appropriate.

Lead researchers Michael Rinker, Karina Lange, Richard Goulet, CNSC; John Kwong, CanmetMINING

Radium Remobilization From Submerged Uranium Tailings (Joint With NRCan CanmetMINING)

Objectives

- 1) Determine the attenuation and release mechanisms of radium at legacy sites.
- 2) Link the identified processes with site characteristics to improve long-term predictability and inform the development of best tailings management strategies to prevent Ra remobilization.

Activities

- 1) Review previous work to identify data gaps and uncertainties.
- 2) Conduct supplementary field investigation and sampling to identify probable key parameters that control the release or immobilization of Ra.
- 3) Perform in situ micro analysis to reveal the mechanism of Ra attachment and column tests to differentiate alternative mechanisms of Ra sequestration and release.