OSRIN Annual Report: 2013/14

Oil Sands Research and Information Network
University of Alberta, School of Energy and the Environment

April 2014

Oil Sands Research and Information Network

The Oil Sands Research and Information Network (OSRIN) is a university-based, independent organization that compiles, interprets and analyses available knowledge about managing the environmental impacts to landscapes and water impacted by oil sands mining and gets that knowledge into the hands of those who can use it to drive breakthrough improvements in regulations and practices. OSRIN is a project of the University of Alberta's School of Energy and the Environment (SEE). OSRIN was launched with a start-up grant of $4.5 million from Alberta Environment and a $250,000 grant from the Canada School of Energy and Environment Ltd.

OSRIN provides:

- **Governments** with the independent, objective, and credible information and analysis required to put appropriate regulatory and policy frameworks in place
- **Media, opinion leaders and the general public** with the facts about oil sands development, its environmental and social impacts, and landscape/water reclamation activities – so that public dialogue and policy is informed by solid evidence
- **Industry** with ready access to an integrated view of research that will help them make and execute reclamation plans – a view that crosses disciplines and organizational boundaries

OSRIN recognizes that much research has been done in these areas by a variety of players over 40 years of oil sands development. OSRIN synthesizes this collective knowledge and presents it in a form that allows others to use it to solve pressing problems.

Citation

This report may be cited as:

OSRIN, 2014. OSRIN Annual Report: 2013/14. Oil Sands Research and Information Network, School of Energy and the Environment, University of Alberta, Edmonton, Alberta. OSRIN Report No. SR-10. 66 pp.

Copies of this report may be obtained from OSRIN at osrin@ualberta.ca or through the OSRIN website at http://www.osrin.ualberta.ca or directly from the University of Alberta's Education & Research Archive at http://hdl.handle.net/10402/era.17507.

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ACKNOWLEDGEMENTS

The Oil Sands Research and Information Network (OSRIN) acknowledges the continuing and valued guidance of the Board of Directors.

OSRIN is also very grateful for the advice and guidance provided by Joseph Doucet, past Director of the School of Energy and the Environment and Chair of the OSRIN Board of Directors, and the leadership provided by Dr. Steven Moran during his tenure as the first Executive Director of OSRIN.

OSRIN is grateful to Leah Vanderjagt and Carrie Jackson of the University of Alberta Libraries for their support of the Education & Research Archive storage facility for OSRIN's reports.

Finally, OSRIN thanks the core funding agencies – Alberta Environment and Water (now Alberta Environment and Sustainable Resource Development) and the Canada School of Energy and Environment Ltd. – for their commitment to the program.

1 INTRODUCTION

This report describes Oil Sands Research and Information Network (OSRIN) activities and accomplishments for the fiscal year (FY) April 1, 2013 to March 31, 2014.

Key accomplishments for OSRIN this past year include:

- Management of 38 research projects, support of 3 conferences and a Student Delegation oil sands tour;
- Publication of 15 technical reports arising from contracted research, for a total of 46 to date;
- Publication of the 2012/13 Annual Report, as well as updating 3 Staff Reports;
- Addition of 15 new articles to the Did You Know series (we are in the process of compiling all of these into a report to be released in December)
- Continued publication of the bi-weekly OSRIN Newsletter – 260 subscribers as of March 31, 2014, a significant increase from 175 at the end of last year;
- Continued digitizing and making publically available historical research and policy reports as pdf documents (370 made available to date);
- Continued adding references to the OSRIN/CEMA Oil Sands Environmental Management Bibliography – currently 2,967 records
- Continued outreach efforts by the OSRIN Executive Director.

Publication of OSRIN reports provides the public and researchers with additional information on environmental management of oil sands impacts. They are available from the University's Education & Research Archive (http://hdl.handle.net/10402/era.17209).

Over 28,500 copies of OSRIN's reports have been downloaded since September 2011[1].

OSRIN is currently slated to wind up at the end of December 2014.

1.1 Board of Directors

The Board of Directors met in January 2014 to discuss allocation of the remaining research funds. The Board was chaired by Dr. Stefan Scherer, Director, School of Energy and the Environment, University of Alberta. Chris Powter, Executive Director of OSRIN participated as a resource to the Board.

[1] The University's ERA site changed the way it measures report downloads in September 2011. Prior to making the change there were 3,739 report downloads.

At the end of the fiscal year the Board members were:

Chris Holly	Alberta Energy
Haneef Mian	NAIT Ledcor Group Applied Research Chair – Oilsands Environmental Sustainability
John Zhou	Alberta Innovates – Energy and Environment Solutions
Julia Foght	University of Alberta
Kem Singh	Alberta Environment and Sustainable Resource Development
Murray Anderson	Alberta Environment and Sustainable Resource Development
Robert Skinner	Canada School of Energy and Environment (CSEE)
Roger Ramcharita	Alberta Energy, Oil Sands Secretariat
Terry Abel	Alberta Energy Regulator

1.2 More about OSRIN

Chris Powter is the Executive Director. Tamara Day provides administrative support on a part-time basis.

More information on OSRIN's research strategy is available in the following report:

> OSRIN, 2011. OSRIN's Design and Implementation Strategy. OSRIN Report No. SR-7. 10 pp. http://hdl.handle.net/10402/era.23574

More information on past work undertaken by OSRIN is available in the following report:

> OSRIN, 2011. Summary of OSRIN Projects – March 2014 Update. OSRIN Report No. SR-5. 97 pp. http://hdl.handle.net/10402/era.20529

1.3 Report Organization

Section 2 provides an overview of projects funded by OSRIN in each of the core research program areas during 2013/14.

Section 3 outlines OSRIN's revenue, expenditures and remaining funds. OSRIN received a $2,000.00 donation from Barr Engineering Company of Calgary and spent $628,518 during 2013/14, leaving $311,228 available for FY 2014/15.

Section 4 provides an outlook for FY 2014/15.

2 2012/13 PROGRAM

OSRIN has identified six program areas in which we are funding work. Within each program area we fund projects to scope out the state of knowledge, identify knowledge gaps, and provide insights regarding research priorities. OSRIN also directs funds to commission or support new work that will expand the knowledge base and fill in knowledge gaps.

The six research program areas are:

- Tailings Reclamation
- Regional Landscape Reclamation
- Monitoring Ecosystem Impacts

- Increasing Awareness
- Social, Economic and Regulatory
- Strategic Design

OSRIN publications, arising from the work described below, and from previous work, are found on the website at http://www.osrin.ualberta.ca/en/OSRINPublications.aspx.

Projects are listed in alphabetical order in each program area. The research performer and their affiliation is noted, followed by a table that shows the project funding and key milestone dates, the title of the final report (if applicable) and a description of the project (or the report abstract, if applicable).

2.1 Tailings Reclamation

This program seeks to identify challenges that must be addressed in accelerating the reclamation of tailings ponds and tailings disposal areas and to catalyze necessary research, demonstration and development efforts to resolve them.

2.1.1 *2013 Tailings Technology Development and Commercialization Seminar – Haneef Mian, NAIT*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	Committed $5,000	Seminar held at NAIT March 19, 2013
2013/14	$5,000	Report released April 9, 2013 Mian, H., N. Fassina, A. Mukherjee, A. Fair and C.B. Powter, 2013. Summary of 2013 Tailings Technology Development and Commercialization Workshop. OSRIN Report No. TR-32. 69 pp. http://hdl.handle.net/10402/era.31012

NAIT-CGCE, NAIT School of Sustainable Building and Environmental Management, and the NAIT JR Shaw School of Business, in collaboration with COSIA, AIEES, and the Oil Sands Research and Information Network (OSRIN), held a technology innovation workshop on March 19, 2013 at the NAIT campus to open the dialogue between oil sands industry, academia, research and development organizations, and third-party innovators. The workshop, titled *2013 Tailings Technology Development and Commercialization: Big Ideas from Small Places*, was attended by approximately 130 people from SMEs, government, industry and academia.

The following common themes arose during the presentations:

- There is considerable public scrutiny and concern about oil sands tailings-related environmental challenges
- Technology development and deployment is key to solving the tailings challenge in a sustainable manner
- There is no single technology solution for tailings disposal– a suite of technologies will be required
- For a technology to be considered suitable it must provide net environmental benefits (e.g., must be evaluated in the context of impacts on solids, liquids, GHG) and be economic (i.e., a systems perspective)
- Technologies must be deployed more quickly than in the past
- There is a need for an entity or organization that can provide a bridge between SMEs, third-party technology developers, and the oil sands companies

The workshop was a first step towards tailings technology development and commercialization. More events may be planned, some specifically focused on bringing the technology developers together and understanding their technologies. The 2nd Tailings Technology and Development Commercialization Workshop will be planned for 2014 in collaboration with all the partners. There may be an opportunity to share some results on SME and third-party vendor technologies within the 2014 workshop.

2.1.2 *A Design-of-Experiment Approach to Optimize the Methylene Blue Titration Method for Oil Sands Tailings Clay Activity – Dr. Haneef Mian, NAIT Applied Research Center for Oil Sands Sustainability*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	\$25,000 committed	Project started March 2014 Report will be released October 2014

The term “fines”, in the oil sands industry, refers to the portion of the oil sands ore which have a particle size of less than 44 μm. These materials are known to have complicating effects on the bitumen liberation and extraction process as well as tailing management strategies. The common contributing factor to the fines problem is variability of the type, structure and activity of the small (< 2 μm) clay minerals present in the ores.

A common tool to assess "clay activity" is the determination of the methylene blue index (MBI). MBI has the units of milliequivalents methylene blue/100 g of sample. Methylene blue is a cationic dye which interacts strongly on the surface of negatively charged clay particles. Since the interaction is on the surface of the clay, it is imperative that the clay minerals be dispersed to improve reproducibility precision of MBI values. Several methods are being used to disperse the clays but a common consensus among the various labs and groups determining MBI has not yet been achieved.

The goal of this project is to use a design-of-experiment (DOE) approach to more definitively define the test method conditions needed to generate reliable MBI data. In the past, a common method development approach was to vary only one factor while all other factors are kept constant. Unfortunately, this approach does not assess the implications of changes in other variables on the test method results. In a DOE approach all factors are varied simultaneously allowing the most significant factors affecting a test method to be identified.

The focus of this study will be optimizing the MBI test method for a slurry based titration of mature fine tailings (MFT). Information gleaned from this project will help define conditions not only for laboratory testing but also for automation of an on-line method enabling rapid feedback to a process operator on the properties of the fluid tailings and other streams.

2.1.3 *Application of Forward Osmosis Membrane Technology for Oil Sands Process-Affected Water Desalination – Dr. Yang Liu, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$25,000	Project started April 2013 Report will be released April 2014

Extracting bitumen from oil sands produces large volume of process-affected water (OSPW) containing a high concentration of total dissolved solids (TDS). The high salinity is a major concern facing the oil sands industry, which hampers the reuse of OSPW in process operations and the safe discharge to the environment. Conventional desalination technologies, such as reverse osmosis (RO), nanofiltration (NF) and electrodialysis (ED), require intensive heat or electrical energy input and produce large volume of concentrated brine streams that need to be managed, which hamper their application for OSPW treatment.

As a newly emerging desalination technology, forward osmosis (FO) has shown great promise in saving electrical power requirements, increasing water recovery, and minimizing the brine discharge. Recent studies also show that FO can be coupled to microbial fuel cells to treat wastewater and produce electricity. However, this technology has never been tested for OSPW treatment. The goal of this project is to evaluate and optimize FO technology to remove the TDS in OSPW and to evaluate its ability to be coupled with microbial fuel cells to self-generate electricity. This project could provide a highly efficient and cost effective treatment option for oil sands industry to recycle process-affected water for reuse without the consequences of toxic stress on the environment.

2.1.4 *Benign By Design: Engineered Si Nanoparticles for Oil Sands Process Water Contaminant Remediation – Dr. Jonathan Veinot, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$44,000	Project started April 2012
2013/14	$0	Report released November 29, 2013 Iqbal, M., T.K. Purkait, J.G.C. Veinot and G.G. Goss, 2013. Benign-by-Design: Synthesis of Engineered Silicon Nanoparticles and their Application to Oil Sands Water Contaminant Remediation. OSRIN Report No. TR-42. 30 pp. http://hdl.handle.net/10402/era.37308

This project was co-funded with the Canada School of Energy and Environment Ltd.

Oil sands are naturally occurring mixtures of sand or clay, water, fine silts, and bitumen. The oil sands extraction process consumes large volumes of water (i.e., *ca.* 3 barrels of fresh water for every 1 barrel of oil). Following the extraction of bitumen from the oil sands, a tailings slurry is produced that consists of oil sands process-affected water (OSPW), sand, silt, clay particles and trace quantities of unrecovered bitumen. This slurry is hydraulically transported to large containment facilities (i.e., open tailings ponds) that, in Alberta, currently occupy approximately 130 km^2 with 200 million litres of mature fine tailings produced each day. These vast storage facilities pose a risk to the environment, wildlife, and society.

There are many candidate technologies that could be applied to the treatment of OSPW. Advanced oxidation processes (AOPs) are particularly useful for degrading biologically toxic or non-degradable materials such as aromatics, pesticides, petroleum constituents, and volatile organic compounds in wastewater.

In this report, we investigate the use of advanced oxidation processes via photocatalysts based on nanoparticles. Silicon nanoparticles were specifically engineered for water remediation by making them water soluble and more potent towards contaminant removal. Si nanoparticles of different sizes and morphologies were investigated for model contaminant (methanol) removal in the presence of UV light. A medium pressure UV lamp was used for the purpose. Control experiments were also performed to ascertain the extent of remediation by the Si nanoparticles. Effect of methanol concentration, nanoparticle concentration and exposure time of UV were systematically studied to optimize the remediation parameters. Moreover, a cost effective and high yielding synthetic protocol was also developed for large scale synthesis of Si nanoparticles which is crucial for scale up. Quantum yield calculations were performed on different Si nanoparticles and compared with titanium dioxide (TiO_2), the most commonly proposed nanoparticle system.

2.1.5 *Community Structure and Bio-Prospecting in Oil Sands Tailings Ponds – Dr. Joel Dacks, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$58,000	Project started May 2012
2013/14	$0	Report will be released October 2014

The microbiology of oil sands tailing ponds is already an active area of research with studies showing that microbes are actively metabolizing organic constituents in the ponds. This echoes research on open ocean bioremediation of hydrocarbons by bacterial action. There is more to microbiology than bacteria, however. Microbial eukaryotes, or protists, represent the vast majority of non-bacterial life on earth, dwarfing the number of animal and plant species. Protists have been shown as crucial components of the microbial food web in naturally occurring and anthropogenically perturbed environments. Indeed, the dynamics of microbial eukaryotes including ciliates, heterotrophic flagellates and fungi have been shown to experimentally improve bioremediation rates of crude oil by modulating bacterial populations and improving carbon flow through the system. The protist community of the tailing ponds is, as yet, entirely unexplored.

This project will determine the community diversity and structure of microbial eukaryotes by analyzing DNA from tailings pond samples. Essentially, we will find out, for the first time, "who is there and in what numbers" in terms of microbial eukaryotes in the tailing ponds.

2.1.6 *Designer Biochar-Coke Mixtures to Remove Naphthenic Acids from Oil Sands Process-affected Water (OSPW) – Dr. Daniel Alessi, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$23,000	Project started February 2014 Report will be released November 2014

Oil sands process-affected water (OSPW) contains naphthenic acids (NAs) which pose significant risk to aquatic ecosystems and shallow freshwater aquifers. The goal of this pilot-scale study is to look at the effectiveness of mixtures of biochar and coke, as adsorptive treatment materials for the removal of NAs from OSPW. The two treatment materials are attractive for different reasons. Oil sands petroleum coke is a byproduct of the processing of oil sands, is abundantly available at mining sites and may prove a good adsorbent for certain types of NAs depending on its activation and solution (pH, water chemistry) conditions. Biochars are the byproducts of the carbonization and/or pyrolysis of many types of biomass, yielding a stable, high surface area, carbon rich product proven to be effective in the removal of metal contaminants and removal of a wide range organics, including chlorinated ethenes, PAHs, and other hydrophobic organic contaminants.

2.1.7 *Development of a Novel Engineered Bioprocess for Oil Sands Tailings Fines/Bitumen/Water Separation – Dr. Mohamed Gamal El-Din, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		

Year	Funding	Project Activity
2012/13		
2013/14	$35,000	Project started January 2014 Report will be released October 2014

The project will investigate a novel environmentally-friendly biotechnology that improves bitumen recovery, tailings dewatering and sedimentation through natural bioprocesses. The core element of the proposed technology is the microbial bioreactors that consist of the BioTiger™ multispecies consortium isolated from a century-old oil refinery in Europe. This bacterial consortium produces a variety of enzymes and metabolites (surfactants, solvents, and polymers) that provide ability to remediate recalcitrant polycyclic aromatic hydrocarbons (PAHs) and heavy metals, flocculate/coagulate clay fines and cations, and alter interfacial forces between bitumen, solids and water. Taking advantage of the engineered bioprocessing systems, BioTiger™ can thrive in extreme environments during bitumen and tailings processing, and maintain sufficiently microbial activity to remove hydrocarbons bound to solids in tailings, therefore, allowing settling and separation of solids.

An additional element of proposed technology is the use of bioreactors, to facilitate bitumen release, bitumen capture, and to control microbial activity. Three areas will be considered: the influence of local microbial activity on tailings capture; hydrocarbon separation/recovery and rheology within the viscous bitumen; and tailings process.

The objective of this project is to understand the bioprocess parameters and how they can be optimized. The principal project outcome will be a bioreactor design optimizing microbial and rheology conditions for efficient bitumen recovery and tailing separation.

2.1.8 *Development of Silicon-based Optofluidic Sensors for Environmental Monitoring – Dr. Ray DeCorby, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$12,000	Project started April 2012
2013/14	$0	Report released October 18, 2013 De Corby, R.G., 2013. Development of Silicon-Based Optofluidic Sensors for Oil Sands Environmental Monitoring. OSRIN Report No. TR-41. 19 pp. http://hdl.handle.net/10402/era.36936

This project was co-funded with the Canada School of Energy and Environment Ltd.

The oil sands industry in Alberta produces large volumes of process-affected water (PAW), which is known to contain heavy metals and organic compounds (such as naphthenic acids, naphthalene, phenanthrene, pyrene, etc.) that are toxic and hazardous to the environment. The industry has an ongoing need to improve the monitoring of concentrations and breakdown of these compounds. Currently, this is mainly accomplished by collecting samples for shipment to a laboratory for analysis. Portable and ideally distributed and real-time monitoring techniques would greatly improve efficiency and the base of knowledge with respect to these environmental concerns.

The principal aim of the project was to develop a prototype lab-on-a-chip (LOC) based sensor for optical detection of target molecules in PAW using spectrally resolved fluorescence detection. The proposed sensor would offer a high level of integration between the fluidic and optical components, potentially reducing the cost and complexity of the overall system while also improving the performance (sensitivity, signal to noise ratio (SNR), alignment tolerance, etc.). In the long term, such miniaturized sensors hold promise as low-cost, highly distributed environmental monitoring devices.

Most of the primary milestones of the project were successfully completed, as follows:

1. A silicon-based air-core waveguide technology was developed and optimized for the ultraviolet-visible wavelength band of interest. These waveguides employ low-loss TiO_2/SiO_2 Bragg reflectors deposited by sputtering deposition at the U of A nanoFab.

2. Tapered air-core waveguides were assembled and tested as visible-band micro-spectrometers. These micro-spectrometers provide resolution on the order of 1 nm over a 100 nm operational band (e.g., wavelengths in the 500 to 600 nm range), and offer compelling advantages for lab-on-a-chip and optofluidic microsystems.

3. Prototype sensing systems were developed, by combining the aforementioned micro-spectrometers with PDMS-based microfluidics. Fluorescence spectroscopy was successfully demonstrated for commercial dyes with fluorescence bands in the ~500 to 600 nm wavelength range.

At the time of writing, ongoing work is aimed at translating the operational band of these sensors to the ~400 to 500 nm wavelength range. This effort has been delayed by processing difficulties, but is expected to reach a successful conclusion in summer 2013. Further work is aimed at extending the operational range of the micro-spectrometers (e.g., 400 to 650 nm), by using more sophisticated multilayer designs. We hope that this work will enable the detection of native fluorescence from hydrocarbon molecules, including the multiplexed detection of multiple species, and intend to pursue this objective in the coming months.

2.1.9 *Engineered Biological Processes to Accelerate Oil Sands Tailings Consolidation and Improve Reuse Water Quality – Dr. Tong Yu, University of Alberta*

Year	Funding	Project Activity
2009/10	$150,000	Project started
2010/11	$0	Ongoing
2011/12	$30,000	Ongoing; additional funds for naphthenic acid analyses
2012/13	$0	Ongoing
2013/14	$0	Report will be released June 2014

Methanogenesis has been demonstrated to occur in oil sands mature fine tailings with improved fine tailings densification. While research is on-going as to the microbial processes occurring, there is no open public research to adapt engineered wastewater treatment technologies that exploit the microbially-mediated processes. This study will explore engineered microbially-activated water treatment to significantly accelerate oil sands tailings consolidation and improve quality of water produced from the treatment processes for reuse. The project will study a number of biological processes and engineering reactor types. The engineered biological processes will employ both suspended and attached microbial growth and both anaerobic and aerobic processes. In addition to determination of the parameters for the design and operation of these engineered reactors, additional measures for enhancement of the reactor performances will also be investigated. If successful, the proactive engineering approach could significantly shorten the time for water-solids separation, reduce the volume of tailings produced, and improve water quality for reuse. The long-term goal is to avoid production of mature fine tailings as we now know it. The knowledge and experience obtained from this study can also be used to better treat existing mature fine tailings.

2.1.10 *Expedited Oil Sands Tailings Consolidation Through Microbial Induced Calcite Precipitation – Dr. Yang Liu, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		

Year	Funding	Project Activity
2012/13		
2013/14	$25,000	Project started January 2014 Report will be released October 2014

Microbial-induced Calcite Precipitation (MICP) is a microbial catalyzed process that allows precipitation of carbonates with an excess of calcium ions to form calcite ($CaCO_3$) in situ. MICP is an emerging technique that has gained world-wide application in civil engineering practice. The process has been applied in many geotechnical projects for loose soil solidification and porous media cementation.

Under suitable conditions, the MICP process may be applied for precipitation of suspended fine particles in oil sands Mature Fine Tailings (MFT), consolidation of settled solids and dewatering MFT slurry by altering surface characteristics of particulate materials, reducing steric or electrostatic stabilizing effects among particles and precipitation of $CaCO_3$ on bacterium and solid surfaces. It should also be noted that, calcium and carbonate ions, the key sources required to MICP process of expeditious $CaCO_3$ precipitation and MFT settlement, are readily available in tailings ponds, which provides a unique opportunity to test the possibility of applying MICP for the consolidation of fine tailings. Calcite precipitation can also reduce released water salinity improving the quality of recycled water.

The overall objective of this study is to evaluate and optimize the MICP processes for MFT consolidation of several tailings sources with different properties.

2.1.11 *In-Situ Tailings Ozonation: A Combined Tailings Consolidation and Remediation Process – Dr. Yang Liu, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		

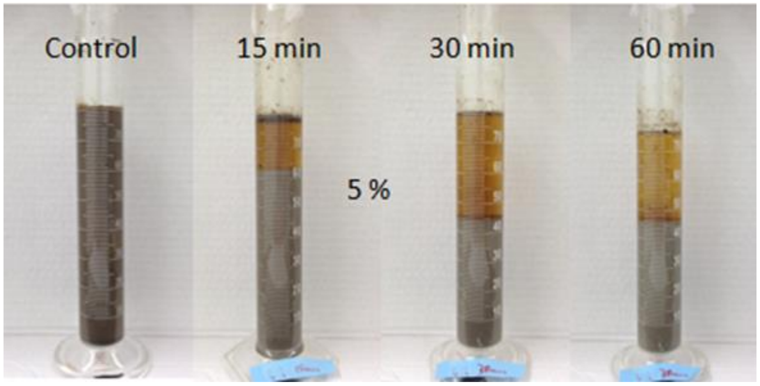
Year	Funding	Project Activity
2012/13	$44,000	Project started April 2012
2013/14	$0	Report released March 17, 2014 Liang, J., F. Tumpa, L.P. Estrada, M. Gamal El-Din and Y. Liu, 2014. Ozone-Assisted Settling of Diluted Oil Sands Mature Fine Tailings: A Mechanistic Study. Oil Sands Research and Information Network, University of Alberta, School of Energy and the Environment, Edmonton, Alberta. OSRIN Report No. TR-46. 43 pp. http://hdl.handle.net/10402/era.38226

This project was co-funded with the Canada School of Energy and Environment Ltd.

The accumulation of mature fine tailings (MFT) in tailings ponds with very slow natural consolidation rate has been a big concern for decades. Previous studies and current practices for tailings consolidation focus on the addition of various inorganic and organic additives to reduce MFT production and accumulation. It is highly desirable to develop more efficient and effective techniques for MFT consolidation to reduce the potential environmental impacts of oil sands tailings.

In this study, the performance and mechanisms of a novel ozone-assisted MFT dewatering method were evaluated. MFT with different solid contents were ozonated for 15, 30, and 60 minutes to determine the optimal ozonation treatment conditions for MFT consolidation. The volume and turbidity of released water, and the solids content of settled sludge (i.e., solids) were measured to evaluate the performance of ozone on MFT consolidation. MFT initial settling curves were developed by monitoring the change of the water and sludge interface positions over time. To investigate the surface interaction mechanisms involved in the process, major ions of MFT release water and the surface charge of MFT fine particles were characterized. Specifically, these parameters included pH, ion concentrations, acid extractable fraction (AEF) concentration of MFT release water, zeta potentials, and surface functional groups of fine particles. Additional experiments were performed to investigate the roles of pH and ion concentrations in ozone assisted MFT consolidation.

Our results showed that ozonation treatment effectively accelerated diluted MFT particle settling at all treatment conditions tested in this study. MFT quickly settled after short (15 minute) ozonation treatment, leaving clear brown water and compact settled sludge. The volume and turbidity of release water and the solids content of settled sludge were comparable at 1 wt% MFT under different ozonation times (15, 30 and 60 minutes). At 3 wt% and 5 wt% MFT, a longer ozonation time improved MFT settling. Therefore, we conclude that the ozonation time needed for MFT settling varied depending on the solids content of MFT suspensions.



Additional studies showed that the ozone-accelerated settling of MFT particles probably results from a change in MFT particle surface properties and the weakening of repulsive forces among fine particles through at least four mechanisms: (1) the desorption of stabilized organic matter on MFT surfaces, which reduces the steric or electrostatic stabilizing effects among fine particles; (2) the release of organic acids (such as oxalic and acetic acids) into the water, which decreases the pH of the MFT suspensions and neutralizes MFT surface charges; (3) ozone breakage of organometallic complexes in MFT, leading to the release of oxidized metal ions such as Fe^{2+}, Mn^{2+}, and Al^{3+} that can act as coagulants; and, (4) an increase in cations and carboxylic groups that facilitate the generation of metal humate complexes, leading to an accelerated precipitation of fine particles.

Compared to the chemical additives currently used or studied to accelerate MFT consolidation, ozone-based processes have several advantages: (1) The process is economical because even a low ozone dose appears to be sufficient to destabilize tailings fine particles; (2) The process is environmentally friendly because ozone decomposes rapidly; and (3) The excess ozone can decompose organic compounds in tailings and thus improve the water quality.

Despite the promise observed in the present study, a cost analysis and a life cycle analysis should be performed to determine the feasibility of this treatment process. The effectiveness of ozonation treatment for undiluted MFT settling should be evaluated. The toxicity of the release water should be evaluated to examine the environmental impact of the process. Additional research on the long-term impact of ozone-assisted MFT settling processes on MFT reclamation is also needed.

2.1.12 *Silicon Nanoparticle Membranes for Photocatalytic Oil Sands Process Water Treatment – Dr. Johnathan Veinot, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$25,000	Project started January 2014 Report will be released October 2014

OSRN funded a previous study that established surface modified silicon nanoparticles (Si NPs) as excellent photocatalysts with unprecedented quantum yields and yield factors when compared to status quo titanium dioxide (TiO_2)-based systems. The project demonstrated that Si NPs can rapidly degrade model contaminants (e.g., methanol) with high efficiency upon exposure to standard UV sources.

This project will expand the scope of the Si NP-based remediation in two ways: (1) Extend the scope of remediated contaminants to include more complex model compounds (i.e., cyclohexanoic acid) and authentic oil sands process-affected water (OSPW) in more complex media, and (2) develop proof-of-concept porous ceramic membranes based upon alumina, silica or zeolites (specific material to be determined) for OSPW remediation.

Photocatalytic membranes (PMs) are membranes that bear immobilized photocatalytic reaction sites that are frequently based upon nanomaterials. PMs are particularly attractive for water treatment because the photocatalytic reaction proceeds at the membrane surface while treated water is continuously discharged without the loss of photocatalyst particles. PMs are typically prepared from ceramics or polymers using various synthetic methods. However, ceramic membranes are preferred because they typically exhibit superior thermal properties, and are more chemically resistant.

2.1.13 *Standard Operating Procedures and Physical Properties of Oil Sands Naphthenic Acids – Dr. Haneef Mian, NAIT Applied Research Center for Oil Sands Sustainability*

Year	Funding	Project Activity
2009/10		
2010/11		

Year	Funding	Project Activity
2011/12		
2012/13		
2013/14	$50,000 committed	Project started March 2014 Report will be released November 2014

Naphthenic acids (NAs) are credited as the main Compound of Potential Concern (COPC) in oil sands process affected water (OSPW). Numerous papers have been written with the focus on identification and/or biochemical elimination of NAs in fresh or old OSPW, or in the environment surrounding oil sands operations.

Toxicity of OSPW has mostly been attributed to NAs, although small presence of PAHs or phenols can result in similar toxic effects. From a measurement and monitoring perspective it has increasingly become necessary to establish sampling and analytical procedures/protocols to quantitate NAs within oil sands OSPW. To establish such protocols, however, a thorough knowledge of physical behavior of NAs, rather than their types and subgroups, is required.

Prior research at the University of Alberta demonstrated that it was extremely important to handle OSPW samples in a way that would prevent losses due to sorption onto storage vessels, during storage in the freezer, or exposure to light. Those tests also demonstrated that processing of samples that included heating or just simple evaporation resulted in significant losses of NAs.

In light of the above, the NAIT Applied Research Center for Oil Sands Sustainability (NARCOSS) will develop a Standard Operating Procedure (SOP) and expand the scope by using both commercial and real NAs extracted from OSPW. A wider variety of test conditions, materials and processes will be utilized.

2.1.14 *Synthesis of Toxicological Behavior of Oil Sands Process-Affected Water Constituents – Dr. Mohamed Gamal El-Din, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$50,000	Project started January 2013
2013/14	$0	Report will be released May 2014

Oil sands process-affected water (OSPW) refers to the water that has been in contact with oil sands or released from tailings deposits and is primarily used for bitumen extraction. OSPW is a very complex mixture of suspended solids, salts, inorganic compounds, dissolved organic compounds, and trace metals. Despite the advances in analytical techniques, the complete characterization of OSPW is still unknown. OSPW contains thousands of organic compounds that have not been identified so far because of the complexity of the OSPW mixture and the variety of different structures of naphthenic acids (NAs), among other organics, present in OSPW. There are concerns about the environmental and human health impacts as a result of any possible future release of treated OSPW into the environment. NAs have been reported to cause both acute and chronic toxicity to a variety of organisms, including fish, amphibians, and mammals. To date, the principal toxic component(s) of OSPW towards test organisms have not yet been identified mainly due to the complexity of the organic fractions in OSPW. The complete characterization of OSPW and the knowledge about the fate of the OSPW constituents are indispensable requirements to assess the long-term cumulative effects of process-affected water on the receiving environment and to determine the most suitable remediation and management strategies for OSPW.

The main objective of this study is to conduct an extensive literature review of the existing basic theoretical and practical knowledge of the physical, chemical, biological, and eco-toxicological behavior of OSPW constituents, both inorganics and organics, for known individual compounds and/or classes of compounds. Any information on the potential biological impacts and the fate of these constituents will also be gathered.

The project will produce:

- A report containing all the gathered information and eventually, a review paper will be developed out of the report, for publication in a peer review journal. The report will contain: (1) physical, chemical, biological and eco-toxicological behavior of OSPW constituents, both inorganics and organics, for known individual compounds and/or classes of compounds; and (2) suggested levels of individual and/or classes of compounds at which there might be no adverse effects based on the literature, internationally accepted standards, etc. The report will also identify the knowledge gaps.
- A database containing all the gathered information in a categorized fashion and with dynamic links to the sources of material will be prepared. The database will be updated in the future on a regular basis by Dr. Gamal El-Din`s research group.

2.2 Regional Landscape Reclamation

This program focuses on providing the knowledge necessary to support development of regional reclamation targets as well as site- and mine-level objectives.

2.2.1 *A Framework for Wildlife Habitat Design for Oil Sands Mine Reclamation: Building Wildlife Communities from the Bottom Up – Dr. Brian Eaton, Alberta Innovates – Technology Futures*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$53,820	Project started October 2013 Report will be released November 2014

The current paradigm for wildlife habitat design in oil sands reclamation rests largely on the *field of dreams* hypothesis: build it, and they will come. However, many factors influence whether wildlife will recolonize reclaimed areas, and these factors operate at a range of spatial and temporal scales. It is generally assumed that establishing some vegetation structure will provide wildlife habitat; however, this is not the case, and wildlife have not recolonized reclaimed habitats as quickly or as completely as had been hoped.

Reclaiming wildlife abundance and biodiversity consistent with similar undisturbed habitats can be markedly enhanced by designing reclaimed wildlife habitat that incorporates ecological patterns and processes across spatial and temporal scales. Reclamation practitioners in the mineable oil sands have expressed a need for better guidance on wildlife habitat design and construction. Development of practical and cost-effective wildlife habitat designs that are based on ecological data and theory would achieve improved outcomes. This project is a first step toward addressing this need and will complement work underway by the Cumulative Environmental Management Association (CEMA).

A framework for wildlife habitat reclamation, supported by available science and professional judgment, will be developed. It will extend and expand on a recent review of existing empirical data and scientific knowledge on habitat-species relationships for wildlife that use aquatic habitats, with a focus on the boreal region of Alberta that was prepared for CEMA. The objective of the project is to address and build on the recommendations made in that review, and develop an overall research and implementation plan that will include the following:

- A framework for wildlife habitat design to promote and support successful recolonization/reintroduction of wildlife species into reclaimed landscapes;
- Landscape and landform scale wildlife habitat designs, design tools, and GIS evaluation tools; and,
- Wildlife habitat enhancement design and construction.

2.2.2 *A Tool for Adaptation Decision-Making in Oil Sands Reclamation Under Risk of Climate Change – Dr. Clive Welham, University of British Columbia*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$25,000	Project started October 2013 Report will be released November 2014

OSRIN, the Cumulative Environmental Management Association (CEMA) and Natural Resources Canada (NRCan) are funding a project to develop quantitative landscape-level reclamation planning tools for oil sands operators to assess climate change uncertainties and develop adaptation strategies to ensure successful reclamation of oil sands disturbances. A regionally applicable reclamation planning tool will improve consistency among operators and provide a means of assessing current best management practices.

This project will:

1. Improve the applicability of two established models that support adaptation decision-making within the context of oil sands reclamation: the state-and-transition simulation model (STSM) for reclamation planning developed for CEMA; and the FORECAST Climate forest ecosystem productivity model, that was used in a three-part OSRIN project to predict reclamation performance under various climate scenarios.
2. Develop a decision support tool (DST) by linking the STSM to the stand-level FORECAST Climate model.
3. Use the DST to evaluate reclamation best management practices in the oil sands sector in terms of climate-related risk exposure and then to inform adaptation and management planning within the context of climate change.
4. Produce a guidance document on how to implement the tools, interpret output, and assess the implications for reclamation principles and practices as reflective of an adaptive decision framework.

2.2.3 *Boreal Plant Species for Reclamation of Athabasca Oil Sands Disturbances – Ann Smreciu, Wildrose Consulting, Inc.*

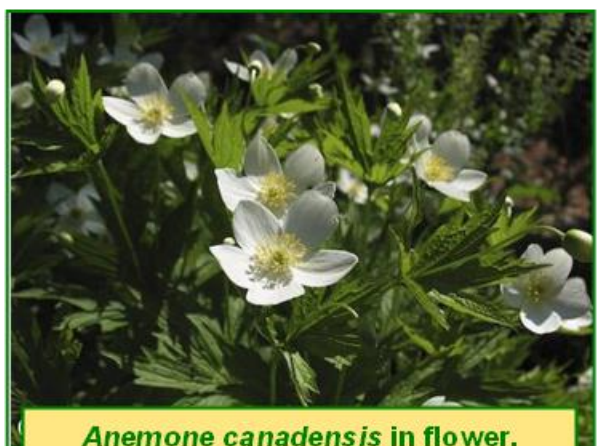
Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$15,964	Project started November 2012
2013/14	$24,704	Report released December 20, 2013 Smreciu, A., K. Gould and S. Wood, 2013. Boreal Plant Species for Reclamation of Athabasca Oil Sands Disturbances. OSRIN Report No. TR-44. 23 pp. plus appendices. http://hdl.handle.net/10402/era.37533 The individual species profiles have been posted to OSRIN's website at http://www.osrin.ualberta.ca/Resources/RevegSpeciesProfiles.aspx

Oil sands reclamation guidance documents prepared by the Cumulative Environmental Management Association and endorsed by the provincial government include lists of potential reclamation species and their characteristics (Alberta Environment 2008, 2010). This report consolidates and updates profiles for 98 of these species.

Each profile contains the following information (where applicable):

- Species Nomenclature – up-to-date scientific names and widely used common names along with plant family designations; common names should be used with caution as many distinct species have the same or similar common names and common names may vary by region
- Plant Description
  - Fruit
  - Seed
- Habitat and Distribution of the species locally and worldwide
  - Seral Stage
  - Soil
  - Distribution based on Moss (1983) unless otherwise noted.
- Phenology – particularly based on observations from north eastern Alberta

- Pollination mechanisms are described if known.
- Genetic Information (ploidy)
- Known Symbioses
- Seed Processing
  - Collection
  - Seed Weight
  - Harvest Dates
  - Cleaning
  - Storage Behaviour
  - Storage
  - Longevity
- Propagation – including seed and vegetative propagation
  - Natural Regeneration
  - Germination
  - Pre-treatments
  - Vegetative Propagation
- Greenhouse timelines for seedling production
- Aboriginal/Food Uses
  - Food
  - Medicinal
  - Other
- Wildlife/Forage Usage
- Reclamation Potential – with examples from oil sands reclamation studies where available
- Commercial Resources
  - Harvest Methods
  - Availability
  - Cultivars
  - Uses (other than the Aboriginal uses noted above)



***Anemone canadensis* in flower.**

- Notes – including comments on alternative names (genera and species names change with increasing knowledge of biology and genetics; caution should be used when consulting older references such as Budd and Best (1969) and Moss (1983) because of potential name changes since these were published)

Each profile is illustrated with photographs of the plant, flowers, fruit and/or seeds if available and line drawings are also included if available (Budd and Best (1969) is an excellent source for line drawings). References for the content are provided with each profile.

Although the original objective for the profiles was to inform decisions made by reclamation planners and practitioners in the oil sands and to promote the inclusion of these species in revegetation, the information has a much wider audience appeal. We continue to be inundated with requests for all types of species information from professionals in other industries as well as provincial, municipal and federal government agencies, nursery producers, aboriginal groups, researchers, archeologists, cultural anthropologists and ethno-botanists, wildlife biologists, foresters, range managers, horticulturalists, naturalists and the general public. At the November 25, 2013 OSRIN workshop *Future of Shrubs in Oil Sands Reclamation* participants noted a lack of awareness of, and in for many species the need for, the types of information contained in these species profiles.

This report is a valuable tool for those directly responsible for planning and executing reclamation in the oil sands as well as for other professionals involved in native plant work.

2.2.4 *Development of a Geomatics Monitoring Tool for Oil Sands Reclamation Monitoring – Dr. Karl Staenz, University of Lethbridge*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12	$50,000	Project started September 2011
2012/13	$0	Ongoing
2013/14	$0	Report will be released April 2014

OSRIN, Alberta Environment and Water, and TECTERRA are providing funding for this project. The project will support both oil sands reclamation monitoring and monitoring related to other forms of industrial land in Alberta. The proposed mapping/monitoring software system will fill a significant gap in monitoring reclamation success by offering a novel technology that can be implemented within Alberta Environment’s reclamation monitoring process. The software system will consist of newly developed algorithms in combination with existing ones, which will be adapted within the context of Alberta Environment's requirements. It will link the processing steps, including a spectral and radiometric normalization module, geometric rectification module, information extraction module, change detection module and results assembly module. The workflow for each type of processing is encapsulated within a dedicated job script that uses different software components including open source, commercial and in-house tools. The software system will provide the capabilities to produce indicators about vegetation condition using LiDAR and passive optical remote sensing technologies.

A report will be prepared for OSRIN providing information on:

- background and utility of remote sensing to assess disturbance and ecosystem recovery including aspects of vegetation succession, site productivity and ecosystem health
- introduction and rationale for study design and technology choices to monitor reclamation success at different scales (well sites, pipelines, coal mines, in situ oil sands, oil sands mines)
- results and recommended approaches

2.2.5 *Evaluating Use of Biochar for Oil Sands Reclamation – Derek MacKenzie, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$22,500	Project started February 2014 Report will be released November 2014

Biochar is the main persistent residue of fire and has been shown in the literature to influence soil biogeochemistry by stimulating nitrogen (N) cycling and microbial activity; possibly making it a 'legacy substrate.' Biochar can also contribute to soil carbon (C) sequestration as it is highly resistant to decomposition and can be stored deep in the soil profile for millennia. Using natural and man-made biochar, or other black C residues from oil sands mining (pet-coke), may simulate the recovery of soil processes after fire in the reclamation environment. However, no information is available on how biochar affects C and N mineralization in different boreal reclamation soils. In this project, bench-top incubations will examine the effect of biochar from natural (wildfire) and man-made (pyrolysis and pet-coke) sources on C and N mineralization in different soil-types typically used for oil sands reclamation.

2.2.6 *Factors Affecting Ecological Resilience of Reclaimed Oil Sands Uplands – Dr. Clive Welham, FORRx Consulting Inc.*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$29,800	Project started October 2012
2013/14	$0	Report released June 7, 2013 Welham, C., 2013. Factors Affecting Ecological Resilience of Reclaimed Oil Sands Uplands. OSRIN Report No. TR-34. 44 pp. http://hdl.handle.net/10402/era.31714

This literature review provides an understanding of ecological resilience as a concept to promote successful land reclamation in Alberta's mineable oil sands region by exploring four key issues.

Defining ecological resilience for boreal forest ecosystems, and assessing whether this definition can be applied to reclaimed oil sands landscapes or requires modification.

Resilience is an emergent property of ecosystems. It is an outcome of their inherent capacity for self-organization – the interaction between structure and process that leads to system development. Resilience constitutes the relative susceptibility of a given community to switches into alternative states as a result of the interaction between autogenic (competition, for example), allogenic (fire, wind, harvesting, and climate, as examples) and biogenic (insect epidemics, diseases, as examples) processes.

In principle, the concept of resilience could have considerable utility in designing reclamation systems for the oil sands. One application of the concept, the length of time that a system takes to return to equilibrium following perturbation (engineering resilience), is to use rates and patterns of development from the natural forested ecosystems in the region as a benchmark. Hence, the resilience of reclaimed systems would be evaluated with respect to the extent to which these patterns and rates are congruent. Several metrics in the current version of the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (indicator species and similarity indices, for example) suggest the utility of this approach has been recognized, though not necessarily within the context of resilience. Ecological resilience, the amount of perturbation a system can withstand before it moves into a different state, is pertinent because it constitutes the conceptual basis for designing practices that confer resilience in reclaimed ecosystems. Examples of these practices include minimizing chronic stress (acid deposition, for example), ensuring the rooting zone is conducive to plant establishment and productivity, and a functionally diverse community (both and above and belowground).

Resilience in natural and reclaimed ecosystems are mirror images. Applying the concept in natural systems is to pose the question, "how much can self-organizing capabilities be *perturbed* and still achieve desired outcomes"? In the case of reclamation the question becomes, "how much of the self-organization capabilities of a system must be *created* to achieve desired outcomes?"

Describing a range of ecological and anthropogenic disturbances a reclaimed oil sands upland site might experience

In terms of the ecological disturbances a reclaimed oil sands upland site might experience, these are fire, insects and pathogens, drought, wind, site dominance (invasion) by non-local species (native and non-native), and climate variability. Anthropogenic disturbances include erosion, issues associated with soil structure and related physical properties, salinity and sodicity, contaminants (bitumen, naphthenic acids), excessively high and low soil pH, and climate change.

Describing physical, chemical and biological characteristics of reclaimed upland sites that would confer resilience to the range of ecological and anthropogenic disturbances identified above

Three approaches are described for addressing the physical, chemical and biological characteristics (structure, composition, function) of reclaimed upland sites that would confer resilience to the range of ecological and anthropogenic disturbances identified above. From the general to the specific, these approaches focus on (a) general ecosystem attributes, (b) on functions that need to be maintained, and (c) attributes that confer resilience against specific perturbations or stressors.

Describing reclamation and management practices necessary to generate ecological resilience in oil sands upland landscapes

Managing for resilience is to implement reclamation practices and procedures that maximize the probability a given desired state will emerge or persist over the time period of interest. The underpinning of resilient ecosystems is a rooting zone conducive to plant establishment and productivity, with a functionally diverse community (both above and belowground) to maximize the potential that development will be maintained along desired trajectories. To create resilient ecosystems, management must focus on both mitigative and adaptive strategies. Mitigative actions confer resilience by eliminating or reducing exposure to chronic stresses (nitrogen and sulfur deposition or salt intrusion, for example). The adaptive approach focuses on traits that allow plant species to tolerate chronic stress or that predispose them to changes in the disturbance regime (fire or climate change, for example).

To measure resilience one needs to define the time scale over which a system is resilient, with the choice of scale dependent of the issue under investigation. In the case of reclamation, relevant scales could vary from several decades (the time period over which a reclamation certificate might be awarded) to a century, or more. In principle, resilience could be predicted from models that incorporate the critical processes driving ecosystem productivity and community development but in practice, this is likely not practical due to data limitations. Nevertheless, models can play a useful role in identifying indicators that may signal ecosystem resilience and vulnerability.

The review identifies the top three characteristics that confer ecological resilience in oil sand upland landscapes. These are

1. Species diversity, with a particular emphasis on functional diversity
2. A quality rooting zone
3. Minimize nitrogen and sulfur deposition.

Designing and assessing resilience in reclaimed oil sands ecosystems will likely require a combination of empirical measures informed by model outputs. Models can be used to project the long-term consequences of a given reclamation prescription while specifying which particular ecosystem attributes are relevant to a monitoring program and the time frame when the requirements for a reclamation certificate could be met. In that respect, model outputs, ecological measures, and checklists which identify management activities, decisions and interventions should be developed collectively, and comprise a decision support system that can address the question 'Does this reclaimed upland site possess or is capable of developing, characteristics of a resilient ecosystem?'

2.2.7 *Future of Shrubs in Oil Sands Reclamation Workshop – Oil Sands Research and Information Network*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$2,574	Workshop held November 25, 2013 Report released January 13, 2013 Oil Sands Research and Information Network, 2013. Future of Shrubs in Oil Sands Reclamation Workshop. OSRIN Report No. TR-43. 71 pp. http://hdl.handle.net/10402/era.37440

A group of 48 people from government, academia, consultants and the oil sands and plant production industries gathered on November 25, 2013 to discuss the current state of knowledge about shrubs and their current and future use in oil sands reclamation. The Workshop was organized around four key topics:

- Session 1: Regulatory Requirements and Policies
- Session 2: Current State of Knowledge
- Session 3: Knowledge Gaps and Policy Needs
- Session 4: Next Steps

In Session 1, participants noted a number of regulatory requirements and policies that support shrub use. However, a far larger list of impediments was identified. These can be roughly divided into two main themes: (1) impediments to efficient and effective use of shrubs; and (2) impediments to effective ecological use of shrubs.

In Session 2, participants said we know *which* species to use but maybe not *why* – current planting density rules require x stems/ha and species doesn't matter so there is no incentive for diversity or selection of species attributes that could be exploited to enhance reclamation success. Participants felt collection, storage, growing and seeding issues are understood for 50% to 75% of species but some are very difficult to germinate and grow. They noted that shrubs are not produced commercially in the volumes needed, and this will be even more of a problem when reclamation ramps up in terms of area per year. Participants felt that we have a relatively good understanding of shrub reclamation for *regular reclamation sites* (no inhibiting factors) for both early and late successional species but we are not as advanced for early successional stages in challenging sites and have little knowledge and experience with late successional species in challenging materials. Finally there was the sense that there are lots of people and sources of information available. Much of the information is in grey literature; the comment was made that we also need to recognize *grey knowledge* – the knowledge (generally operational experience of growers and company reclamation staff) that isn't even written down. A better mechanism is needed to access and share the information.

In Session 3, participants provided a long list of characteristics that could be used to determine successful shrub reclamation, but noted that success was seen to be determined by the goal, policy, scale, or timeframe. A long list of research needs was identified, mostly grouped into categories such as: (1) synthesis of existing knowledge, (2) developing *how to* guidance, (3) developing and improving seed management practices, and (4) monitoring outplanting results. In terms of scale of research needed, lab and greenhouse tests could be used to pinpoint the causes of problems observed in the field, while landscape level studies are required to understand the interaction with environmental variables (soils, climate, other species) and provide proof of concept / ability / success. Participants provided some context for revising policies and then provided specific changes that are required to improve efficiency and effectiveness of shrub reclamation.

In Session 4, participants suggested that a *shrub research roadmap* be developed (an alternative for a broader revegetation roadmap was also suggested). The roadmap would begin with a compilation of existing knowledge which would lead to development of an Action Plan. A team would have to be established to steer development of the roadmap and to secure funding; similarly a home for the project would be required – COSIA, OSRIN or CEMA were suggested as potential homes.

Some key projects suggested to be included in the Action Plan are:

- A gap analysis (flowing from the compilation of existing knowledge)
- Recommendation to government of policy changes necessary to support effective and efficient use of shrubs for reclamation
- Confirmation of reclamation goals and criteria relative to shrubs to allow for focused research and development work
- Retrospective analysis of existing reclaimed sites
- Best Management Practices for shrub use (collection, propagule management, deployment)
- An evaluation of the feasibility, location(s) and costs of seed orchards / stoolbeds
- A shrub monitoring program, including protocols that all operators will follow to ensure a common set of data
- Establishing a system to share existing and developing knowledge and coordinate future work
- Inventory of experts who can / will share knowledge
- Identification of training needs, and development and deployment of training programs
- Review the role of the Oil Sands Vegetation Cooperative, particularly if the rules governing plant and seed collection and movement are changed

2.2.8 *Oil Sands Terrestrial Habitat and Risk Modeling for Disturbance and Reclamation – Dr. Clive Welham, FORRx Consulting Inc.*

Year	Funding	Project Activity
2009/10	$104,000	Phase I start April 2009
2010/11	$70,000	Phase I completed; report released November 30, 2010 Welham, C., 2010. Oil Sands Terrestrial Habitat and Risk Modeling for Disturbance and Reclamation – Phase I Report. OSRIN Report No. TR-8. 109 pp. http://hdl.handle.net/10402/era.22567 Start Phase II

Year	Funding	Project Activity
2011/12	$87,500	Phase II completed; report released November 5, 2011 Welham, C. and B. Seely, 2011. Oil Sands Terrestrial Habitat and Risk Modelling for Disturbance and Reclamation – Phase II Report. OSRIN Report No. TR-15. 93 pp. http://hdl.handle.net/10402/era.24547 Start Phase III
2012/13	$0	Phase III ongoing
2013/14	$0	Phase III completed; report released June 27, 2013 Welham, C. and B. Seely, 2013. Oil Sands Terrestrial Habitat and Risk Modelling for Disturbance and Reclamation: The Impact of Climate Change on Tree Regeneration and Productivity – Phase III Report. OSRIN Report No. TR-36. 65 pp. http://hdl.handle.net/10402/era.31900

The overall objective of this project is to develop a framework that integrates risk management and strategic decision-making to evaluate the impact of disturbance (natural and industrial) on ecosystem products and services, and on habitat availability for terrestrial species in Alberta's Lower Athabasca planning region. This also includes an evaluation of conservation, and reclamation activities associated with oil sands development both at the lease and regional levels.

The project has been conducted in phases. Each phase is sequential such that its results and conclusions represented the foundation for subsequent work. This report summarizes activities conducted as part of Phase III, consisting of the following: (1) Model projections of tree regeneration under climate change on actual oil sands reclamation materials, and (2) A comprehensive model analysis of the risks to ecosystem productivity from climate change as a consequence of the impact of moisture stress on tree mortality.

Model projections of plant regeneration under climate change on actual oil sands reclamation materials

Six climate change scenarios for Alberta were selected that encompassed a range of predictions in future temperature and precipitation change. The tree and climate assessment (TACA) model was calibrated for reclaimed sites that varied in their soil moisture regimes (from xeric to subhygric) and three natural sites, High Level (subxeric), Calling Lake (mesic), and Fort Chipewyan (subhygric). TACA was used to predict regeneration probabilities on these sites for jack pine, aspen, and white spruce, in conjunction with the climate change scenarios.

A comparison between the natural sites and their corresponding moisture regimes on reclaimed sites showed little quantitative difference in predicted regeneration for High Level. Regeneration probabilities for Calling Lake and Fort Chipewyan, however, were lower than the corresponding moisture regimes on reclaimed sites (mesic and subhygric, respectively). The differences in the Calling Lake and Fort Chipewyan sites are largely a consequence of the fact that percolation rates were higher on natural versus the reclaimed sites. These results highlight the importance of assessing soil moisture regime using a variety of metrics.

Across climate periods, regeneration in this northern region was generally improved in jack pine and aspen because of the warming temperatures and in some scenarios, increases in annual precipitation, predicted under climate change. This was particularly the case in the wetter moisture regimes (submesic to subhygric) than the subxeric and xeric regimes, probably due to increases in growing season moisture deficits in the latter. Aspen regeneration from suckering had substantially greater predicted success than aspen regenerated from seed. Predicted trends in white spruce regeneration were in sharp contrast to the other species. Spruce regeneration was reduced substantially in future periods to the point where it was predicted to be less than 20% in subxeric and xeric moisture regimes. These results indicate that from a reclamation perspective, the impact of climate change on regeneration requires careful consideration of the tree species and its associated moisture regime.

Soil moisture regime generated pronounced differences in regeneration probabilities both within a given future time period, and across periods. As might be expected, regeneration was highest in the wettest moisture regime and declined as the moisture regime became drier. However, the difference between moisture regimes within a given time period also increased over time for all species. From the perspective of reclamation outcomes, these results suggest soil prescriptions should be developed and/or applied which generate moisture regimes that are submesic and wetter. Drier regimes (subxeric and xeric) appear to introduce a substantially greater average risk that revegetation success in a future climate may be compromised through regeneration failure.

How well might current reclamation prescriptions be expected to perform under climate change with respect to regeneration success? Overall, results suggest that no single set of prescriptions will be adequate to maintain the current suite of tree species common to the region. Nevertheless, current one-layer prescriptions seem adequate for maintaining pine and aspen regeneration, at least on average. Practices governing spruce, in contrast, should transition over the next several decades towards an emphasis on constructing two-layer prescriptions only, in an effort to minimize the risk of inadequate regeneration. This has important implications for mass balance calculations associated with soil amendment materials. In short, drier sites should focus on pine and possible aspen regeneration, and spruce on wetter sites.

For a risk management perspective, reclamation practices that generate the two wettest moisture regimes (mesic and subhygric) are most likely to result in successful outcomes, at least through the 2050s. Drier moisture regimes can have lower regeneration probabilities but results were often highly inconsistent across the climate scenarios; constructing covers that generate drier moisture regimes thus entails considerably more risk of inadequate regeneration. Although regeneration was high in the 2080s, in many moisture regimes uncertainty in model predictions was also high. However, because of this extended time frame, modifying current reclamation practices or planting prescriptions to mitigate this risk is not warranted. Taken together, results emphasize the point that the climate will continue to change and highlight the necessity for ongoing investment in this type of analysis to facilitate the process of continuous learning that can form the basis for adaptive management.

Analysis of risks to ecosystem productivity from climate change using FORECAST Climate

Drought is anticipated to be an increasingly limiting factor for plant productivity and survival in the Fort McMurray region. Regional climate data indicate that this trend has already begun with patterns of growing season moisture deficits increasing since the 1960s.

A new drought mortality function was developed and implemented within FORECAST Climate. In contrast to the threshold mortality approach employed in previous analyses, the new continuous function simulates drought mortality using a two-year running average of a species-specific moisture stress as a predictor of annual mortality. The 2-year running average is designed to capture the compounding effect of consecutive dry years. The amplitude of the function curve was fitted to historical climate data for each species so that mortality rates were consistent with empirical observations of actual mortality events. Two different mortality curves (low and high) were simulated for each tree species to explore the sensitivity of the model to assumptions regarding tree susceptibility to drought stress. To simulate the effects of a changing climate, five climate-change and associated emissions scenarios were utilized, and one scenario representing the historical climate regime. Simulations were conducted for ecosites dominated by jack pine (ecosite a1), aspen (d1), and white spruce (d3).

Jack pine showed very little mortality under the historical climate regime at either index of drought sensitivity. In the case of aspen (ecosite d1) and spruce (ecosite d3), historical drought-related mortality events were not uncommon in the simulations, consistent with empirical data.

Projections of future climate conditions generated mixed results in terms of mortality, depending on the emission scenario. With the exception of A1FI, all other emission scenarios triggered mortality below historical conditions at various points in the simulation. Given that primary productivity at high latitudes is temperature limited, a warming climate thus has the potential to improve survival under some circumstances, though not necessarily on sites where drought is already problematic. Within a given species, the highest mortality almost always occurred under the A1FI emissions scenario. Though A1FI was considered a pessimistic outcome in terms of CO_2 emissions, current evidence indicates that, in fact, it may be close to reality.

Pine and spruce appear generally robust to drought conditions at least over the next several decades, regardless of the climate regime. Mortality tended to increase thereafter as the simulation years got longer (i.e., later in the century). In absolute terms, pine is projected to have the lowest overall drought-related mortality (the exception being mortality under the A1FI emission scenario) while spruce is projected to have the highest mortality, particularly late in the century. Aspen showed a small increase in mortality over time beginning in the first decade of the simulations.

The Climate Response Index (CRI) is a metric calculated in FORECAST Climate that integrates the impact of temperature and precipitation. Similarly, the decomposition response index (DRI) links decomposition (i.e., nutrient availability) to temperature and moisture. Both indices thus serve as proxy measures of climate-related growth conditions. The A1FI scenario, by example, always generated higher CRI and DRI values than occur under historical climate conditions. Nevertheless, assumptions regarding tree sensitivity to drought stress had a significant impact on volume production and its relation to climate change. When the mortality rate was low (i.e., species were robust to moisture stress), volume production under climate change always exceeded that projected under the historical climate regime. If species are less tolerant of moisture stress (i.e., the mortality rate function was high) climate change will have a negative impact on stand-level productivity later in the century, though how much depends on the particular species and a given emissions scenario.

Significant reductions in productive capacity from climate-driven mortality threaten to destabilize ecosystems beyond their resilient capacity. One feature that would serve to promote resilience by avoiding drought stress is to ensure the rooting zone possesses adequate available water holding capacity. This can be accomplished by ensuring capping materials have higher organic matter content, are not predominantly coarse textured, and of sufficient depth. Layering of capping materials to generate textural breaks also serves to increase moisture storage, at least temporarily. Another important feature in creating resilience is to properly match tree species to their edatopic position. Aspen, and particularly spruce, occupy wetter positions on the edatopic grid. For the most part, these species are more prone to drought than pine. It is important then to ensure they are not planted on sites that may become marginal in terms of available moisture. In that respect, another consideration is to actively modify planting prescriptions in anticipation of a drier climate. Conceptually, this approach is based on the assumption a given soil moisture regime will for all intents and purposes transition to a drier edatopic position with further climate warming.

In Europe, mitigative activities against climate change at the stand level are focusing on the regeneration phase. This is because a well-established plant population will have better prospects for surviving the vagaries of future (and largely uncertain) climate conditions and the fact little can be done to affect survival in stands that are mature today. Hence, one approach is to increase the genetic or species diversity in seeded and planted stands. This can be accomplished with traditional tree-breeding programs (termed provenance trials) though molecular genetics techniques have been developed that significantly reduce the time and resources needed for the selection process. Other possible silvicultural measures to promote establishment and maintenance of desired communities include moving up the planting season to take advantage of earlier spring conditions, using containerized stock to reduce drought risk, enhancing drought tolerance by employing seedlings with higher root:shoot ratios, and reduced spacing to increase recovery after dry periods.

Quantitative models, such as TACA and FORECAST Climate, can project forest responses and the goods and services those forests provide to a range of future climate change scenarios. Predictions made using these climate-based models need to inform best management practices and can be coupled to the continuous learning that forms the basis of an adaptive management process, thereby reducing the uncertainty associated with reclamation decisions.

The report closes with conclusions and associated recommendations, and a final section describing potential next steps.

2.2.9 *Potential Impacts of Beavers on Oil Sands Reclamation Success – Brian Eaton, Alberta Innovates - Technology Futures*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12	$24,500	Project started June 2011
2012/13	$0	Ongoing
2013/14	$0	Report released August 15, 2013 Eaton, B., T. Muhly, J. Fisher and S-L. Chai, 2013. Potential Impacts of Beaver on Oil Sands Reclamation Success – an Analysis of Available Literature. OSRIN Report No. TR-37. 65 pp. http://hdl.handle.net/10402/era.32764

The North American beaver (*Castor canadensis*) is a large semi-aquatic rodent that has played a central role in shaping the Canadian boreal landscape, and colonial Canadian history. Exploitation of North American beaver populations to supply the European hat industry spurred the westward expansion of European explorers and traders into the continental interior. With intensive unregulated harvest, beavers virtually disappeared across much of their range; though populations are recovering, the species is only about 10% as abundant as it was before the fur trade took its toll. As a result, much of the recent ecological history of the Canadian boreal forest has occurred in the absence of this keystone ecosystem engineer, and the ecological state that we perceive as natural is in many regions quite different than it was a century ago.

Beavers, while playing an important role in structuring streams and wetlands by altering vegetation communities and water flow patterns, may also affect human structures. In the mineable oil sands region of northeastern Alberta, much of the landscape will be impacted by mining. Mine sites will have to be reclaimed, and those reclaimed sites will consist of engineered landforms (including water bodies and waterways); the long-term hydrological and ecological function of those sites may be vulnerable to beaver activity. In an effort to determine if approaches exist that could manage the risk of beavers colonizing and negatively impacting reclaimed sites, we performed an extensive literature search and analysis. Our objective was to examine characteristics of beaver ecology that might potentially impact reclamation plans, and to identify possible methods to mitigate those impacts. We also include information on traditional use, historical abundance, and current abundance in the mineable oil sands region to provide important historical and ecological context. Although beavers inhabit a range of aquatic habitats, the focus of our review is on watercourses that could be dammed by beavers. Of the aquatic habitats which will be constructed during reclamation, these systems are probably the most vulnerable to impacts from beaver activity. Note, however, that inlet and outflow streams from lakes may be vulnerable to beaver activity, which could impact the performance of constructed lakes in a variety of ways.

Beavers alter stream form and function, create wetlands, and change vegetation patterns. The most important predictor of beaver occurrence is stream gradient, with low gradients being associated with higher beaver activity. Stream depth and width, soil drainage, and stream substrate are also important. Although beavers may also respond to vegetation factors, such as tree or shrub species and density, hydrological factors are more important predictors of beaver occupancy of a site.

The primary forage preferred by beavers includes deciduous tree and shrub species. Aspen (*Populous tremuloides*) is the species most preferred by beaver, and is a common component of reclamation plantings and natural recolonization of reclamation sites in the oil sands region. Beavers are central-place foragers, meaning foraging is concentrated around a central home base. They typically harvest deciduous trees and shrubs up to 60 m or more from the water, but most harvest occurs less than 30 to 40 m from the water's edge. Predation (and predation risk) restricts the size of beavers' foraging areas, and may also regulate their population size. Management of wolf populations to limit predation on caribou in northeastern Alberta may have significant indirect effects on beaver abundance and distribution by releasing them from predation pressure.

The boreal forest ecosystem of Canada evolved over millennia with the beaver as a keystone species altering hydrological systems, creating vast areas of wetlands and beaver meadows, changing vegetation communities and modifying geomorphological processes. Reclamation of functional ecosystems in the region must therefore integrate beavers and their engineered structures. The most ecologically- and cost-effective approach is to design reclaimed areas with the objective of including beaver, but directing beaver activity to areas away from vulnerable reclamation structures. Ecological function requires the presence of beaver on the post-reclamation landscape, and the species is important to First Nations peoples and other trappers in the area. Although beaver abundance can be expected to increase in the area after reclamation, their activities will result in the replacement of existing vegetation with species of lower nutritional quality to beaver (conifer trees). This is expected to result in a beaver population decline and then stabilization over time. With beavers an integral component of the functional landscape, it is important to create "beaver exclusion zones" to ensure that the impact of the species is diverted to areas where beaver activity does not damage reclamation structures.

There are very few existing studies of beaver impacts to reclaimed areas. Incorporating ecologically-based strategies for keeping beaver density low in sensitive areas at the outset of a reclamation project, and then monitoring the effectiveness of that strategy, is the best advice that can be derived from our analysis of the existing literature. Beavers could be discouraged from settling at a site by creating streams with steep gradients (>10%) that are wide and deep enough to ensure substantial water flows, are armoured with rock or cobble bottoms, and are bordered by coniferous tree species and/or grass and sedge species. Trees should be planted at high density to prevent growth of shrubs and deciduous trees in the understory, as these are preferred by beaver. Deciduous vegetation should not be planted during reclamation near sites where beavers are to be excluded, and it may be necessary to remove existing deciduous trees and shrubs and replace them with conifers, grasses and sedges in these areas. Although planting specific types of vegetation may be used to discourage beavers from settling a certain area in the short term, natural succession could eventually result in other vegetation communities attractive to beavers. Therefore, unless long-term vegetation management is envisioned, reclamation plans should not rely on using vegetation to dissuade beaver activity in sensitive areas alone, though this approach may be used in combination with other methods, especially in the few decades immediately following reclamation. Note that the goal is to plan for a maintenance-free environment in which ongoing beaver control is unnecessary, and the use of multiple strategies in tandem to guide beaver activity is more likely to achieve this goal.

More active, maintenance-intensive techniques could be used to limit the damage caused by beaver dams to sensitive areas. These techniques include lethal (e.g., kill trapping or shooting) and nonlethal (e.g., relocation) methods to reduce population density. However, these methods require constant effort, and can be expensive. Another approach is to manipulate water flow through existing beaver dams using pipe drainage systems; this allows the beaver dam to stay in place, while reducing the risk that it will trap enough water to be dangerous if the dam should fail. Again, however, these drainage systems require long-term maintenance.

One approach may be more sustainable in the long term and require less maintenance: minimize or maximize water flow through engineered channels, as beavers are less likely to use very low-flow and very high-flow watercourses. Note that beavers may still affect these channels, especially when population densities are high or other habitat is unavailable; however, the probability of beavers affecting very low-flow or high-flow channels is lower than for watercourses with more moderate flows. Creating several dispersed low-flow channels may make an area less desirable to beavers compared to a single moderate flow channel. Similarly, multiple low- to moderate-flow channels could be created, with some having characteristics that attract beavers (“decoys”) and others that do not (“exclusions”), allowing water flow to continue through some channels even in the presence of beavers. “Pre-dam” fences can be installed on decoy streams to create a structure to encourage beavers to occupy a site where damage is not a concern. Discharge could be controlled by regulating water flow through exclusion streams that are not dammed, or by installing flow devices though dams on decoy streams. A similar approach might be used on culverts that allow streams to flow beneath roadways; flow devices could be used proactively at these sites, and/or oversized culverts could be installed to allow maintenance of the natural width of the stream channel and reduce the noise of running water, which attracts beaver activity.

Although many different landforms on the reclaimed landscape may be vulnerable to beaver activity, a few are considered critical areas where beaver impacts must be controlled, including the outlets of lakes, side-hill drainage systems, and constructed peatlands. Beaver activity at the outlet of constructed lakes could cause instability in containment structures, negatively affect littoral and riparian zones around the lake, and increase the probability of catastrophic outburst flooding. Damming of side-hill drainage systems could cause stream avulsion and routing of water flow into a new pathway not engineered for a stream, causing increased erosion. Flooding of constructed peatlands could convert them to open-water systems, thereby subverting their intended ecological function. These critical areas should be protected from beaver activities, while other areas should be designed to accommodate this important species.

In practice, several different approaches – tailored to specific situations and landforms – will be necessary to develop and implement plans that accommodate beavers as a part of the post-reclamation landscape. As so few data exist to inform effective reclamation in the presence of beavers, all of the methods we suggest carry an unknown degree of risk. This risk can be decreased in the future by adapting methods based on observed effectiveness. We recommend implementing a research and adaptive management program on the influence of beavers on reclamation within the context of oil sands reclamation in northeast Alberta. Lack of existing information, particularly in northeast Alberta, illustrates the need to implement research that documents the positive and negative influence of beavers on reclamation sites and tests alternative methods to prevent negative and support positive influences. Otherwise reclamation strategies will be ad-hoc and tenuous, with a mixed success rate. A research and monitoring program would ideally contribute to a standardized strategic approach to mitigating negative beaver influences on reclamation of watercourses in the oil sands region.

Beavers are, to a certain extent, unpredictable. No single approach will guarantee that a site will be unaffected by beaver activity. We suggest that multiple management approaches be simultaneously implemented at sites that are particularly vulnerable or critical for the functioning of the reclaimed landscape (e.g., outlet streams from constructed lakes). It is impossible to predict all eventualities, as the character of the reclaimed landscape will change over time due to successional processes, fire, global climate change, and resource extraction. The information we provide is the best available based on limited current knowledge, and provides the best chance for minimizing risk while accommodating this keystone species. Ultimately, the presence of beavers on reclaimed oil sands leases will increase biodiversity, enhance ecosystem goods and services, and assist in developing ecosystems that are consistent with natural systems in the boreal region.

2.2.10 *Preliminary Watershed Hydrology and Chemical Export Model for Reclaimed Oil Sands Sites – Dr. Gordon Putz, University of Saskatchewan*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12	$70,000	Project started September 2011
2012/13	$0	Ongoing
2013/14	$0	Report released October 3, 2013 Watson, B.M. and G. Putz, 2013. Preliminary Watershed Hydrology Model for Reclaimed Oil Sands Sites. OSRIN Report No. TR-39. 193 pp. http://hdl.handle.net/10402/era.34250

The main goal of this research project was to take the first steps towards development of an integrated hydrologic and water quality model to support oil sands mine reclamation efforts in Alberta. The model utilized in this study is a modified version of the Soil and Water Assessment Tool (SWAT), which has been called $SWAT_{BF}$. This report provides a detailed description of the $SWAT_{BF}$ model, a list of the key parameters (and their ranges) utilized in $SWAT_{BF}$ and the availability of data sets in the oil sands geographic area to set up and operate $SWAT_{BF}$. Furthermore, an application of the model to five regional watersheds and an industrial reclaimed watershed is described and discussed. Recommendations for further research directions are also provided.

Currently there are few high quality data sets available for reclaimed watersheds in the oil sands region that can be used to stringently test the performance of $SWAT_{BF}$ or similar models. Although several good quality data sets do exist in the oil sands region, they were not available to the authors of this report for testing purposes. The model was applied to five regional watersheds in the oil sands geographic area for the period 1976 to 1993. The overall performance of the model for predicting the long-term water yield from these regional watersheds was deemed to be satisfactory based upon statistical comparisons of predicted and measured streamflow. The modelling results for the regional watersheds were encouraging and demonstrate that $SWAT_{BF}$ has the potential to be utilized as a practical tool for conducting hydrologic assessments in the oil sands geographic area. It may also be suitable for water quality modelling purposes following future data collection.

Limited data sets were available from the Wapisiw Lookout reclaimed watershed, which was constructed by Suncor Energy Inc. Using runoff estimates derived from changes in the water level of the Wapisiw wetland, it was possible to test calibrate $SWAT_{BF}$ for 2011 and 2012. The results achieved for 2011 were deemed to be good. It is recommended that further testing of the model on reclaimed watersheds be undertaken using high quality data sets. The data that are scheduled to be collected from the Wapisiw Lookout watershed by the Forest Watershed and Riparian Disturbance (FORWARD) Project will be used to further improve the performance of $SWAT_{BF}$ and extend its capabilities to chemical transport. However, it will take several years to collect the data sets necessary to further develop $SWAT_{BF}$ into a useful management tool to support reclamation efforts in the oil sands. Several proprietary data sets exist in the oil sands that, if made available, may expedite this research effort. The authors have made several recommendations on how future research efforts should proceed to aid and further develop the capabilities of $SWAT_{BF}$ for reclaimed watersheds in the oil sands region.

2.2.11 *Review of Alternative Seed Packaging and Delivery Systems for Oil Sands Reclamation – Dr. Amanda Schoonmaker, Northern Alberta Institute of Technology*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$13,200 committed	Project started March 2014 Report will be released November 2014

In addition to common seeding and planting methods that are widely used in agriculture and forestry, a variety of alternative methods have been proposed and tested for enhancing seedling establishment and performance. These methods can be roughly divided into two categories: those that enhance individual seeds (e.g., fertilizer or mycorrhizal coatings), and those that package multiple seeds with a variety of beneficial materials to facilitate germination and early establishment of the seed.

The Canadian Forest Service (CFS) is working with Canada's Oil Sands Innovation Alliance (COSIA) to develop and test a specific seed packaging method for use in the oil sands. This project will support the CFS/COSIA work by reviewing existing literature on alternative seed packaging and delivery systems to identify the pros and cons of various alternative systems and provide a basis against which to judge the relative merits of the CFS/COSIA system.

2.2.12 *Soil Microbiology as an Index of Oil Sands Reclamation Success – Dr. Sylvie Mercier Quideau, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$25,000	Project started April 2013 Report will be released April 2014

Following surface mining, reclamation efforts involve the reconstruction of entire landforms. Salvaged surface soils and near-surface geological materials are placed as a new soil cover on the reconstructed landscapes. The goal of reclamation in Alberta is to achieve land capability equivalent to that which existed prior to disturbance. Soil parameters that are currently used to examine reclamation success include chemical and physical attributes known to limit plant growth. Although it is essential to the functioning of these reconstructed ecosystems, soil biology is not yet included as part of the assessment.

This project will characterize for the first time the biodiversity of soil mesofaunal populations on natural and reclaimed oil sands sites. Specifically, we will focus on soil protists, as these bacteria-consuming organisms are responsible for much of the nutrient fluxes through the soil food web and have crucial downstream impact on animal and plant biodiversity. Protists are used as indicators of soil quality, allowing comparisons with other environments. A direct outcome of this project will be the definition of a sampling and analytical strategy to quantify protist diversity, and to examine how protists could be integrated as biological indicators in oil sands reconstructed soils.

2.2.13 *What Constitutes Success for LFH Salvage and Replacement – Dr. Anne Naeth, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11	$0	Project started February 2011
2011/12	$25,000	Ongoing

Year	Funding	Project Activity
2012/13	$0	Ongoing
2013/14	$0	Report released June 20, 2013 Naeth, M.A., S.R. Wilkinson, D.D. Mackenzie, H.A. Archibald and C.B. Powter, 2013. Potential of LFH Mineral Soil Mixes for Land Reclamation in Alberta. Oil Sands Research and Information Network, University of Alberta, School of Energy and the Environment, Edmonton, Alberta. OSRIN Report No. TR-35. 64 pp. http://hdl.handle.net/10402/era.31855

LFH salvaged with small amounts of upper horizon mineral soil for land reclamation (hereafter LFH mineral soil mix) has proven to be an important source of seeds and vegetative propagules for forest plant communities. Until recently in Canada, LFH mineral soil mix was not selectively salvaged from upland forest sites prior to disturbance and was mainly incorporated with deeper mineral soil horizons or subsoil as part of conventional salvage and placement practices. The Alberta government is beginning to require oil sands and mountain and foothills coal mines to salvage and store this material separately from underlying mineral soil and subsoil for use in reclamation. The potential of LFH as a source of native propagules for revegetation of disturbed landscapes and a source of organic matter and nutrients in soil reclamation has not been widely tested. This report summarizes available literature on potential use of LFH material in Alberta and provides an analysis of the current state of knowledge and future directions.

Although donor soil seed banks have been successfully used as a revegetation technique on mine sites and land disturbances in other ecosystems for some time, only recently has research been conducted using forest LFH for mine revegetation in Alberta. Most of this research has been conducted on a small scale with few operational scale studies and a rigorous experimental approach is often lacking. Currently there are only a few peer reviewed publications on the use of LFH as a propagule source or reclamation soil in Canada.

Recent research shows LFH mineral soil mix is a good source of propagules for native and woody species that are not readily available commercially or by wild collection. Most plants in LFH mineral soil mix establish from seed and resultant communities have greater plant cover, more upland species and fewer non-native species than with traditional peat mineral soil mix used in oil sands mines. Stockpiling before placement reduces seed viability and species diversity, thus direct placement is recommended although stockpiling still results in more diverse and abundant plant communities than peat mineral soil mix. Placement depth has greater effect on plant community development than salvage depth. Thresholds for salvage and placement have not been determined and are dependent on donor soil texture, ecosite, topography, forest type and substrate placed on.

Besides using LFH mineral soil mix to revegetate disturbed landscapes, it can be used to improve soil quality. Compared to conventional peat mineral soil mixes in the oil sands, LFH mineral soil mix has a texture and pH more similar to natural forest and provides greater available phosphorus and potassium. Soil microbial activity and diversity is also greater which may lead to a more productive and resilient plant community in the long term.

Recent research on LFH mineral soil mix for forest reclamation has led to development of regulatory requirements. Short term research results (< 10 years) clearly show benefits of LFH mineral soil mix for reclamation. However, whether short term effects will persist with time and lead to a more natural, diverse and sustainable plant community than conventional reclamation techniques is unknown. Enhanced soil properties and native regeneration strongly suggest reclaimed communities are on a trajectory towards the structure and function of self-sustaining natural forest. By researching a few key operational and ecological questions, benefits of LFH mineral soil mix can be maximized and ongoing reclamation costs reduced.

2.3 Monitoring Ecosystem Impacts

This program focuses on components of a comprehensive, robust system in Alberta to monitor the effects of oil sands mining operations on ecosystem health – a system that is scientifically sound and has the confidence of the general public.

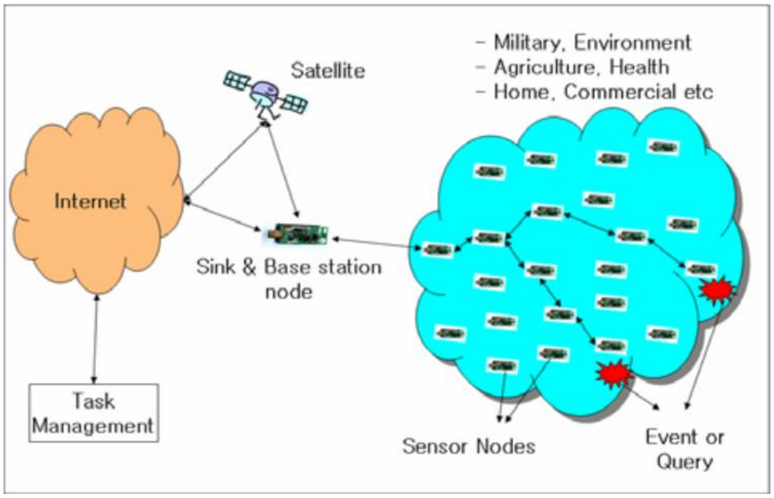
2.3.1 *An Evaluation of Wireless Sensor Networks and their Potential Implementation to Monitor Environmental Variables at Oil Sands Sites – Dr. Arturo Sanchez-Azofeifa, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$25,000	Project started December 2012
2013/14	$0	Report will be released May 2014

Wireless sensor networks are emerging as standards for environmental monitoring for their flexibility to install, operate and also because they provide levels of information at spatial scales not available with common environmental monitoring systems. This project will provide OSRIN with a comprehensive report on:

- Current status of the technology in terms of sensor development, field deployment and data analysis approaches based on all available literature since 1998 (1998 is selected since this year is the first which mentions wireless sensing technologies in the scientific literature).   It is estimated that there are between 50 to 80 scientific papers published in several areas: sensor design, sensor implementation, cyber-infrastructure, and visualization. Journals range from pure ecological journals to more technology driven such as IEEE journals.

- Implementation of cyber-infrastructure efforts to monitor, visualize and analyze information from wireless sensor networks, and linkages to metadata generation.
- Economic costs associated to the implementation of wireless sensor networks in oil sands regions.
- Opportunities and limitations associated to the implementation of wireless sensor networks for environmental monitoring.



2.3.2 *A Rapid Solution for Screening and Quantifying Targeted and Non-Targeted Analytes in Oil Sands Process Water and Natural Waters in the Athabasca Region – Dr. Jonathan Martin, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$60,000	Project started October 2012
2013/14	$0	Report released January 23, 2014 Pereira, A.S. and J.W. Martin, 2014. On-Line Solid Phase Extraction – HPLC – Orbitrap Mass Spectrometry for Screening and Quantifying Targeted and Non-Targeted Analytes in Oil Sands Process-Affected Water and Natural Waters in the Athabasca Oil Sands Region. OSRIN Report No. TR-45. 33 pp. http://hdl.handle.net/10402/era.37793

In response to mounting evidence of local environmental contamination around the Alberta oil sands industry, the Alberta Environmental Monitoring Panel announced a new *world class environmental monitoring program* for the Alberta oil sands region in early 2011, and a new monitoring system is now being delivered jointly by the Government of Canada and the Government of Alberta. This new program involves much more frequent sampling of water at many locations around oil sands activity. However, a particular challenge remains that there are currently no proven or validated analytical methods for characterizing the highly complex mixture of organic compounds in bitumen-impacted waters which meet requirements for qualitative and quantitative accuracy, sensitivity, precision, and high throughput.

To address this need, an on-line solid phase extraction (SPE) technique was developed for oil sands process-affected water (OSPW), and for natural surface and groundwater samples in the Athabasca oil sands region. The on-line SPE method was connected directly to a high pressure liquid chromatography – Orbitrap mass spectrometry (SPE-HPLC-Orbitrap MS) instrumental system, allowing comprehensive profiling of thousands of dissolved organic compounds, and quantitative analysis of naphthenic acids (NAs), with only 5 mL of a natural water sample. The new method improves upon existing methods by reducing sample volume requirements, eliminating sample preparation time, reducing the possibility of contamination, and increasing the accuracy and precision without sacrificing chromatographic performance, method sensitivity, or method quantitative quality.

The new method is anticipated to be useful for high-throughput environmental water monitoring for purposes of current or future environmental compliance by industry, or for forensic source elucidation by monitoring programs and researchers. The method requires a small investment in equipment to setup, but can pay for itself in terms of cost (e.g., solvents and disposable SPEs), and time savings (cost of technician's time in manual solid phase extraction or other extraction step), not to mention the more precise and higher quality data that are resultant. Considering the capital cost of any HPLC-ultra-high resolution mass spectrometer system (e.g., minimum $600k), it is the opinion of the authors that the minor additional cost of on-line solid phase extraction can be well justified for Provincial and/or Federal water monitoring around oil sands development.

2.3.3 *Assessment of Air Quality Remote Sensing Technology for Alberta's Oil Sands Region – Dr. Zaher Hashisho, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$26,000	Project start July 2013 Report will be released April 2014

Production of Alberta's oil sands generates emissions, including nitrogen (NO_2) and sulphur oxides (SO_2), carbon monoxide (CO), and particulate matter. Additionally, the region has other anthropogenic sources such as non-oil sands industries, and natural emissions such as forest fires. The fire frequency at high latitudes (>55° N), is expected to increase as a result of global warming which is accompanied by increased dryness and temperature. Air monitoring is needed to quantify the contribution of different emissions sources. Several studies have been conducted to understand the impact of the oil sands projects on air quality over Alberta using ground-based measurements. However, these data are limited in spatial coverage as they reflect local air quality and cannot provide information about the overall regional air quality. A complementary approach to ground-based measurements is satellite-based monitoring which can provide large spatial and vertical coverage and allow monitoring of local and regional air quality. Remote sensing can fill in areas where there are data gaps, both horizontally and vertically.

The objectives of this study are:

- To conduct a literature review on available satellite remote sensing technologies, their capabilities and the feasibility of using these technologies to monitor the air quality over Alberta oil sands region.
- To study the impact of major sources (oil sand, biomass burning and transportation) on carbon monoxide levels over Alberta through the intensive use of satellite, meteorology and ground studies.

2.3.4 *Characterizing the Organic Composition of Snow and Surface Water Across the Athabasca Region – Phase 2 – Dr. Jean Birks, Alberta Innovates – Technology Futures*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$68,000	Project started January 2014 Report will be released August 2014

In 2012, OSRIN funded Alberta Innovates Technology Futures to conduct a pilot project using existing data from Alberta Environment and Sustainable Resource Development and Regional Aquatic Monitoring Program on PAH distributions in snow and surface water. They also conducted ultra-high resolution analysis of the dissolved organic composition using Electrospray Ionization Fourier Transform Ion Cyclotron Mass Spectrometry. Both analytical techniques allowed the researchers to investigate the potential transfer of organics present in the snowpack to surface water bodies across the region.

The overall objective of the Phase 2 project is to characterize the composition of organics present in additional snow and surface waters and to see if similarities and/or differences in the composition of organics present in snow, rivers or lakes can be used to identify linkages or potential sources. The Phase 2 project will include a similar comparison of the composition of organics present in snow and surface water as was conducted in Phase 1, but will be based on a more spatially and temporally comprehensive set of samples collected over the 2012 and 2013 and will more fully investigate spatial and species variations within the snow organic composition.

The snow data for Phase 2 will come from 45 samples distributed over the Athabasca oil sands region compared to the 7 samples used in Phase 1. The surface water samples will include monthly samples from 17 sampling locations over a 12-month period in Phase 2 instead of only the 5 month open water period included in Phase 1.

2.3.5 *Metrics for Assessing Fisheries Productivity of Oil Sands Compensation Lakes – Dr. Mark Poesch, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$25,000	Project started February 2014 Report will be released November 2014

Recent changes to the federal *Fisheries Act* (circa 2012), have drastically altered the way in which industry needs to offset fisheries habitat losses. Habitat compensation remains a key component of the *Fisheries Act*, but only when there is a Commercial, Recreational or Aboriginal (CRA) fishery present. When habitat that is deemed vital for CRA fisheries is destroyed; mitigation and offsets are required to ensure No Net Loss in fisheries productivity. With the ongoing and expanding production in Canada's oil sands area, the creation of reservoirs/lakes (i.e., compensation lakes) has provided a new avenue for offsetting such losses, and presents opportunities for ecological restoration. However, the development of compensation lakes remains in its infancy and many questions and challenges remain for how to develop robust lakes for sustainable and long-term fisheries compensation.

This project will compare different metrics of fisheries productivity and productive capacity to provide both researchers and industry a contemporary toolbox for implementing offsets related to the loss of CRA fisheries and their habitats.

2.3.6 *Modeling and Assessing the Impact of Oil Sands Contaminants on Aquatic Food Webs – Dr. Mark Lewis, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$25,000	Project started January 2014 Report will be released October 2014

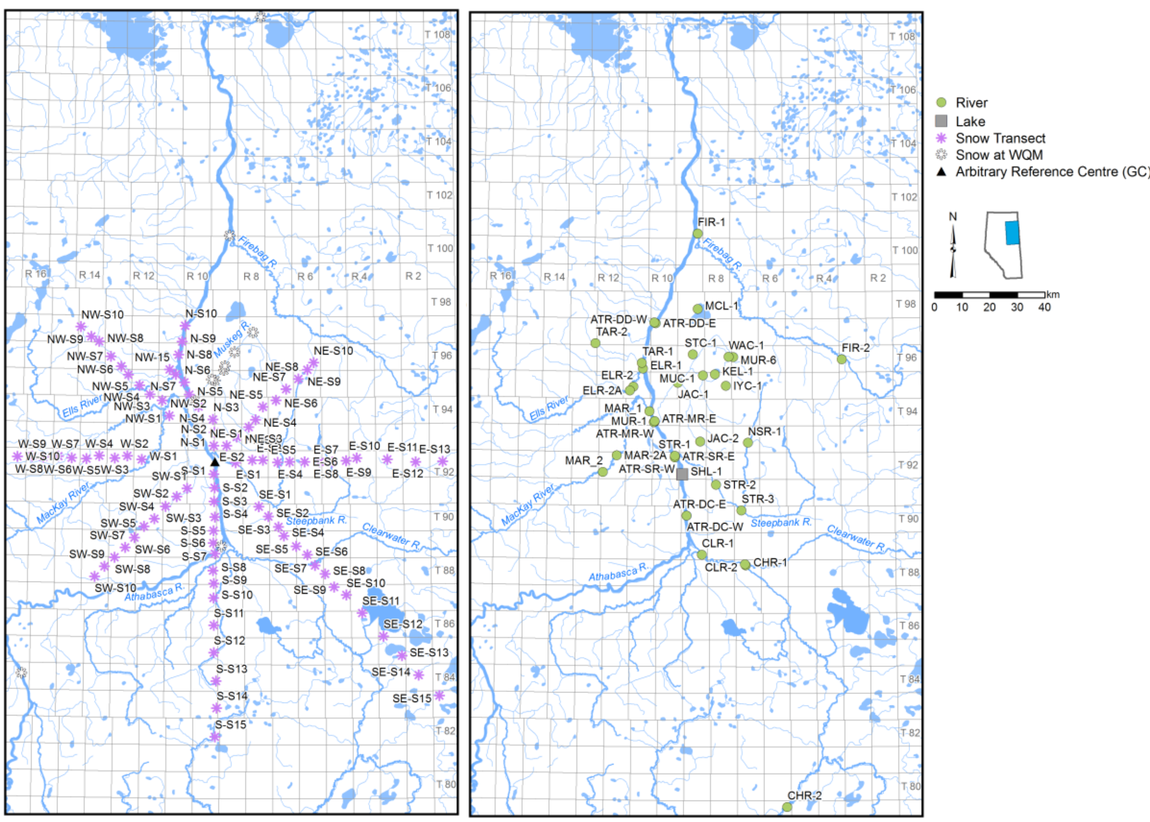
The goal of this project is to quantify the impact of environmental contaminants on a variety of aquatic organisms within the oil sands area of northeast Alberta. A new mathematical model that allows incorporation and evaluation of the flow of contaminants through aquatic trophic interactions into aquatic ecosystems will be developed. It will be an extension of existing collaborative work between the University of Alberta and Alberta Environment and Sustainable Resource Development that studied contaminant toxicity in aquatic species and effects on species abundance at a single trophic level. Individual-level doses for a variety of contaminants will then be estimated to assess the risk to individuals as well as to populations. Development and testing of this model will be a significant step towards providing effective decision-making tools to support development of water quality criteria for aquatic organisms for priority chemicals.

2.3.7 *Organic Footprint of Atmospheric Deposits: Snow and Surface Water Fingerprinting Across the Athabasca Region – Dr. Jean Birks, Alberta Innovates – Technology Futures*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12	$0	Project started March 2012

Year	Funding	Project Activity
2012/13	$60,600	Ongoing
2013/14	$0	Report released October 10, 2013 Birks, S.J., Y. Yi, S. Cho, J.J. Gibson and R. Hazewinkel, 2013. Characterizing the Organic Composition of Snow and Surface Water in the Athabasca Region. OSRIN Report No. TR-40. 62 pp. http://hdl.handle.net/10402/era.36643

This pilot study was conducted by Alberta Innovates – Technology Futures (AITF) to characterize the composition of organics present in snow and surface waters in the Athabasca Oil Sands Region (AOSR) with the goal of identifying whether atmospherically-derived organics present in snow are a significant contributor to the organics detected in rivers and lakes in the region. This study is divided into two parts, each describing a different approach to characterizing the organics present in snow and surface waters. In Part 1, we interpret existing polycyclic aromatic hydrocarbon (PAH) concentration data, collected from various monitoring programs in 2011, to compare the composition of PAHs in snow and surface waters across the AOSR. In Part 2, we interpret new ultra-high resolution mass spectrometry analyses of snow and surface water samples collected in 2012 to compare the dissolved polar organics present in snow and surface waters in the Athabasca Oil Sands region (AOSR).



The first approach applied in this study uses existing data from snow, river and lake monitoring programs conducted during 2011 which measured total (dissolved + particulate) PAH concentrations in snow and surface waters in the region. The 2011 dataset includes total (dissolved + particulate) concentrations for 34 parent and alkylated PAH species for 105 snow, 272 Athabasca River and tributary, and 3 lake samples. These data were compiled so that the composition of PAHs in the Athabasca River, its tributaries and a small number of lakes could be compared with that of snowmelt. The snow data show compositional differences between the PAHs present in snow sampled from areas closest to oil sands activities (i.e., near-field sites) and from more distant (i.e., far-field) snow sampling locations. Despite large concentration variations in snow along geographic gradients, the composition of PAHs are found to be similar among near-field sites, but change significantly at far-field sites. Both the near- and far-field snow samples have PAH compositions that are different from the PAHs present in the Athabasca River, its tributaries and lakes. Compositional differences in PAH assemblages are also evident between tributaries and the Athabasca River. PAH concentrations in rivers are found to vary seasonally, with peak concentrations observed in July 2011 when Athabasca River levels were at their highest. However, the composition of PAHs present in July 2011 do not resemble the composition of PAHs identified in snow, suggesting that direct transfer of PAHs accumulated on snow from atmospheric deposition to Athabasca River and its tributaries in the area is not a major source of PAHs present in surface waters. The timing of peak PAH concentrations in rivers, which coincides with a high flow period during freshet, does suggest that snowmelt may contribute indirectly to increases in PAH concentrations due to processes such as increased catchment runoff, erosion of stream channels, and snowmelt-induced groundwater inputs during this dynamic hydrologic period.

The second approach applied in this study uses Electrospray Ionization Fourier Transform Mass Spectrometry (ESI-FTICR MS) to characterize the dissolved polar organic composition of snow and surface water samples provided by various Alberta Environment and Sustainable Resource Development (AESRD) programs conducted in 2012. The 2012 samples analyzed by ESI-FTICR MS include 7 snow samples, 73 Athabasca River and tributary samples, and 6 lake samples. This profiling method identified thousands of dissolved polar compounds including the acidic organic components in negatively charged ESI(-) mode, and basic components in positively-charged ESI(+) mode. Although based on a limited number of samples, the organic profiles obtained for the snow samples in ESI(-) mode show compositional differences in the dissolved organics present in snow sampled from sites closest to oil sands activities (<5 km) and those sampled from more distant locations. There are also very significant compositional differences between the dissolved polar organics present in snow and surface waters in the AOSR. The composition of dissolved organics present in the Athabasca River upstream of the AOSR (i.e., Athabasca River at Athabasca) are found to be different from samples obtained from downstream sites in the vicinity of AOSR (i.e., Athabasca River at Fort McMurray and Athabasca River at Firebag confluence). The upstream Athabasca River sites tend to share some compositional similarities with far-field snow deposition, while the downstream Athabasca River sites are more similar to local tributaries. This contrast likely indicates shifts in the relative importance of regional snowmelt versus local inputs from small tributaries.

The results of these two separate approaches, which characterized different components of the organics present in snow and surface waters in the AOSR, leads to some similar conclusions. Both show compositional differences between the organics present in the snowpack near the centre of oil sands activities compared with more far-field locations and between the Athabasca River and its tributaries. The compositional differences between organics present in snow and those sampled in surface waters in the region suggest that even though the spring freshet is a period when elevated PAHs have been found in the Athabasca River the organics released directly from snow are not the dominant inputs during this peak discharge. These compositional differences may be useful tools for differentiating air-borne vs. water-borne organics away from the AOSR. The two methods used show the usefulness of PAH composition (i.e., relative concentrations of PAHs) and polar organic profiling in differentiating sources of organics in the region. The role of potential transformations of PAH and ESI-FTICR MS composition profiles during spring melt and during interactions along typical surface and subsurface flowpaths within wetland-dominated catchment areas typical of the region remains to be better understood.

2.3.8 *Wild Plant and Soil Sampling in Support of Oil Sands Contaminant Load Assessment – Dr. Cindy Jardine, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$50,000	Project started August 2012
2013/14	$3,425 returned (unspent)	Report will be released May 2014

Wild plant and soil samples will be collected in the mineable oil sands region, with an emphasis on the area around Fort McKay, and analyzed for metal and polycyclic aromatic hydrocarbon concentrations. The data will be used as input into a separate project on environmental health risk assessment that will focus on chemical exposures from multiple media and sources. A report will be prepared that explains how environmental samples related to consumption of country foods fit into the overall Human Health Risk Assessment process and the issues related to their sampling and analysis.

2.4 Increasing Awareness

This program aims to increase awareness of OSRIN and oil sands issues through an active website presence (www.osrin.ualberta.ca), sponsoring oil sands related conferences, digitizing historical information and publication of OSRIN research results, sponsoring oil sands related conferences, digitizing historical information and publication of OSRIN research results.

OSRIN provides support to conferences and other venues to ensure that there are opportunities for practitioners to access oil sands information.

In 2012/13 we changed the way we account for these sponsorship expenditures:

- Where a conference is focused primarily on one of OSRIN's other research program areas we account for the expenditure in that program area (for example the 3rd International Oil Sands Tailings Conference is accounted for in the Tailings Reclamation program).
- Where a conference is more general in nature, or covers more than one of OSRIN's research program areas it is accounted for in the Increasing Awareness program (for example the RemTech 2012 Conference). Rather than group these together into one lump sum we will report each event sponsorship as a separate entry in this report.

2.4.1 *Digitizing Historical Research Project Reports*

OSRIN staff have digitized historical oil sands related government-sponsored research work from the Alberta Oil Sands Environmental Research Program (access all 217 reports or access list of digitized reports) and the Reclamation Research Technical Advisory Committee (access all 41 reports and two conference papers or access list of digitized reports) and placed them on the University of Alberta's Education & Research Archive website to make information more readily accessible to stakeholders. These reports provide context and, in the case of the AOSERP reports considerable baseline information, to help stakeholders appreciate the depth and breadth of research undertaken since the mid-1970s to understand oil sands impacts and develop appropriate mitigation. Other Government of Alberta reports are also being digitized to provide additional context (access all 112 reports or access list of digitized reports).

Year	Funding	Project Activity
2009/10		
2010/11	$334	Begin digitizing and posting reports
2011/12	$1,717	Ongoing digitization work
2012/13	$1,393	Ongoing digitization work
2013/14	$1,387	Ongoing digitization work

OSRIN appreciates the significant assistance from the University of Alberta Libraries and the submissions of digitized versions of reports from Environment Canada, Alberta Government Libraries (Great West Life branch), Pedocan Land Evaluation and Millennium EMS Solutions. OSRIN also appreciates receiving permission from Alberta Agriculture and Rural Development for digitization of a series of 1970's reports and Alberta Health for digitization of 10 reports from 1968 to 2000.

2.4.2 *COSIA Oil Sands Water Conference and Workshops 2014*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$1,000	Conference held March 2014 in Edmonton

2.4.3 *Tailings and Mine Waste 2013 Conference Sponsorship*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$3,750	Sponsor conference
2013/14	$0	Conference held November 3-6, 2013 in Banff

2.4.4 *University of Alberta Oil Sands Student Delegation Sponsorship*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$1,500	Sponsorship to provide educational opportunities for students
2013/14	$2,000	Sponsorship to provide educational opportunities for students

The University of Alberta Oil Sands Student Delegation (OSD) is a student organization that exists to provide an annual trip to Fort McMurray for student leaders from the University of Alberta.

Due to the University's proximity and unique relationship with Alberta's oil sands, we students are in a privileged position to take a leadership role in developing solutions. The OSD was conceived to achieve this, by facilitating deeper understanding among students regarding the oil sands and issues related to its development through a bias-balanced presentation of information. In this trip, students can tour development facilities, assess technical features, and expose themselves to the various stakeholders' perspectives on oil sands development. The trip will be supplemented with on campus information sessions approximately two weeks prior to the trip, as well as forums and events that will share the trip's experiences with the wider community.

The five values of OSD, neutrality, quality, credibility, networking and education, inform every level of decision making. In light of the escalating and increasingly polarized debates, the bias-balanced and interdisciplinary approach of OSD is of vital importance to the discussion around oil sands development. Our long term vision is to increase the number of students attending this trip, and to encourage and assist other schools in Alberta in developing oil sands delegations.

2.4.5 *WaterTech 2013 Conference Sponsorship*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$2,287	Sponsor conference
2013/14	$0	Conference held April 10-12, 2013 in Banff and featured oil-sands specific sessions.

2.5 Social, Economic and Regulatory

This program seeks to identify social, economic and regulatory issues that may affect environmental management of oil sands and to evaluate the effectiveness of environmental management in addressing social, economic and regulatory issues.

2.5.1 *Oil Sands Then and Now: How the Dialogue has Changed – Janice Paskey, Mount Royal University*

Year	Funding	Project Activity
2009/10		
2010/11		

Year	Funding	Project Activity
2011/12		
2012/13	$32,430	Project started October 2012
2013/14	$0	Report released August 22, 2013 Paskey, J., G. Steward and A. Williams, 2013. The Alberta Oil Sands Then and Now: An Investigation of the Economic, Environmental and Social Discourses Across Four Decades. OSRIN Report No. TR-38. 108 pp. http://hdl.handle.net/10402/era.32845

A detailed study of dozens of documents pertaining to the Alberta oil sands produced by the Alberta government over the past 40 years shows the government's perspective regarding this vast resource has undergone a major shift.

In the 1970s and early 1980s, the Alberta government initiated detailed studies and scientific investigations to better determine oil sands policy. By the mid-1990s documents suggest the government had abandoned that role in favour of promotion and marketing of the oil sands.

It is quite clear from government documents produced in the 1970s that most of the economic, environmental, and social impacts associated with rapid expansion of oil sands operations (often referred to as tar sands in the 1970s) were anticipated. Various studies and surveys were also undertaken by the government of the day to determine how to avoid these negative impacts.

For example, a 1973 Alberta Environment report – *An Environmental Study of the Athabasca Tar Sands* – states: "The disposal of tailings from the hot water extraction process represents the most imminent environmental constraint to the future expansion of this recovery method."

Documents reviewed suggest that at the time the Alberta government saw itself as being primarily responsible for further development of the oil sands. To this end, the government invested millions of dollars in the Alberta Oil Sands Technology and Research Authority (AOSTRA) to kick start expansion. AOSTRA initiated and funded research into technological innovation for the extraction of bitumen. Another government agency – Alberta Oil Sands Environmental Research Program (AOSERP) – investigated social conditions for people living near oil sands plants and environmental impacts such as air emissions and tailings ponds.

By the mid-1980s the Alberta government had pulled back from this direct kind of involvement with oil sands development. And even though much research into environmental and social impacts had been carried out it was put on the back burner in favour of more immediate economic benefits.

This study also examined documents pertaining to the oil sands produced by industry, academia, non-governmental organizations, and the news media over the past 40 years during which time oil sands operations expanded from two to seven oil sands mining projects, 26 commercial in situ projects approved, in addition to about 130 primary recovery projects and 12 experimental schemes.

The study revealed that public discourse about the oil sands has shifted from one that was primarily focused on the economic benefits of oil sands development to a conversation that involves a multiplicity of issues and voices.

Economic signifiers such as job creation, royalty revenues, foreign investment, and markets are still key when it comes to talking about the oil sands. But in the last 10 to 15 years, global issues such as climate change, indigenous rights, pollution of the air and major waterways, and sustainability have become embedded in the discourse about the oil sands. Nowadays, the oil sands are talked about as if they are an arena in which key players and issues vie for attention.

The entry of other voices into the discourse about the oil sands has also affected Canada's dialogue with the United States regarding oil exports. Whereas the United States was once discussed as the prime customer that must be satisfied at all costs, now governments and industry talk about the U.S. as a riskier market and seek to export the oil to China, India and other emerging markets as well.

There are some significant language choices that stand out in the media, particularly the distinction between "tar sands" and "oil sands." It has been suggested in media coverage that supporters for the development of this resource use the label "oil sands", whereas critics deploy "tar sands". While this claim rings true, in the media sample reviewed it becomes evident that "tar sands" was used during the 1980s and 1990s in a completely neutral way, simply in reference to the "Athabasca Tar Sands." "Tar sands" became a more negative term only when it is associated with vivid descriptors such as being a "monster" that "needs to be fed", or as the "black stain of Canada", or simply talked about as something "dirty", "sticky", "gooey", or "oozing." These types of expressions are most often used by Aboriginal sources, environmentalists, political figures (members of the opposition), and sometimes journalists themselves. These stakeholders deploy such terms when they want to criticize the development of this resource. In the sample of articles examined, it was not until 2008 when the environmental action group Environmental Defence published *Canada's Toxic Tar Sands: The Most Destructive Project On Earth* that these types of negative add-ons started to appear.

All of the documents examined in the study were in English, as were the news articles. This is an admitted limitation as we do not capture dialogue in francophone Canada. Most of the documents collected and analyzed for this report came from a database established by the Cumulative Environmental Management Association (CEMA), a collaborative organization based in Fort McMurray, Alberta that includes representatives from government, industry, academia, First Nations, civic and community organizations, and environmental groups. Other documents were collected from university, government, industry and NGO libraries and databases. The news articles were collected from two databases – CBCA Complete and Canadian Newsstand.

Discourse about the oil sands is one of the most important conversations occurring in Canada and abroad. The deeper we can delve into that conversation, the more we can come to understand all the complexities, risks, and rewards that this vast resource presents to Albertans, Canadians and the world.

2.5.2 *Review of Environmental Responsibility for Oil Sands Developments under Federal Legislation – Dr. Michael Howlett, Simon Fraser University*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13	$32,430	Project started October 2012
2013/14	$0	Report released May 27, 2013 Howlett, M. and J. Craft, 2013. Application of Federal Legislation to Alberta's Mineable Oil Sands. OSRIN Report No. TR-33. 94 pp. http://hdl.handle.net/10402/era.31627

This report examines the Government of Canada's legislation that may impact oil sands environmental management in Alberta. It focuses on the evolution, and current state of, pertinent federal legislative Acts in the environmental, natural resource, and energy policy sectors. As detailed below, five Acts form the core of the review. A limited number of additional Acts, policies, and Canada-Alberta agreements are examined given their direct applicability to oil sands activity. In particular, the report focuses on descriptively setting out the implications and potential impacts stemming from recent legislative changes spurred by the passage of the 2011 and 2012 federal 'omnibus' budget implementation bills (Bills C-38 and C-45, respectively). These bills not only amended a large existing suite of legislation in the environmental, energy, and natural resources sectors, they also created *new* legislation with direct implications for oil sands environmental management. This report reviews and assesses these changes.

The five Acts that form the core of this examination are: the *Fisheries Act (FA, 1985)*, the *Canadian Environmental Protection Act* (CEPA, 1999), the *Canadian Environmental Assessment Act* (CEAA, 1999 and 2012), the *Species at Risk Act* (SARA, 2002), and the *Migratory Birds Convention Act* (MBCA, 1994). The study takes a 'project life cycle approach' to descriptively examine if, and how, federal legislation applies to oil sands environmental management in relation to (1) the pre-construction phase; (2) the operational phase; and, (3) the reclamation and post-certification phase.

The focus of this study is *exclusively* on federal legislation. However, the constitutional division of powers in Canada's federal system necessitates some attention to intergovernmental and multi-level governance issues. As such, the report includes a brief overview of federalism and its continued relevance for legislation in the environmental, natural resources, and energy sectors with a focus on environmental management.

Passed in 2011 and 2012, Bill C-38 and Bill C-45 are recent Acts and have yet to be subjected to few, if any, descriptive or analytical scholarly examinations. The dearth of studies is even more extreme from an environmental management perspective. This study therefore uses primary document analysis of the above listed Acts as its core method. This is supplemented with reference to secondary academic sources, Government of Canada policy documents and audits, media sources, access to information requests, and recent joint panel reviews conducted as part of the environmental assessment of some existing oil sands projects. Finally, a series of informal consultations were also conducted with senior federal officials from multiple departments to seek comment and clarification on the legislation examined and for technical clarifications as required.

The findings detailed in this study suggest that Bills C-38 and C-45 are watersheds in environmental and natural resources policy sector governance in Canada. The Acts fundamentally reorient the Government of Canada's approach to environmental regulation, Canada-Alberta environmental assessment processes and represent a clear shift towards greater Ministerial discretion for regulation under several Acts amended by the two omnibus budget implementation bills. The report documents that, from a federal perspective, only a few provisions in each of the Acts are directly applicable to environmental management. The general pattern identified in amendments is a clear attempt to devolve, delegate, and harmonize federal activity in the policy sector with the Government of Alberta. From a project life cycle perspective, federal legislation was found to be most pronounced at the pre-construction phase (front-end) through project applications for permitting under federal legislation and the environmental assessment processes. However the permitting and environmental assessment regimes reviewed also included some provisions requiring monitoring, reporting, and enforcement that have implications for the operational and reclamation and post-certification phases.

The current federal administration has made its explicit intention to reduce if not remove regulatory delay, duplication, and burden to expedite economic and resource development. As this report emphasizes, a review of pertinent legislation and consultations with government officials reveals a considerable degree of uncertainty remains related to environmental management. Not all new potential regulations under the amended budget implementation bills have been brought into force. In some instances, transitional provisions apply while in others regulations are expected but had not yet been publicly disclosed. As such, officials and official government documents were unclear as to their applicability to environmental management.

The report concludes that recent legislative changes have increased uncertainty related to the application of federal legislation to oil sands development. This is due to the lack of precedent by which to understand its application, and because not all regulations have been brought into force. The report concludes this uncertainty is particularly acute for the reclamation and post-certification phase because of the limited reclamation and certification that has occurred to date.

2.6 Strategic Design

This program focuses on the development and refinement of OSRIN's strategic intent and program delivery.

2.6.1 *Launch of Knowledge Translation Program for the Proposed Alberta Centre for Reclamation and Restoration Ecology (ACRRE) – Dr. Ellen Macdonald, University of Alberta*

Year	Funding	Project Activity
2009/10		
2010/11		
2011/12		
2012/13		
2013/14	$25,000	Project started February 2014 Report to be released November 2014

The proposed Alberta Centre for Reclamation and Restoration Ecology (ACRRE) at the University of Alberta will serve as a nucleus for the development of world-class research programs, education of natural resource professionals, application of scientific knowledge to best management practices and policies, and enhancement of public education. The Faculty of Agricultural, Life & Environmental Sciences (ALES) is working with industry and government to secure funding to establish a world-class Centre with the expertise, skills, infrastructure and financial support to tackle today's pressing challenges in reclaiming and restoring damaged ecosystems.

Outreach and application of knowledge is a key component of ACRRE's mandate. Over the past few years OSRIN has developed a reputation as the 'go to' place for information on oil sands reclamation. With OSRIN scheduled to wind down activities in December 2014 we are planning for a seamless transition through which ACRRE can fill this gap. We can leverage existing strengths by transitioning the skills and knowledge platform developed in OSRIN into ACRRE. This project will begin that process by delivering Outreach and Application of Knowledge activities that will provide immediate value to ACRRE's and OSRIN's stakeholders. These include:

- Establishing a website for ACRRE and linking it to the existing OSRIN website to ensure easy access to the valuable publications OSRIN has produced, all of which are archived on the University of Alberta's Education and Research Archive site.
- Produce a series of Research Notes summarizing recent research findings relating to reclamation and restoration ecology. ALES has experience in producing such

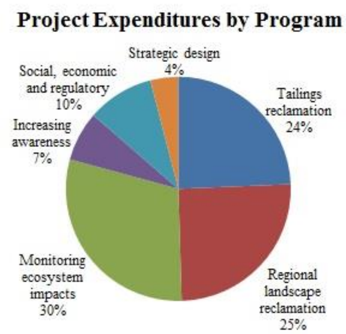
Research Notes, which have been well received by government and industry partners. At least five such Research Notes will be produced.

- Hold the first of what is envisioned to be an on-going Lunch 'n Learn series in Calgary and Edmonton; these sessions will be aimed at sharing recent research findings with industry and government partners but more importantly will serve as an opportunity to discuss further application of those findings to practice and policy.

3 FINANCIAL STATUS

3.1 Revenue

During 2013/14 OSRIN received a $2,000 donation from Barr Engineering Company of Calgary.



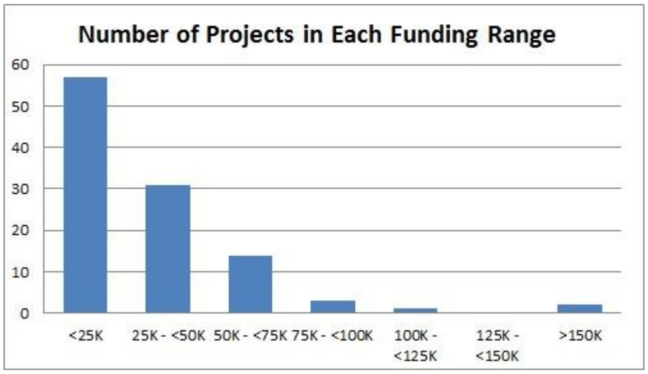
3.2 Expenditure

In 2013/14, OSRIN spent $628,518.23 (broken down by program area and administration in the table below). The figure to the right shows the split of project funding by program from 2008 until March 31, 2013.

Cost Centre	$ Spent[1]	% of Total $ Spent
Tailings Reclamation	$138,000.00	21.9
Regional Landscape Reclamation	$153,599.08	24.4
Monitoring Ecosystem Impacts	$140,574.75	22.4
Increasing Awareness	$4,387.65	0.7
Social, Economic and Regulatory	$0.00	0
Strategic Design	$25,000.00	3.9
OSRIN Expenses[2]	$166,956.75	26.6
TOTAL	$628,518.23	

[1] Includes grants, purchase orders, invoices and GST related to projects.

[2] Includes salaries, travel and expenses for OSRIN staff.



Section 2 summarizes expenditures by project. As shown in the figure to the left, the majority of OSRIN projects costs less than $50,000, allowing us to undertake more research for the available budget.

3.3 Remaining Budget

At the end of March 31, 2014, total cumulative OSRIN expenditure since 2008 was $4,487,373.33. An additional $138,200.00 in outstanding commitments leaves an uncommitted balance of $173,028.75 which is available for future research work and to cover overhead.

4 FUTURE RESEARCH

OSRIN is currently slated to wind up at the end of December 2014. We have allocated the majority of our remaining research funding to the projects noted in this report. One of the key legacy projects we will complete in 2014/15 will be a survey of research needs that can help inform future work by other research programs.

5 ACRONYMS USED IN THIS REPORT

AESRD	Alberta Environment and Sustainable Resource Development
AIEES	Alberta Innovates – Energy and Environment Solutions
AITF	Alberta Innovates – Technology Futures
AOP	Advanced Oxidation Processes
AOSERP	Alberta Oil Sands Environmental Research Program
AOSR	Athabasca Oil Sands Region
AOSTRA	Alberta Oil Sands Technology and Research Authority
CEMA	Cumulative Environmental Management Association
COPC	Compound of Potential Concern
COSIA	Canada's Oil Sands Innovation Alliance
CRI	Climate Response Index
DNA	Deoxyribonucleic Acid
DRI	Decomposition Response Index

DST	Decision Support Tool
ED	Electrodialysis
ESI	Electrospray Ionization
FO	Forward Osmosis
FORWARD	Forest Watershed and Riparian Disturbance
FY	Fiscal Year
FTICR-MS	Fourier Transform Infrared Mass Spectrometry
GHG	Greenhouse Gas
GIS	Geographic Information System
LFH	Luvic-Fulvic-Humic (or Litter-Fibric-Humic)
LOC	Lab-on-a-Chip
MFT	Mature Fine Tailings
MICP	Microbial-induced Calcite Precipitation
MS	Mass Spectrometry / Spectrometer
NA	Naphthenic Acid(s)
NF	Nanofiltration
NRCan	Natural Resources Canada
OSD	Oil Sands Student Delegation
OSPW	Oil Sands Process Water
OSRIN	Oil Sands Research and Information Network
PAH	Polycyclic Aromatic Hydrocarbon
PAW	Process-Affected Water
PDMS	Polydimethylsiloxane
PM	Photocatalytic Membrane
RO	Reverse Osmosis
SEE	School of Energy and the Environment
SME	Small and Medium Enterprises
SNR	Signal to Noise Ratio
STSM	State-and-Transition Simulation Model
SWAT	Soil and Water Assessment Tool

TACA	Tree and Climate Assessment
TDS	Total Dissolved Solids
UV	Ultraviolet

LIST OF OSRIN REPORTS

OSRIN reports are available on the University of Alberta's Education & Research Archive at https://era.library.ualberta.ca/public/view/community/uuid:81b7dcc7-78f7-4adf-a703-6688b82090f5. The Technical Report (TR) series documents results of OSRIN funded projects. The Staff Reports (SR) series represent work done by OSRIN staff.

OSRIN Technical Reports – http://hdl.handle.net/10402/era.17507

BGC Engineering Inc., 2010. Oil Sands Tailings Technology Review. OSRIN Report No. TR-1. 136 pp. http://hdl.handle.net/10402/era.17555

BGC Engineering Inc., 2010. Review of Reclamation Options for Oil Sands Tailings Substrates. OSRIN Report No. TR-2. 59 pp. http://hdl.handle.net/10402/era.17547

Chapman, K.J. and S.B. Das, 2010. Survey of Albertans' Value Drivers Regarding Oil Sands Development and Reclamation. OSRIN Report TR-3. 13 pp. http://hdl.handle.net/10402/era.17584

Jones, R.K. and D. Forrest, 2010. Oil Sands Mining Reclamation Challenge Dialogue – Report and Appendices. OSRIN Report No. TR-4. 258 pp. http://hdl.handle.net/10402/era.19092

Jones, R.K. and D. Forrest, 2010. Oil Sands Mining Reclamation Challenge Dialogue – Report. OSRIN Report No. TR-4A. 18 pp. http://hdl.handle.net/10402/era.19091

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