2020 COSIA LAND EPA

In Situ Research Report

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INTRODUCTION

This report is funded by members of Canada's Oil Sands Innovation Alliance (COSIA) Land Environmental Priority Area (EPA):

Canadian Natural Resources Limited (Canadian Natural)
Cenovus Energy Inc. (Cenovus)
ConocoPhillips Canada Resources Corp. (ConocoPhillips)
Husky Energy Inc. (Husky)
Imperial Oil Resources Limited (Imperial)
Suncor Energy Inc. (Suncor)
Syncrude Canada Ltd. (Syncrude)
Teck Resources Limited (Teck)

COSIA publishes two reports, 2020 COSIA Land EPA – Mine Research Report and 2020 COSIA Land EPA – In Situ Research Report. This report summarizes progress for projects related to in situ reclamation of the COSIA Land EPA.

The project summaries included in this report do not include all projects completed under the Land EPA. In 2020 some projects were significantly impacted by the COVID-19 pandemic and consequently no summary is provided this year. Please contact the Industry Champion identified for each research project if any additional information is needed.

2020 COSIA Land EPA – In Situ Research Report. Calgary, AB: COSIA Land EPA.

Front cover image of reclaimed area within Suncor's Firebag Project courtesy of Suncor.

WETLANDS

Removing the Wellsite Footprint (iFROG)

COSIA Project Number: LJ0216

Research Provider: Circle T Consulting Inc.

Industry Champion: ConocoPhillips

Industry Collaborators: AOC Lesimer Corner Partnership, Canadian Natural, CNOOC Petroleum North America ULC, Harvest Operations Corp., Husky, Imperial, Japan Canada Oil Sands Limited, MEG Energy Inc.

Status: Year 4 of 6

PROJECT SUMMARY

The purpose of the industrial Footprint Reduction Options Group (iFROG) is to develop, fund and implement a balanced portfolio of boreal wetlands research projects that:

- Follow the fundamental guiding principles of land stewardship, intelligent research, and collaboration;
- Demonstrate iFROG members are meeting the intent of the applicable wetland research conditions in their respective Environmental Protection and Enhancement Act (EPEA) Approvals (for oil sands in situ projects);
- Contribute to mitigating impacts to wetlands during operations; and
- Increase the knowledge base for, and confidence in, wetland reclamation efforts.

In 2020, three projects were supported: Japan Canada Oil Sands Limited (JACOS) Road Reclamation, From Dirt to Peat, and Pad TT Road Construction Best Practice.

JACOS Road Reclamation Study (Year 3 of 3)

The JACOS Road Reclamation Study involves the continuation of reclamation work first initiated in 2010 within a bog peatland. Whereas the initial study restricted treatments to three treatment blocks established on only a subsection of the road, the entire road was reclaimed in the present study and examines two primary reclamation strategies. Partial fill removal is used in both strategies, where only enough fill was removed to establish a revegetation surface where the elevation is continuous with the adjacent peat. One strategy attempts to establish peatland vegetation on the mineral fill surface, while the second attempts to establish peatland vegetation on varied depths of organic substrate.

The road was divided into two study areas, one for each of the revegetation strategies. Fill on the mineral substrate section was removed until the surface was continuous with the adjacent peatland and the surface was inoculated with fen peatland propagules from a nearby donor site and covered with straw mulch. Fill on the organic substrate section was excavated to below the elevation of the adjacent peatland to the desired depth of organic substrate, and then filled to the adjacent peatland elevation with stockpiled peat. The peat surface was inoculated with bog peatland propagules from a nearby donor site and covered with straw mulch.

The objectives of the peat substrate study are to evaluate revegetation methods such as substrate depth and fertilization, as well as identify drivers of the emerging plant community (e.g., soil pH, electrical conductivity, water content, and soil and water chemistry).

The objectives of the mineral section are to compare revegetation success on two surface treatments (smooth and lightly scarified), to identify drivers of the emergent vegetation, and assess any physico-chemical effects of the exposed mineral surface on the adjacent peatland.

From Dirt to Peat (Year 2 of 3)

This study is a three-year, multi-site, meta-analysis examining ecological recovery in response to a range of reclamation practices over a range of conditions, including both partial and complete removal of fill from roads and pads constructed within wetlands. Seven pads and two linear features are being studied, including the iFROG Canadian Natural pad and the JACOS road study sites.

The study objective is to characterize each site in terms of its functioning, or potential to function, as a healthy peatland based on peat accumulation potential and GHG balance. Ecological response variables that will be used include vegetation composition, accumulation of organic matter ("peat thickness"), above and below ground biomass productivity, biomass decomposition, peat accumulation potential (calculated) and GHG balance. Explanatory variables include the site-specific treatments, as well as environmental conditions such as local climatic indicators, soil and water chemistry, soil moisture and soil temperature. Reclamation site response variables will be compared with similar variables on reference peatlands within the oil sands areas in which the study sites are located.

Pad TT Road Construction Best Practice (Year 3 of 3)

Devon Canada constructed a road at the Jackfish 2 project (now Canadian Natural Jackfish 2) intersecting several areas of deep fen peat that are each approximately 180 m long. Timber corduroy was used as road foundation over the soft peat sections in conjunction with several culverts that were closely spaced within each section. High-density polyethylene (HDPE) pipe culverts or log bundles were installed among the culverts to facilitate additional drainage. Seventeen culverts and seven bundles were installed along the 1.5 km length of road. Study objectives are to:

- Determine whether or not the road allows water to pass through effectively as a result of the corduroy and drainage conduit installations;
- Characterize flow rates and patterns in the vicinity and through the road to assess the effectiveness of the type and number of conduits; and
- Assess road performance in the corduroy sections as indicated by progressive road settlement over time, and identify any problem areas.

PROGRESS AND ACHIEVEMENTS

JACOS Road Reclamation Study

Bog species have established on the organic section of the reclaimed road, but many competitive undesirable species such as tickle grass (*Agrostis scabra*) and alsike clover (*Trifolium hybridum*) have also established, likely originating from the seed bank within the stockpiled peat. The overall vegetation community differs between two subsections of the organic section. This is believed to be based more on timing of bog species propagule inoculation than on substrate depth. Both of these communities differ from the adjacent bog reference. A subsection of the road where there was one growing season delay between excavation/ refilling with peat and inoculation with propagules, was characterized by an abundance of grass and early successional forbs, while a subsection of the road where there was no delay before propagule inoculation had an abundance of clover, sedges, and rushes. The apparent ecological drivers on the delayed inoculation subsection were soil nutrients and organic matter depth, while the principal driver for the non-delayed inoculation subsection was distance to subsurface drainage channels used to connect water between upstream and downstream sides of the road. Expectations are that prevailing moisture conditions will favour the applied bog species and the undesirable species will diminish over time.

Fen species established on the mineral section of the road, and fen vegetation cover increased from the first to second year of the study. Fen species were significantly more abundant on inoculated plots than non-inoculated controls. Primary environmental drivers of vegetation occurrence were soil pH, electrical conductivity, and magnesium concentration. Subsurface drainage channels were more responsible for soil water chemistry changes in the adjacent peatland than surface flow, but changes were limited to 2 m from the road in either case. While the road still impedes water flow from the upstream side to the downstream side, the increased effect on adjacent water chemistry near the drainage channels indicates the channels are assisting in reducing the impediment to water flow caused by the road.

From Dirt to Peat

Peatland vegetation has established at all of the sites studied within this project and peatland species are generally more abundant than non-peatland species. Nevertheless, all vegetation communities on reclaimed sites remain different from their adjacent peatland references. However, the two sites that were inoculated with peatland propagules are more similar to reference communities than sites that were not inoculated. Greatest peatland species development was observed on sites with mixed soil substrates, but peat vegetation development on mineral substrate was similar to that on peat substrate.

All sites are accumulating peat, but depths vary widely among sites depending on vegetation type, soil chemistry, moisture, and site age. Further analysis of data is required to understand which sites are most successful in carbon storage. The organic substrate section of the reclaimed JACOS road sequestered more carbon in the form of CO_2 via photosynthesis than it released through respiration, with net carbon gain similar to adjacent peatlands. However, the reclaimed organic section released more carbon in the form of methane (due to decomposition) than the adjacent peatland, particularly on deeper peat substrate. There was very little carbon flux on the mineral section due to sparser vegetation, particularly during the first year of the study (2019). Continued change in carbon flux is expected as vegetation continues to develop in coming years.

Pad TT Road Construction Best Practice

Water table measurements were recorded on only one occasion in 2020 due to access restrictions brought about by the COVID-19 pandemic. The single measurement event confirmed the overall observation in 2019 that the road does not present a barrier to water flow overall, but evidence of flow concentration exists near the Pad TT end of the road.

The road elevation survey indicated that some additional settling of the road occurred on a short section of the road during 2020. However, there was very little change in elevation along remaining road and drainage conduit transects from 2019 to 2020, indicating road settling may have stabilized.

LESSONS LEARNED

JACOS Road Reclamation Study

Initial vegetation establishment on the reclaimed surfaces indicates that inoculation with moss fragments from suitable donor sites is an effective tool for revegetating wetland reclamation surfaces. The comparative vegetation outcomes on the mineral and organic substrate subsections of the road identify some trade-offs that may need to be considered with respect to peatland reclamation planning, specifically with respect to topsoil salvage and management. Revegetating a mineral surface necessitates using fen species because of the neutral to alkaline pH of the substrate. Doing so appears viable with inoculation with appropriate donor species propagules. Furthermore, less excavation and less movement of materials are required when revegetating a mineral substrate left in place versus an organic substrate applied to mineral fill excavated to below the final target elevation. Therefore, it may be preferable to leave more fill in place and revegetate the surface with fen vegetation. However, starting the restoration with fen vegetation results in a very long delay in the establishment of bog vegetation (if that is the final reclamation target) because of the time required for vegetation succession from fen to bog. Bog species adapted to acidic soil conditions will not establish until sufficient depth of peat can accumulate to reduce the influence of alkaline fill on the vegetation community. This ecological pathway to bog vegetation can take a very long time depending on fill chemistry, initial vegetation established, climate, and other factors. Alternatively, bog vegetation can immediately be established on a peat substrate of appropriate pH. However, there is a concern that a seed bank of undesirable species could accumulate in peat that has been stockpiled for reclamation use and could potentially interfere with bog species development by establishing competitive non-target communities. Undesirable species seeds accumulating in peat stockpiles could include local native species from different ecosites, as well as non-local or invasive species introduced over time depending on the location of the stockpile and overall vegetation management on a given site. The additional costs related to starting restorations with bog vegetation on a peat substrate versus mineral substrate (extra excavation and movement of stockpiled materials) may not be worthwhile if bog establishment is sufficiently delayed because of this.

From Dirt to Peat

In general, on the range of sites and practices studied the successful establishment of peatland vegetation and the accumulation of peat confirms that revegetation success is a reasonable expectation of wetland reclamation, provided suitable conditions for establishment are produced and maintained. Inoculation with moss fragments from donor sites increases the likelihood of revegetation success and also increases similarity between reclaimed sites and adjacent peatlands. Peatland vegetation establishment is equally viable on mineral or peat substrate, but a mix of substrates (both types present, as opposed to blended) increases abundance of peatland species.

Pad TT Road

When compared to resource roads constructed in similar conditions but using more conventional culvert spacing, the timber corduroy foundation that was built with an increased number of closely spaced conduits has improved the flow of water beneath the road and minimized flow impediment.

Roads constructed on deep peat can be expected to experience substantial settling during the initial two years but most settling will likely have been completed by the third year.

PRESENTATIONS AND PUBLICATIONS

Published Theses

Guérin, P. 2020. Restoration of fen plant communities on the mineral substrate of a peatland impacted by a road. MSc Thesis. University of Laval.

Conference Presentations/Posters

Albricht, R. and T. Osko. 2020. Research Collaboration for Advancing Best Practices in the In Situ Oil Sands. Presentation at World Wetlands Day, Mount Royal University, Calgary. 4 February 2020.

Osko, T. 2020. Research Collaboration Advances Best Practices and Ecological Outcomes for In Situ Oil Sands. Presentation at CLRA Alberta Chapter Annual General Meeting and Conference, Red Deer. 26-28 February, 2020.

Available at: https://static1.squarespace.com/static/5977ae4ef14aa1a84a5f2bad/t/5e7d0fce822a6a19aa803707/1585254380963/Thursday+14+00+Research+Collaboration+Advances+Best+Practices+and+Ecological+Outcomes+for+In+Situ+ Oil+Sands.pdf

RESEARCH TEAM AND COLLABORATORS

Institution: Circle T Consulting, Inc.

Principal Investigator: Terry Osko

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Line Rochefort	Université Laval	Professor of Peatland Ecology		
Bin Xu	NAIT Boreal Research Centre	NSERC Industrial Research Chair in Peatland Restoration		
Clayton Gillies	FPInnovations	Senior Researcher		
Christine Isabel	Université Laval	MSc	2019	2021
Pascal Guérin	Université Laval	MSc	2019	2021

Research Collaborators: Dr. Maria Strack, University of Waterloo

Boreal Wetland Reclamation Assessment Program (BWRAP): Industrial Research Chair in Oil Sands Wetland Reclamation

COSIA Project Number: LE0037

Research Provider: University of Calgary

Industry Champion: Suncor

Industry Collaborators: Canadian Natural, Cenovus, ConocoPhillips, Husky, Imperial, Syncrude, Teck

Status: Year 1 of 5

PROJECT SUMMARY

The natural landscape of the Athabasca Oil Sands (AOS) region is dominated by wetlands and peatlands. Following the completion of mining activities, reclaiming these landscapes requires new knowledge and techniques to develop operational best practices for reconstructing forests and wetlands to achieve equivalent land capability. While industry is currently creating new wetlands in the reclaimed landscape, there is currently no clear guidance against which to evaluate the success of these efforts and to guide adaptive management. The scientific and technical expertise needed to develop measures of success is being enabled by the new Industrial Research Chair (IRC) program — the *Boreal Wetland Reclamation Assessment Program* (BWRAP), led by Dr. Jan Ciborowski.

Dr. Ciborowski's Senior NSERC/COSIA Industrial Research Chair in Oil Sands Wetland Reclamation was established on April 1, 2020, with support from NSERC, eight COSIA partners and the University of Calgary, to address the issues associated with wetland reclamation following bitumen mining in the AOS region. Ciborowski's research program is developing and testing the *Reclamation Assessment Approach,* a transformational methodology to characterize and assess the ecological condition of young wetlands in AOS reclamation landscapes and to ultimately enable industry to better reclaim land and promote biodiversity.

BWRAP intends to answer the following questions:

1. How can industry best predict the early development, biodiversity, and persistence of wetlands in a reclaimed landscape?
2. What environmental or biological indicators best reflect long-term resilience and/or persistence in young wetlands?
3. What reclamation features will promote young wetlands' formation, resilience and persistence?

Currently, there are no accepted methods of assessing wetland construction effectiveness or 'functionality' of a wetland reclamation target. However, several attributes are recognized as either modulators or indicators of a wetland's successional state or its environmental or biological condition. This project's Scope of Work is to measure a suite of environmental and biological characteristics of newly-formed and maturing wetlands and their surroundings in order to document the range of natural variation. These ranges will form the basis of comparison against which to assess the 'success' of constructed wetlands in the post-mining landscape and by which to determine if mitigation may be required. The following wetland features are recognized as being important measures of ecological condition:

Time to Recovery: Recovery rates of wetlands vary primarily with respect to wetland size. In a meta-analysis of 621 globally-distributed wetland sites, Moreno-Mateus et al. (2012) reported that hydrological features become similar to reference values and vertebrate and macroinvertebrate species recolonize within five to ten years. In contrast, community composition and biogeochemical processes had not fully recovered after 50 years. Further, the rate of recovery was strongly related to wetland area: biological structure in wetlands ≥ 100 ha become similar to reference wetlands within five years of reclamation. Perhaps counterintuitively, created wetlands became similar to reference wetlands much more quickly than restored wetlands.

Water quality Influences: Water quality constrains the abundance and composition of wetland biota. Most undisturbed wetlands in the AOS have low conductivity, but natural seeps increase salinity and contain halophilic communities. Wetlands forming in sodic overburden storage areas on oil sands leases are also saline enough to influence community composition. Some biota may tolerate higher salinity from natural or runoff sources than from tailings waters, possibly due to interactions of the latter with residual bitumen-extraction byproducts.

Landscape and Microtopography Influences: Wetland persistence depends on receiving and maintaining an adequate water supply. Evapotranspiration often exceeds precipitation in the AOS, emphasizing the need to trap and store water during wet events. Constructed wetlands have been hypothesized to need at least a two to one ratio of watershed to wetted area for precipitation to sustain fen habitat in the AOS (Price et al., 2009). Land disturbance (altered forest cover, soil or drainage pattern) is also a key stressor. For example, roads and culverts alter both hydrology and habitat use by biota. Wetland geometry (e.g., slope, emergent zone width, microtopography) influences abundance, richness, and distribution of aquatic communities.

Permanence: Marsh-like wetlands are a focus of AOS reclamation because they are persistent and relatively easy to construct. However, seeps and naturally-forming minerotrophic wetlands wet 10% to 17% of reclaimed areas (Little-Devito et al., 2019; Hawkes et al., 2020), leading to questions of the determinants of where 'opportunistic' wetlands occur and the extent to which they match prescriptions and predictions.

Biological indicators of wetland condition: No integrated criteria exist to assess the overall effectiveness of wetland reclamation for the mineable AOS, despite extensive surveys and adoption of biological integrity indices from previous studies (vegetation, aquatic invertebrates, birds, amphibians), and a framework to assess toxicological risks (Arciszewski et al., 2017). Current wetland impact assessment initiatives designed to detect risks to mature off-lease wetlands (difference from wetlands in the Reference Condition Area [RCA]) are not necessarily applicable to young constructed wetlands or to those formed opportunistically in reclaimed areas.

Overall Objective: Formulating a *Reclamation Assessment Approach* for oil sand reclaimed wetlands

Since reference locations in the RCA focus on 'climax', stable state or a mosaic of successional states, recovering or newly reclaimed areas require a different frame of reference. The BWRAP will compile data from suites of wetlands at early time-points since their formation or creation. These data, essential as a frame of reference for assessing developing landscapes, will be collected and summarized to document the range of natural variation in indicator variables for opportunistically-forming and reclaimed wetlands. Such information will inform guidelines that will determine whether adaptive management may be needed to achieve closure outcomes (maximize the likelihood of a wetland becoming functional and exhibiting the desirable ecological properties of natural systems).

Over the course of the three-phase, five-year BWRAP program, up to 120 candidate reclaimed wetlands (minerotrophic fens, swamps, and marsh-like areas) approximately three, eight, 20, 40 years post-formation and 'mature' (age-indeterminate), will be assessed. Some of these age-states are similar to those used for assessing upland forest stands in Alberta and broadly correspond to times since various pilot reclamation projects were undertaken by COSIA partners.

Phase 1 – Recruiting and Database Creation: The first phase entails compiling and harmonizing existing data — a 20 year record of research conducted on natural and reclaimed wetlands in and around the Fort McMurray oil sands leases. As well, remote sensing imagery of reclaimed lease areas and reference areas collected by the partner companies will be analyzed and used to create an inventory of the number, size, age and permanence of the constructed and opportunistic reclaimed wetlands. A representative set of wetlands varying in age, size, permanence, disturbance history and water quality will then be selected for field studies over the next three years (Phase 2).

Phase 2 – Field Investigations: Each year, teams of fieldworkers will assess a suite of approximately 40 wetlands (minerotrophic fens and swamps and marshlike areas) using; in situ instrumentation; field sampling; drone surveys to assess wetland morphometry; water chemistry and balance; and riparian disturbance. The biological condition of each wetland will be characterized by surveying the communities of aquatic invertebrates, aquatic vegetation and birds.

Phase 3 – Data Compilation, Analysis and Synthesis: During the third phase, the environmental data will be compiled to align the wetlands of different ages with respect to three gradients of environmental stress —permanence, water quality, and topographic heterogeneity (disturbance). Differences in the composition of biota among wetlands across each stress gradient will be used to identify thresholds of biological characteristics (bioindicators) of each wetland age class, distinguishing 'acceptable', 'intermediate', and 'unacceptable' classes of wetland health. Successful wetlands will have environmental conditions and associated biota characteristic of 'acceptable' conditions for their successional stage of development. These features (and the landscape features that promote or sustain them) can be used to guide future reclamation protocols and ultimately provide objective criteria by which to anticipate the longer term persistence of reclaimed wetlands.

PROGRESS AND ACHIEVEMENTS

Although the original start date proposed for this IRC program was October 2019, the actual start date was offset by six months to April 1, 2020. Many planned activities were deferred further due to restrictions on research imposed by the need to observe COVID-19 protocols. Consequently, some milestones described in the Activity Schedule of the original IRC proposal have become misaligned with actual timing of individual research activities. Nevertheless, significant initial progress was achieved on several objectives during 2020. Details of progress related to the research objectives are described below, in relation to specific research activities outlined in the original IRC proposal.

The principal activities carried out in Year 1 (Phase 1) of this IRC program were directed to four key themes:

1. Recruiting and training an initial team of Highly Qualified Personnel (HQP)
2. Developing the configuration and design of the BWRAP database to house existing and anticipated data
3. Compiling existing point source data and acquiring remote sense imagery
4. Planning and executing initial field studies and associated laboratory analyses

Objective 1: Recruiting and training an initial team of Highly Qualified Personnel (HQP)

The BWRAP study was configured to engage an administrative manager and two database programmers (supported by start-up and supplemental funds), nine graduate students (five MSc, four PhD), eight Post-Doctoral Fellows and at least 13 undergraduate thesis and/or field assistants. By June 2020, an administrative manager , two Post-Doctoral Fellows, three MSc, and five undergraduate thesis students had joined the program. Three of the undergraduate students have applied to University of Calgary graduate studies in 2021. From June through August, lab members received daily online training in wetland ecology and study design through Zoom presentations, lectures and discussions led by the Principal Investigator and Post-Doctoral Fellows.

COVID-19 safety restrictions eased in late summer permitting students to work in the laboratory and receive introductory instruction in wetland sample processing and aquatic invertebrate identification.

Objectives 2 and 3: Database configuration and design and data acquisition

Funds to purchase computer hardware and to engage programmers to build and populate the geospatial relational database were acquired through a grant from the John R. Evans Leadership fund of the Canadian Foundation for Innovation and Alberta Economic Development and Trade, awarded in November. The system will be configured and tested over the winter by a programmer (recruitment in progress) with the assistance of University of Calgary IT services.

BWRAP has had successful discussions with global information system (GIS) and database researchers at Suncor, Syncrude, and with representatives of Alberta Biodiversity Monitoring Institute and Alberta Environment and Parks to review existing database frameworks and opportunities to maximize the interoperability and compatibility of data collection approaches. BRWAP is also working closely with the COSIA-funded *Boreal Ecological Recovery and Assessment II* project to maximize database compatibility.

Data sharing agreements with Suncor and Syncrude have been developed, providing access to the high resolution remote sensing data from which to inventory the location and age of opportunistic wetlands forming on reclaimed landforms. Post-Doctoral Fellow/Research Scientist Mir Mustafiz Rahman is the chief liaison between BWRAP and the partner organizations.

Objective 4: Planning and executing initial field studies and associated laboratory analyses

Opportunities to conduct pilot-scale fieldwork were limited by travel restrictions through most of the 2020 field season. However, permission was received from the University of Calgary to conduct a one-week field trip in September 2020. A field crew of three graduate students and four undergraduate assistants visited several mature fen sites and conducted extensive sampling from pools in a saline fen complex south of Fort McMurray (Wells and Price, 2015).

Over a five day period, the team measured the conductivity, temperature and dissolved oxygen concentration of 72 pools and swales along a north-south gradient. Conductivity ranged from 3,750 µS to 21,000 µS. A subset of 50 waterbodies was stratified-randomly selected to span the conductivity gradient. At each of these wetlands the team sampled the benthic invertebrate fauna by collecting sweep net samples. Water samples were also collected for later analysis of cations, anions and stable isotopes.

The benthic invertebrate community exhibited marked differences in composition across the conductivity gradient. Wetlands with relatively low conductivity had an abundant and diverse fauna. In contrast, swales and ponds exhibiting the highest conductivity were dominated by high numbers of Diptera, especially mosquito larvae, and a few beetles and water boatmen. These samples and data, which form the basis of Brenten Vercruysse's MSc, will be used to develop a bioindicator of salinity against which the biota of reclaimed wetlands can ultimately be assessed.

LESSONS LEARNED

This project is in early stages so there are few emerging outcomes or lessons learned for 2020. One provisionally significant finding is that a broad diversity of aquatic invertebrate taxa appear to be able to develop in a naturally saline fen with conductivity values that match or exceed the readings typically observed in landscapes reclaimed with sodic overburden.

LITERATURE CITED

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Moreno-Mateos, D., Power, M. E., Comy, F. A., Yockteng, R. 2012. Structural and functional loss in restored wetland ecosystems PLoS Biology 10(1):1-8.

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Wells, C. M., Price, J. S. 2015. A hydrologic assessment of a saline-spring fen in the Athabasca oil sands region, Alberta, Canada – a potential analogue for oil sands reclamation Hydrological Processes 29:4533-4548.

PRESENTATIONS AND PUBLICATIONS

Ciborowski, J. J. H. 2020. The Reclamation Assessment Approach - calibrating bioindicators of environmental condition to monitor boreal wetland reclamation. Invited Presentation, Alberta Environment and Parks, Chief Science Officer Seminar series. May 5, 2020 (virtual presentation).

Ciborowski, J. J. H. 2020. Evaluating Biodiversity in Reclaimed Wetland Landscapes – New Tools for New Systems. Keynote Address, World Wetlands Day Research Symposium, Mount Royal University, Calgary, AB, Feb 4, 2020.

Ciborowski, J. J. H. 2020. Calibrating Bioindicators of Environmental Condition and Recovery from Degradation. Invited Seminar, University of Lethbridge, Lethbridge, AB, Jan 31, 2020

Ciborowski, J. J. H. 2019. Calibrating Bioindicators of Environmental Condition and Recovery from Degradation. Invited Seminar, Thompson Rivers University, Kamloops, BC. Nov 14, 2019.

Conference Presentations/Posters

Tomal, J., Ciborowski, J. J. H. 2020. Detection of environmental thresholds by assessing discontinuities in slopes and variances via a Bayesian regression model. Annual meeting of Canadian Mathematical Society, December 3-8 2020. (virtual meeting).

Ciborowski, J. J. H., J. J. H., Menard, J. A. Dings-Avery, C., Wiseman. H., Barr, L. 2020. Early development and controls on aquatic and semiaquatic invertebrate community composition in the Sandhill Constructed Watershed, (Alberta, Canada). Geoconvention 2020, September 21 to 23, 2020 (virtual meeting).

RESEARCH TEAM AND COLLABORATORS

Institution: University of Calgary

Principal Investigator: Dr. Jan J. H. Ciborowski

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Camille Sinanan	University of Calgary	BWRAP Admin Manager		
Mir Mustafizur Rahman	University of Calgary	Post-Doctoral Fellow/ Research Scientist		
Jeremy Hartsock*	Southern Illinois University	Post-Doctoral Fellow		
Ashlee Mombourquette	University of Calgary	MSc	2020	2022
Brenten Vercruysse	University of Calgary	MSc	2019	2021
Michael Wendlandt	University of Calgary	MSc	2020	2022
Steven Blair	University of Calgary	BSc	2015	2020
Elizabeth Gillis	University of Calgary	BSc (thesis)	2016	2021
Liam Mebesius	University of Calgary	BSc (thesis)	2016	2021
Emily Moore	University of Calgary	BSc (thesis)	2016	2021
Manveet Waraich	Mount Royal University	BSc	2018	2022

* Travel restrictions associated with the COVID-19 pandemic prevented Dr. Hartsock from travelling to Canada and resulted in his leaving the program at the end of August.

Research Collaborators:

The following collaborators indicated their willingness to participate in the program as envisioned during the proposal phase of the research plan. The timing and extent of collaboration will vary according to the stage of research and the individuals' expertise.

Name	Institution or Company	Role/Expertise
Greg McDermid	Geography, University of Calgary	Remote sensing (BERA program)
Laura Chasmer	Geography, University of Lethbridge	Wetland ecosystem change detection
Kevin Devito	Biological Sciences, University of Alberta	Landscape controls on boreal ecohydrology
Alice Grgicak-Mannion	Earth Sciences, University of Windsor	Disturbance mapping and analysis
Bernhard Mayer	Geosciences, University of Calgary	Stable isotope analyses
Leland Jackson	Biological Sciences, University of Calgary	Nutrient and water chemistry analyses
Jean Birks	Alberta Innovates, Calgary	Isotope techniques to quantify water balance
Christopher Weisener	Earth Sciences, University of Windsor	Microbial controls on wetland biogeochemistry
Dale Vitt	Biological Sciences, S. Illinois University	Wetland succession and biogeochemistry
Rebecca Rooney	Biological Sciences, University of Waterloo	Bioindicator development, Fuzzy Cognitive Mapping
Lee Foote	Renewable Resources, University of Alberta	Community structure and bioindicators
Colin Daniel	Apex Resource Management Solutions	Wetland state and transition modelling
Leonardo Frid	Apex Resource Management Solutions	Wetland state and transition modelling
Jabed Tomal	Thompson Rivers University	Statistical modelling

COSIA Swamp and Bog Reclamation Workshop: Investigating Innovation Opportunities for Reclaiming In Situ and Mining Developments in the Alberta Oil Sands Region

COSIA Project Number: LE0062

Workshop Facilitator: Vertex Professional Services Ltd.

Industry Champion: Suncor

Industry Collaborators: Cenovus, Canadian Natural, ConocoPhillips, Husky, Imperial, Syncrude, Teck

Status: Complete

PROJECT SUMMARY

The *COSIA Swamp and Bog Reclamation Workshop: Investigating Innovation Opportunities for Reclaiming In Situ and Mining Developments in the Alberta Oil Sands Region* was held on February 3 and 4, 2020, in Calgary, Alberta, and was attended by invited guests from industry, academia, government and consulting. The overall goal of the workshop was to engage wetland and reclamation experts in a review of the current state of knowledge around swamps and bogs on reclaimed landscapes.

Specific workshop objectives were to:

1. Establish the current state of knowledge regarding swamps and bogs on reclaimed landscapes;
2. Identify potential learnings from natural and constructed systems regarding re-establishment of swamps and bogs in the Alberta Oil Sands Region (OSR); and
3. Share perspectives and proposed strategies relating to wetland establishment on closure mining or in situ landscapes.

PROGRESS AND ACHIEVEMENTS

Key speakers, Dr. Dale Vitt (Southern Illinois University), Dr. Kevin Devito (University of Alberta), Dr. Jonathan Price (University of Waterloo), and Dr. Maria Strack (University of Waterloo) were invited to present on current knowledge regarding wetland reclamation of mining and in situ oil sands developments, and the abundance and characteristics of swamps and bogs in the Alberta OSR. Industry representatives, Lisa Bridges (Suncor) and Carla Wytrykush (Syncrude), also presented, providing context regarding reclamation of mining and in situ operations in Alberta. Discussions during the key speaker presentations and subsequent panel discussion generally focused on the functions of each wetland type within the wider landscape and whether reclamation goals should target specific wetland types or wetland functions, regardless of wetland classification.

The key speakers agreed that the main drivers of wetland development in reclaimed landscapes include landscape position and hydrologic regime. As hydrologic conditions on reclaimed sites cannot be precisely controlled, they recommended that wetland reclamation goals should focus on creating functioning wetland complexes rather than specific planned wetland types within the reclaimed landscape.

Through facilitated activities, workshop participants identified numerous key questions related to bog and swamp reclamation in post-mining and in situ environments. The questions were consolidated and can be summarized as follows:

1. What are the best indicators of successful wetland reclamation trajectories?
2. How can landscapes be designed/created in a way that encourages wetland reclamation success?
3. What are the functional roles of bogs and swamps in natural and reclaimed landscapes?
4. What is the acceptable range of water quality and quantity that will allow specific wetland types to develop?
5. What are the expected ranges of surface and groundwater quality on reclaimed landscapes?
6. Should bog and swamp attributes be included as specific reclamation goals, or is it desirable to create wetlands that provide particular functions and which may develop attributes divergent from swamps and bogs?
7. How should target vegetation communities be considered in wetland reclamation planning?

On the second day, the COSIA Land Environmental Priority Area Wetlands Working Group member company representatives held a discussion with the key speakers regarding the key questions identified on Day 1, and the overall feasibility of the approaches proposed to address these gaps.

LESSONS LEARNED

COSIA industry member company representatives and key speakers considered the knowledge gaps and approaches proposed by all participants during the first day of the workshop and arrived at the following conclusions:

- Swamp identification is inconsistent due to the variety of historical classification systems applied within Alberta, and the difficulty in remotely sensing this wetland type. As a result, the abundance of swamps within the Alberta OSR is unclear.
- Given that swamps are forming opportunistically in reclaimed post-mined landscapes in the Alberta OSR, swamp reclamation for in situ sites is technically possible. Future work could assess water chemistry, vegetation communities and thresholds of change in natural and opportunistic swamps in the Alberta OSR.
- Future work could include exploring how a study of natural and opportunistic swamps would help to address the knowledge gaps. The study could include using natural saline and/or sodic wetlands as natural analogues to vegetation communities that might develop opportunistically in discharge areas in reclaimed mining environments.
- Reclaiming linear features such as roads associated with in situ developments to bogs is likely technically possible and methods could be further explored. Existing guidance could be reviewed to determine if additional decision support is required.

- Creating bogs on reclaimed mine substrates with inherently high pH levels and limited peat source for live transfer was thought to be unfeasible. The term '*Sphagnum*-dominated wetlands' was generally agreed upon as a potentially achievable reclamation target.

PRESENTATIONS AND PUBLICATIONS

Workshop

2020 COSIA Swamp and Bog Reclamation Workshop – Executive Summary. Available at: https://cosia.ca/sites/default/files/attachments/Executive%20Summary%20-%20Final_Light.pdf

WORKSHOP FACILITATION TEAM AND KEY SPEAKERS

Facilitators: Vertex Professional Services Ltd.

Key Speakers:

Name	Institution or Company	Job Title
Dr. Dale Vitt	Southern Illinois University	Professor Emeritus
Dr. Kevin Devito	University of Alberta	Professor
Dr. Jonathan Price	University of Waterloo	Professor
Dr. Maria Strack	University of Waterloo	Professor
Dr. Bin Xu*	NAIT Centre for Boreal Research	Program Lead - Centre for Boreal Research
Lisa Bridges	Suncor	Reclamation Specialist - Biodiversity
Carla Wytrykush	Syncrude	Ecologist – Mine Closure Research

* Dr. Bin Xu co-authored the presentation given by Dr. Maria Strack. He was scheduled to present but was unable to attend due to restrictions brought about by the COVID-19 pandemic.

Assessment of Relevant Indicators for the Monitoring of Reclaimed Sites in Peatlands

COSIA Project Number: LJ0328

Research Providers: LOOKNorth, NAIT Centre for Boreal Research, InnoTech Alberta, Natural Resources Canada (Canadian Forest Services), Rankine Geospatial

Industry Champion: Canadian Natural

Status: Year 2 of 2

PROJECT SUMMARY

The peatland monitoring framework will help industry develop cost-efficient, relevant and effective monitoring and reporting programs that support reclamation objectives. Understanding reclaimed peatland recovery in comparison to natural peatland areas will help identify whether current reclamation practices are successful at achieving reclamation targets both on regional and site levels. It also allows for adaptive management approaches that will address problems in a timely manner for long-term ecosystem sustainability. Identifying indicators that are relevant for monitoring recovery, as well as those that replace conventional methods, may reduce the labour requirements for monitoring footprint disturbances and the financial burden of annual monitoring programs.

Five research providers have teamed up to bring together the right expertise to achieve a whole-ecosystem approach to wetland monitoring and assessment. Together, they will develop an integrated, scientifically robust and financially sustainable monitoring pilot program to assess the ecological recovery of physical, chemical and biological indicators for vegetation, soil, water and biodiversity at reclaimed and natural peatland sites across the Athabasca oil sands region.

The intent of the monitoring framework is to increase the feasibility and efficiency of in-field monitoring; identify indicators that are the most relevant (in terms of peatland recovery); identify technologies that can streamline and remove labour-intensive conventional sampling; and increase the consistency of sampling across sites. LOOKNorth anticipates that this will provide industry with the ability to communicate and report more efficiently with regulators on peatland recovery and compare results between sites (within company and between companies, if warranted) for landscape integration planning. The early identification of indicators that are not performing well will also allow early intervention to help ensure reclamation success. The expected benefit from the project is more efficient allocation of reclamation budgets and resources (i.e., more area monitored with less or equivalent effort), which will eventually lead to a better performance of the aggregate total reclaimed areas.

This project scope includes several in situ oil and gas sites (well pads and linear features) reclaimed to peatland status in the last decade or so. A series of natural and reclaimed sites have been selected and instrumented to establish benchmarks for monitoring and to assess site progress towards meeting provincial criteria. Observations on regional hydrology, soil, vegetation – particularly ground layer bryophytes – and soil/water chemistry were collected at multiple spatial scales using field-based methods, unmanned airborne vehicles (UAV) and satellite remote sensing.

The multi-scale data will be analyzed and evaluated for contributions and insights related to progress from disturbed areas towards fully functional boreal wetlands. While wildlife surveys are not within the scope of the activity, the project will consider wildlife use of the study areas as a habitat value indicator.

The main objectives of this project are to:

1. Consolidate ground-truthed field data from a series of reclaimed in-situ peatland sites;
2. Identify key indicators for field monitoring;
3. Pilot and field test ground based and remote sensing techniques appropriate for monitoring peatland indicators; and
4. Develop a monitoring framework integrating indicators across temporal and spatial scales to inform planning and reclamation decision making.

Achieving the goals listed above will require execution of the following major tasks over two years (2020-2021):

1. Selection of peatland indicators through survey and consultation, involving industry, consultants, government, and academia;
2. Design of a two-year pilot monitoring plan. Use of existing field sites with options to add additional sites, both field and conducting remote sensing monitoring; and
3. Execution and analysis of the two-year pilot plan, with annual review and updates.

The project aims to advance and optimize the manner in which wetland reclamation is monitored. This project builds on the existing state of knowledge regarding reclamation of wetlands in the oil sands region, as gathered and established through multi-stakeholder discussions and presented in 2007 as reclamation guidance by the province of Alberta. The guidelines presented to the province through the Reclamation Working Group under the now defunct Cumulative Environmental Management Association (CEMA) do not consider recent advancements in harmonization of wetland monitoring by industry via COSIA and by Alberta Environment and Parks (AEP). The recent advancements have created an opportunity to establish a framework for assessing reclamation success against these indicators. In addition to producing the reclamation monitoring framework, which is missing from the developed monitoring system, this project provides an opportunity to advance best practices by utilizing novel methods to quantify changes in indicators diagnostic of wetland function. Assessing these indicators efficiently can significantly reduce monitoring costs related to the assessment of reclamation success beyond the operational phase of assets. The envisioned framework is expected to leverage data generated by provincial policies and frameworks to support planning, design, construction and monitoring of reclaimed wetlands in an integrated approach as outlined by existing provincial wetland policies and objectives.

PROGRESS AND ACHIEVEMENTS

Activities completed towards achieving project goals in 2020 included:

1. Continuation of the two-year pilot monitoring plan. Identification of two additional field sites to validate experimental results.

The project team met in the spring of 2020 to discuss project progress, scope, and identify areas for improvement during Year 2 of the pilot study. A data collection and analysis plan for the 2020 field season was developed that would complement the project steps undertaken in 2019, with an increased focus on chemistry, microtopography, and water table indicators and on reclaimed and disturbed features. In addition to the four regions in the Peace River area utilized for field and UAV data collection in Year 1 of the project, two new study sites were also added to the project in 2020 and are shown in Figure 1. One bog in the Peace River area and one treed fen in the vicinity of Drayton Valley were selected to act as validation sites to test monitoring framework predictions created from data collected at the four original sites.

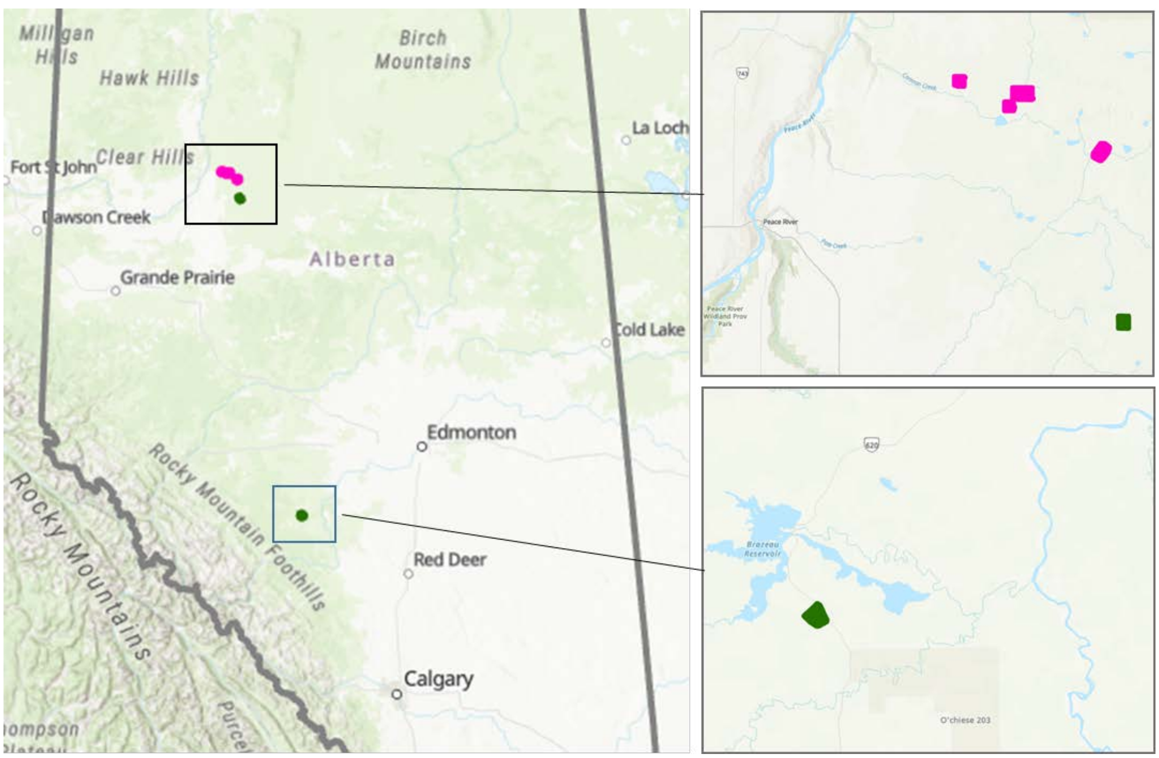

Figure 1: Location of the 2019 UAV survey sites (pink) and 2020 (green).

2. Execution and analysis of the second year of the pilot plan.

Field infrastructure, which was installed in 2019 at the four original study sites, was re-used during the 2020 field season. This includes field sensors, ground control points, hydrology wells, and select vegetation plots. Additional vegetation plots were added to the reclaimed areas and disturbed linear features (cutlines, winter roads) within the four original study sites prior to aerial data collection. The remote sensing team completed one flight of each of the six study sites in July/August 2020 during peak plant biomass. Vegetation percent cover, soil chemistry, soil moisture, and shallow groundwater levels were measured in July and August 2020 close to the time of the aerial data collection. Water samples were also collected for nutrient analysis during winter 2020/2021. A high-precision real-time kinematic (RTK) global positioning system (GPS) was utilized to record field data collection locations and to collect measurements of ground surface microtopography. Field data from 2020 will be incorporated and used to refine and validate the preliminary monitoring framework developed in year-one of the pilot study.

2020 Preliminary Results

Ground Layer Vegetation Identification from Aerial Imagery

During the winter of 2019/2020, a preliminary model was created using the 2019 leaf-on aerial imagery and field observations of vegetation percent cover within the four original study areas. During this process, it was observed that identification of ground layer vegetation (mosses, lichens, and liverwort) from the aerial imagery was inhibited by vegetation layers, which were physically positioned above the ground layer vegetation (such as trees, shrubs, and herbaceous species). As ground layer bryophytes are such an important component in boreal peatland ecosystems, the project team is currently working to establish a method for predicting ground layer vegetation based on the vegetation which is visible within the aerial imagery.

Ground Layer Vegetation Regression from Field Data

In order to predict ground layer bryophytes masked by shrubs, herbs, and tree layers (referred to as visible vegetation layers by UAV and remote sensing imageries), a regression approach was taken to associate bryophytes with visible vegetation layers using field data. Vegetation observations collected in 2020 were classified into categories of peatland moss (Sphagnum moss and true moss), weedy moss (those which grow primarily on disturbed sites), lichen, liverwort, aquatic herb, broad leaved herb, narrow leaved herb, grass, deciduous shrub, evergreen shrub, deciduous tree and conifer tree. In datasets where observations of some vegetation types were infrequent, categories may be further combined into peatland moss (Sphagnum moss and true moss), lichen (lichen and liverwort), herbaceous (broad leaved herb, narrow leaved herb, and grass), shrub (deciduous and evergreen shrub), and tree (coniferous and deciduous) for increased power in statistical analyses. A number of multiple linear regressions have been undertaken to test the significance of visible vegetation layers (coniferous trees, deciduous trees, evergreen shrubs, deciduous shrubs, broad-leaved herbs, and narrow leaved herbs) to ground layer observations of Sphagnum moss, true moss, lichen, litter, and bare peat. Refinement and validation of these linear regressions is still ongoing. However, preliminary results for Sphagnum mosses can be seen in Table 1.

One aspect of the current process is to evaluate if a predictive equation developed using data from all observed site features (natural, reclaimed, and disturbed) is appropriate for prediction of the ground layer parameter of interest on all site features, or if equations developed using data only from individual feature types are needed for predictions within those areas. Root mean square error (RMSE) was calculated for each regression equation to evaluate its accuracy in predicting Sphagnum moss in the different area types and is presented along with the regression equations in Table 1.

Following validation of the regression results and selection of the most appropriate equations to predict ground layer features, the selected regression equations will be incorporated into the aerial imagery classification model for increased accuracy.

Table 1: Preliminary multiple linear regression results for Sphagnum mosses based on visible vegetation layers. R^2 adjusted describes the explanatory power of the model, adjusted for the number of predictors included. R^2 predicted describes the ability of the model to predict responses for new observations. RMSE describes the error in the model at predicting observations.

Dataset	Equation	R^2 adjusted	R^2 predicted	RMSE general area	RMSE reclaimed	RMSE disturbed	RMSE natural
All Areas	Sphagnum = 37.94 - 0.601 NLHERB + 0.403 EVGSHB + 1.666 DCDTR	30.11	28.36	32	23	-	-
Natural	Sphagnum = 27.35 + 0.445 EVGSHB	12.17	8.46	-	30	-	36
Reclaimed	Sphagnum = 36.4 + 1.992 EVGSHB - 5.03 SQRTNLHERB	72.81	58.39	-	14	-	-
Disturbed	Sphagnum = 68.75 - 0.931 NLHERB	19.64	16.17				

UAV Imagery Collection in 2020

In August 2020, the four sites from 2019 plus two additional sites in the Peace River region of Alberta were imaged with the same Altum six-band multispectral imaging sensor used in the 2019 surveys. A new UAV platform, which allowed for lower flights, improved the resolution of the captured multispectral imagery from 10 cm (as in the 2019 surveys) to 6 cm. A natural colour RGB (Red, Green and Blue) survey at 1 cm spatial resolution was collected over the two new sites. Acquired in the late summer of 2020, this survey captured the vegetation in leaf-on conditions.

UAV Processing of 2019 Data

Data analysis completed in 2020, as discussed below, used the datasets collected in 2019. Analysis of the 2020 datasets is currently underway.

A random forest classification algorithm was used on the following channels: Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil Adjusted Vegetation Index (SAVI), Modified Soil Adjusted Vegetation Index (MSAVI2), Enhanced Vegetation Index (EVI), Chlorophyll Index Red Edge, texture values of entropy, contrast and Geary's C, slope and hillshade. These channels were found to enhance the discernible spectral characteristics of the vegetation of interest. The model was trained and tested using a combination of ground-truth (field survey) data and visual interpretation of the 1 cm RGB imagery. Forty percent of the training sites were used to validate the model.

The same methods established for the analysis of the 2019 collected datasets were used to classify the vegetation cover at a species level from the multispectral imagery. These methods included both pixel based classification and object based image analysis (OBIA). The results and vegetation classes are shown in Table 2. The OBIA method reached an overall accuracy of 53%, and the pixel-based classification method achieved an overall accuracy of 87%. Due to the outstanding performance of the pixel-based classification method only those results are described in this report.

As summarized in Table 2, users and producers accuracy provided better than 70% in all classes except for Broad Leaved Herb (BLHERB) at 65%. The results showed a consistent misclassification in the (BLHERB) class, which was often confused with Narrow Leaved Herb (NLHERB). All tree species were classified with more than 90% accuracy. Moss species (True Moss and Sphagnum) resulted in over 90% accuracy while shrubs resulted in approximately 75% accuracy. Barren and open water were consistently classified at 99% accuracy in all cases. Based on these results, the pixel based method, using Random Forest algorithm, was selected for all future vegetation classification for images taken during the leaf-on season.

Table 2: Users and Producers Accuracy summarized per class

CLASS	CLASS NAME	CLASS_ID	COLOUR	ACCURACY
SPHGNM	Sphagnum	1		0.90
TRMS	True Moss	2		0.93
LICHEN	Lichen	4		0.79
LITTER	Litter / Coarse Wood Debris	5		0.82
CNFRTF_PM	Conifer Tree - Picea Mariana	6		0.91
CNFRTRLL	Conifer Tree - Larix Laricina	7		0.92
DCDTR	Deciduous Tree	8		0.98
EVGSHB	Evergreen Shrub	9		0.79
DCDSHB	Deciduous Shrub	10		0.75
BLHERB	Broad Leaved Herb	11		0.65
NLHERB	Narrow Leaved Herb	12		0.83
AQUATIC	Aquatic Herb	13		0.93
GRASS	Grass	14		0.84
OP	Open Water	15		0.99
BARREN	Urban / barren	16		1.00
TOTAL ERROR				**0.87**

Figure 2 shows a representation of the classification process that starts with a natural colour survey of a complex study site (left image), followed by the multispectral data and relevant indexes calculated as additional channels (centre). The right image of Figure 2 shows the predicted values extracted from the classification results obtained after performing the machine learning classification algorithm. The process was executed on the four study sites at the same time to leverage the variability of the classes. The model established will be applied to the multispectral images collected in 2020.

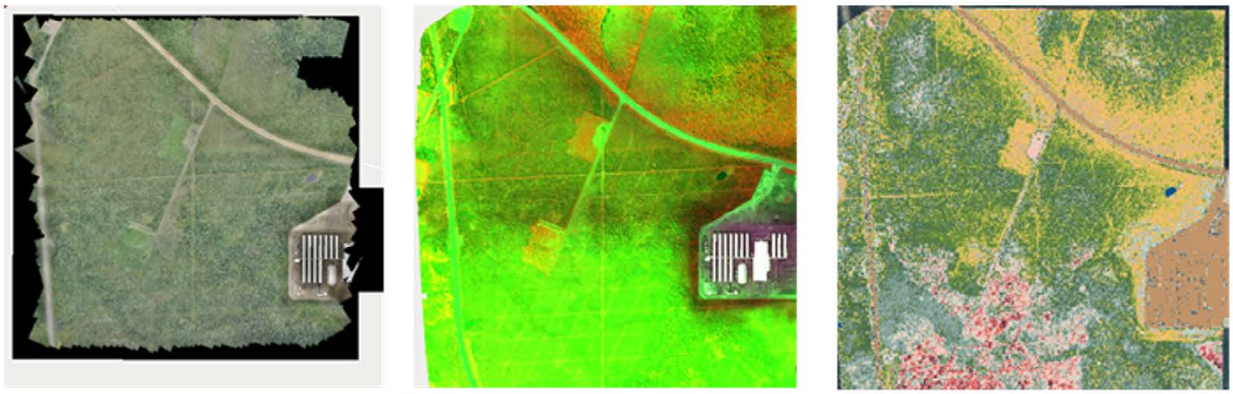

Figure 2: Natural colour imagery (left), multispectral imagery (centre) and classification results at AOI3-Skeg.

Microtopography

A preliminary workflow has been developed to extract a Digital Terrain Model (ground) from the raw point cloud data of the Digital Surface Model (includes vegetation canopy), collected by the UAVs during the surveys, to produce a microtopography layer. The methodology consists of filtering all the non-ground points from the point cloud, labelling them as noise and eliminating them before rasterizing and finally comparing them with ground truth measurements (Polat and Uysal, 2017). This procedure is computationally intensive and performed in a cloud-based virtual machine designed for 3D processing.

LESSONS LEARNED

A number of lessons have been learned from the work conducted in 2020 and are discussed in this section. The final Monitoring Framework report will contain a list of the total lessons learned over the course of the project. These lessons will allow others to plan and execute reclamation monitoring programs more efficiently and at a lower cost.

The preliminary results indicate that a regression relationship can be developed between ground layer vegetation and visible vegetation layers using field data. Additional parameters (i.e., soil moisture, pH, Electrical Conductivity [EC], microtopography) could be included to further increase the accuracy. Ultimately, UAV and remote sensing tools can be used to estimate various aspects of natural, disturbed, and reclaimed peatland sites needed for management and reclamation assessments.

The experiences with analyzing the datasets collected in 2019 identified that hand-held GPS units were not accurate enough for the centimetre-scale resolution of the collected imagery. Considerable effort was spent using the 1 cm RGB imagery and the experience of the team to manually classify the vegetation in the training area pixels. To avoid this in 2020 acquisitions, the team added an RTK GPS to increase the latitude and longitude accuracy of the collected field samples. The enhanced accuracy of the RTK GPS will diminish the need for visual interpretation of the imagery to manually classify the training pixels and reduces the requirement for RGB images in future studies.

It was identified that in an ideal case, the field survey data used in the classifier training needed to be conducted at a granularity similar to the resolution of the multispectral imagery and contain one class of vegetation. In reality, finding samples of only one species is not usually possible and it was necessary to infer the presence of the other species in order to provide a spectral signature for those species. A pixel unmixing method was used. It consists of finding the spectral information of pixels that corresponds to a single vegetation class and avoiding the end member pixels of the same class. In other words, the objective is to filter out pixels containing more than one feature coverage type that results in a mixed pixel. This method requires consistency in the use of pure pixels in order to detect the spectral separability of the ground layer classes versus the herbs and/or shrubs (Hsieh, Lee and Chen, 2001) and to produce a spectral signature that helps to improve the prediction of sphagnum and moss mixed classes.

A combined classification analysis that included imagery acquired during leaf-on (summer) and leaf-off (early fall) conditions was planned. However, due to a non-uniform, random misalignment of 3 to 7 pixels between the leaf-on and leaf-off acquisitions observed in most of the training sites, the two datasets could not be stacked and aligned as required for the analysis. Consequently, in order to include the leaf-off, a completely new set of training data would be required to create a second set of classification results. In consideration that the main purpose of the second (leaf-off) survey was to enhance the classification of bryophytes, the team decided not to add the leaf-off season images as part of the classification methodology. At these high resolutions, small non-uniform offsets in the imagery can cause large issues for the analysis and highlighted the importance of collecting the UAV imagery during optimal environmental conditions.

LITERATURE CITED

Hsieh, P. F., Lee, L. C., and Chen, N. Y. (2001). Effect of spatial resolution on classification errors of pure and mixed pixels in remote sensing. *IEEE Transactions on Geoscience and Remote Sensing*, *39*(12), 2657–2663. https://doi.org/10.1109/36.975000

Polat, N., and Uysal, M. (2017). DTM generation with UAV based photogrammetric point cloud. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *42*(4W6), 77–79. https://doi.org/10.5194/isprs-archives-XLII-4-W6-77-2017

PRESENTATIONS AND PUBLICATIONS

Due to COVID-19 associated restrictions and the development stage of the project, the project teams have not been able to present or publish preliminary results. There will be opportunities in the Spring of 2021 to publish once the models are developed.

RESEARCH TEAM AND COLLABORATORS

Institutions: LOOKNorth[1], NAIT Centre for Boreal Research[2], C-CORE[3]

Principal Investigators: Mark Kapfer[1], Bin Xu[2], Garrett Parsons[3]

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Meyra Fuentes	C-CORE	Remote Sensing Engineer		
Rebekah Ingram	NAIT Centre for Boreal Research	Research Associate		
Melanie Bird	NAIT Centre for Boreal Research	Research Officer		
Frankie NcCorchuk	NAIT Centre for Boreal Research	Research Assistant		
Dani Degenhart	Natural Resources Canada	Research Scientist		
Jaime Pinzon	Natural Resources Canada	Restoration Ecology Scientist		
Neal Tanna	Innotech Alberta	Research Scientist		
Cassidy Rankine	Rankine Geospatial	Owner		

SOILS AND RECLAMATION MATERIAL

Topsoil Replacement Depth Study

COSIA Project Number: LJ0335

Research Provider: NAIT Centre for Boreal Research

Industry Champion: ConocoPhillips

Industry Collaborators: CNOOC Petroleum North America ULC

Status: Year 0 of 5

PROJECT SUMMARY

Approvals issued for in situ facilities under the Alberta Environmental Protection and Enhancement Act typically require operators to place a minimum of 80% of site pre-disturbance topsoil to ensure that the entire area has a uniform placement of topsoil during reclamation. The topsoil depth target of 80% relative native soil is also part of the 2010 reclamation criteria for well sites and associated facilities.

The application of approaches developed under an agricultural context often results in reclaimed areas being uniformly capped with topsoil when heterogeneity in placement depth is in reality more desirable and more similar to a natural forest system. Though heterogeneity of both site and plant community targets are acceptable and even desirable goals in the 2010 reclamation criteria — and the guidelines allow for stratification during certification assessments — no guidance is provided on how to achieve these goals. The ability to vary soil-cover design depths also has implications for optimizing the placement of available topsoil where the objective is to achieve the best reclamation outcomes across multiple sites where some may be locally deficient in available topsoil.

There has been significant interest in coversoil placement depths in mining (i.e., Farnden et al., 2013), but less attention has focused on the evaluation of recommended topsoil capping depths (80% threshold target) for smaller-scale industrial disturbances such as those at in-situ and conventional oil and gas sites. This study encompasses four trials aimed at investigating both the effect of limited capping depths on forest establishment (Trial 1), as well as alternative approaches to mitigate for potential limitations associated with shallow topsoil capping on industrial disturbances in the boreal region (Trials 2 to 4). The study site is a former gravel pit, approximately 15 hectares in size, which will allow for sizeable plot installations with replication of treatments.

The specific context and objectives of each trial are described below:

Trial 1: Effects of topsoil replacement depth on forest establishment

The purpose of this investigation is to evaluate the effect of capping depth on forest regeneration and soil properties. This trial will comparatively evaluate three topsoil capping depth targets (no topsoil, shallow [5 cm] and standard [20 cm]) in a randomized complete block design. Recognizing that there will be variation around these targets, especially if the topsoil is placed under frozen conditions, it is anticipated that the shallow depth will vary from 0 cm to 10 cm and the standard depth will vary from 10 cm to 20cm.

A lack of native seed propagules as well as early invasion by non-native species are two potential constraints with limited (or no) topsoil placement. This trial will attempt to mitigate these concerns using two approaches.

First, numerous plant species will be planted in order to evaluate species-specific survival and growth responses. In addition, intentional planting of native forbs specifically will be done through hitchhiking with jack pine (*Pinus banksiana*) or white spruce (*Picea glauca*) since this planting prescription may be beneficial to increasing the initial coverage and diversity of native understory species.

The second approach will be an operational-scale test of strip-applied pre-emergent herbicide that will be applied as a split-plot treatment within each capping depth plot replicate. This treatment will create growing space for nursery stock seedlings, thereby potentially speeding the development of woody plant cover while concurrently reducing the cover and dominance of non-native species.

The following questions will be answered through this trial:

1. In an operational setting with placement of soil under frozen conditions, how closely does the resultant topsoil depth match the planned topsoil depth and how does this change through time? (as measured later in the same year after placement and thawing, and again after one and four years)
2. What is the impact of topsoil depth placement on native understory species?
    a. Does the absence of topsoil preclude development of a forest plant community?
3. What are the impacts of topsoil placement depth on the;
    a. Survival of planted woody species?
    b. Natural ingress of woody species?
    c. Growth of woody species?
4. How does the application of a pre-emergent herbicide affect;
    a. The ingress of non-native species, particularly where no topsoil has been placed?
    b. Survival and growth of planted woody species?

Trial 2: Nutrient loading with organic forms of nutrition to improve early growth following field out-planting (i.e., giving seedlings a lunchbox before their field trip)

Another often cited motivation for utilizing topsoil is the soil nutrition present in this medium. In a separate investigation (LJ0226 Interim Reclamation), researchers have observed some evidence, in some species, that supports this assertion. While broadcast application of fertilizers or other forms of organic amendments is possible, there are often unintended consequences. Namely, there may be increased competition from the grasses and other herbaceous species that are quick to capitalize on the abundant nutrient availability. An alternative approach could be to provide a more localized source of nutrition to the seedlings, thereby reducing the site-wide flux in soil nutrients.

Recently at the NAIT Centre for Boreal Research (CBR) in Peace River, a preliminary study was conducted to examine the concept of creating a 'lunchbox' for seedlings by incorporating different rates of alfalfa pellets in containers planted with two deciduous tree species (aspen and paper birch). This study found that alfalfa pellets applied at 10% and 20% of the total planting container cavity volume led to a 50% increase for all measured plant growth parameters — including seedling height, root collar diameter, leaf biomass and stem biomass — when compared to plants grown in containers with lower rates of alfalfa pellet incorporation.

Although the pilot study confirmed that it was possible to grow these seedlings, a field test to validate real-world growth is still required. Utilizing the positive results from this bench scale test, a plot-scale field study is proposed to further validate this 'lunchbox' approach to seedling growth against conventionally grown seedlings, as well as against nutrient loaded seedlings developed with inorganic fertilizers (following Schott et al., 2013; Schott et al., 2016). Four commonly occurring tree species will be evaluated including white spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*).

The objectives of this trial are to:

1. Compare the post out-planting growth and survival of nursery tree seedlings that are nutrient loaded through conventional means (inorganic fertilizer) versus those grown with the inclusion of an organic form of nutrition (alfalfa pellets).
2. Evaluate these 'improved' stock types under contrasting reclamation conditions;
    a. the span of soil placement depths (no topsoil, shallow or standard); and
    b. high versus low competition (no topsoil treatment only).

Trial 3: Hitchhiking native forbs with contrasting woody species: using the principle of hitchhiking forbs for varying purposes

Hitchhiking multiple plant species in the same nursery plug has two key benefits including a direct increase in on-site species diversity and a cost reduction associated with planting. Even though larger containers are utilized, raising the per seedling cost and concurrently reducing the rate at which planters can plant these seedlings, the overall cost is still approximately 20% lower due to increased efficiency (i.e., shared plug, two plants established in one planting hole). There is also added logistic simplicity in reducing the number of individual plant orders made and coordinated. Incorporating or 'hitchhiking' native forbs into the same container as a shrub or tree is a potential means of efficiently establishing native forbs on a disturbed site. This concept was previously explored with white spruce (*Picea glauca*) and two different native forbs (*Chamerion angustifolium* and *Eurybia conspicua*), where these mixed-species plugs were successfully grown and established in a variety of reclamation sites (Mathison, 2018). Three different deciduous species (*Betula papyrifera, Alnus viridis* and *Salix discolor*) were also hitchhiked with fireweed with some success — though the interspecific competition was more challenging (Hudson, 2020). While these studies have provided a framework from which to provide guidance on the use of this type of nursery stock, much of this research had focused on hitchhiking with fireweed and additional research is still required to examine other woody plant–forb mixtures and optimize their production.

This trial will evaluate three deciduous species, each representing different growth forms or growth strategies, in combination with one of three native forbs that also vary in their growth morphology as well as in known rates of spread and egress. These seedlings will be established in four contrasting condition types within the Trial 1 study design to evaluate the utility of these stock types across the span of capping depths (no topsoil, shallow or standard) and in high versus low competition (no topsoil capping depth only).

Trial 4: Hitchhiking ericaceous shrubs with conifers

As described above, a concern with not placing topsoil is the potential lack of seed propagules of native species. As in Trial 3, the concept of planting additional species is one approach to mitigate for this concern. Trial 4 will examine another configuration of hitchhiker seedlings. It will combine low-growing ericaceous shrubs (bog cranberry [*Vaccinium vitis-idaea*], common blueberry [*Vaccinium myrtilloides*] or Labrador tea [*Rhododendron groenlandicum*]) with coniferous tree species (jack pine [*Pinus banksiana*] or white spruce [*Picea glauca*]). Although, NAIT Centre for Boreal Research has previous experience growing these mixtures of species the logistics of combining two slow-growing species are quite distinct from the constraints and challenges found in Trial 3 using deciduous species.

The ericaceous shrubs must be started six to eight weeks ahead of the conifers due to their extremely slow growth.

These shrubs can either be grown in trays or mini-blocks and then transplanted into the primary container with the emerging conifer, or they can potentially be grown in this cavity from the beginning thereby reducing the number of handling times required. A potential issue with this second approach is the development of mosses or liverworts that may inhibit seed emergence of the conifer which will be sown many weeks after sowing the shrub. This trial will evaluate both approaches in order to provide empirical evidence to support the most cost-effective and practical approach. In addition, these seedlings will be out-planted across the range of capping depths in order to evaluate the conditions that are conducive to the healthy growth and persistence of these species combinations.

Relevance of study to industry

The product of this work can be used as the basis to support soil cover design for both in-situ and conventional operations that incorporate varying topsoil depths. This study should also provide evidence to support increasing flexibility for operators to move topsoil between dispositions to focus on reclamation outcomes rather than following a prescriptive approach to topsoil placement (i.e., use the topsoil where it is most needed). In addition, this study will also provide practical tools that operators will be able to employ to mitigate potential concerns with areas of limited topsoil placement. Overall, the results of this study are envisioned to support improved reclamation outcomes across the boreal forest.

PROGRESS AND ACHIEVEMENTS

Experimental seedlings for Trial 2 and Trial 3 (paper birch and balsam poplar) were produced at the CBR greenhouse in 2020 in preparation for field establishment in spring 2021. The buffaloberry mixtures will be produced in 2021.

Higher concentrations of alfalfa (1:2) delayed seed emergence for all tested species resulting in plants of smaller stature and leaf development throughout the growth cycle (Figure 1). Nevertheless, extractable seedlings were produced; though the relative quantity of viable plants tended to be lower relative to the other treatments.

Hitchhiking native forbs with deciduous tree species is a delicate process, as both species have a tendency to grow quickly. Comparing treatments, it was found that; goldenrod was the most aggressive in terms of growth; showy aster to be similar to goldenrod in terms of competitive root development but did not grow tall (and therefore was less likely to shade out the tree species); and dogbane was substantially less competitive both in terms of root development as well as shoot growth (Figure 2). Goldenrod tolerated later sow dates more readily compared with both showy aster and dogbane; in addition, goldenrod sown at later dates tended to overtake the tree species sown at the earliest dates.

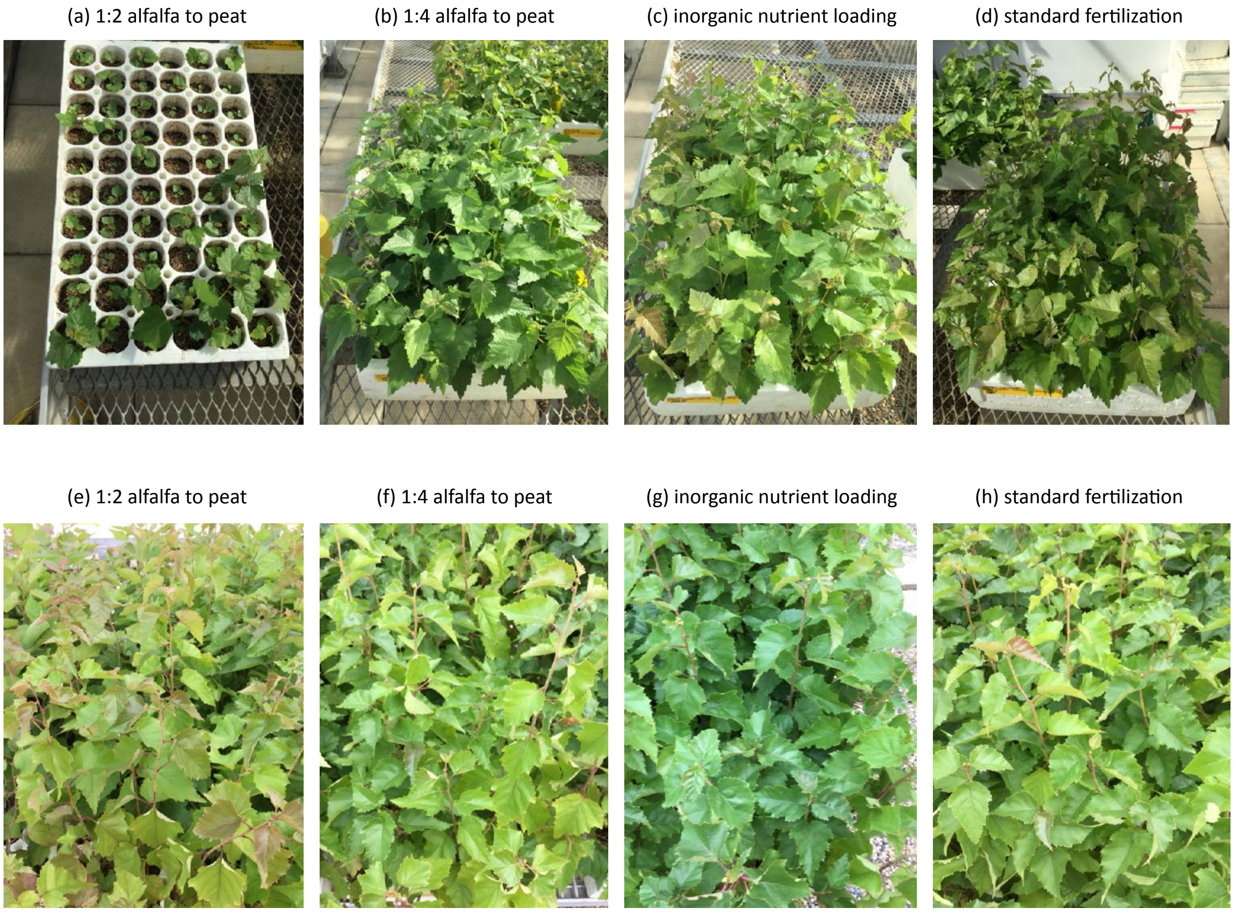

Figure 1: Example of Trial 2 experimental seedlings illustrating paper birch on July 6, 2020 (a to d) and August 20, 2020 (e to h).

Figure 2: Example of Trial 3 experimental seedlings on August 20, 2020. The treatments illustrate paper birch growing with each of the three forbs where the forb was sown into the styroblock 0, 2 or 4 weeks following the sowing of paper birch (which was sown on May 13, 2020).

LESSONS LEARNED

This project is in initial stages and there are no lesson learned for 2020.

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Hudson, J. J. 2020. An evaluation of hitchhiker seedlings with native boreal species as a revegetation tool of industrially disturbed sites in Alberta, Canada. MSc thesis, Department of Renewable Resources, University of Alberta. 162 pages.

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Schott, K. M., Snively, A. E. K., Landhäusser, S. M. 2016. Nutrient-loaded seedlings reduce the need for field fertilization and vegetation management on boreal forest reclamation sites. New forests 47: 393-410

Schott, K. M., Pinno, B. D., Landhäusser, S. M. 2013. Premature shoot growth termination allows nutrient loading of seedlings with an indeterminate growth strategy. New Forests 44: 635-647

PRESENTATIONS AND PUBLICATIONS

No public presentations or publications in 2020.

RESEARCH TEAM AND COLLABORATORS

Institution: NAIT Centre for Boreal Research

Principal Investigator: Dr. Amanda Schoonmaker

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
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*Students assisted with the greenhouse propagation work at various stages in 2020.

Research Collaborators: Dr. Dani Degenhardt, Northern Forestry Centre, Canadian Forest Service

REVEGETATION

Cluster Planting

COSIA Project Number: LJ0314

Research Provider: NAIT Centre for Boreal Research

Industry Champion: ConocoPhillips

Industry Collaborators: CNOOC Petroleum North America ULC

Status: Year 4 of 4

PROJECT SUMMARY

Most of the current knowledge and best practices for tree establishment in Alberta are founded on practices developed in the forest industry that optimize productivity of commercial forest tree species intended for merchantable harvest. However, the goal of many reclamation operations, as directed by current regulatory criteria, is less focused on merchantable timber (though this is often still an objective) and rather more on whether a functional, resilient, native vegetation community becomes established on the reclaimed site. Regeneration of deciduous tree species after other commonly occurring disturbances, such as fires and forest harvesting, is often patchy with uneven distribution of trees. Establishing these species in a similar manner on disturbed industrial sites will likely lead to a more natural, heterogeneous landscape with diversity in vegetation structure. This diversity in structure may allow other native species to ingress, leading to faster site recovery and vegetation resilience. Due to slower growth rates of nursery stock deciduous seedlings, non-native and fast-growing ruderal species may achieve site occupancy first and compromise reclamation success. Using cluster planting (i.e., the overwhelming of portions of a site with planted native tree species) may therefore be a viable alternative approach that could preclude the development of ruderal species and enhance regeneration capacity of other native species that ingress over time.

The concept and evaluation of cluster planting is being tested within two recently reclaimed industrial sites. Comparisons of tree establishment, early growth and surrounding vegetation development around uniformly planted (non-clustered) seedlings and cluster-planted seedlings are being undertaken.

This trial will evaluate two factors to answer questions related to the size of a cluster and spacing of deciduous tree seedlings within clustered planted arrangements. Three sizes (dimensions) of clusters were used; tree seedlings were planted at 0.75 m spacing within clusters of 3 m x 3 m, 5 m x 5 m or 7.5 m x 7.5 m. The performance of the seedlings in the clusters is compared against seedlings planted individually at a conventional spacing of approximately 1.4 m. The effect of seedling spacing within a cluster is tested by spacing seedlings at 0.5 m, 0.75 m or 1.0 m in the same size cluster of 5 m x 5 m. The layout of each treatment combination was spaced in order to achieve a density of 5,000 stems ha^{-1}. The following three deciduous tree species were combined within all cluster treatment types noted above:

- Aspen (*Populus tremuloides*), 25% composition
- Paper birch (*Betula papyrifera*), 50% composition
- Balsam poplar (*Populus balsamifera*), 25% composition

Different cluster sizes and within-cluster plant spacing is evaluated based on the following:

1. Does the physical size (dimensions) of a cluster of deciduous trees impact the early growth and development of individual trees? Is there a difference in understory vegetation development within and adjacent to differently sized clusters?
2. Is it better to create clusters with tighter plant spacing (shortening time to canopy closure but increasing space between clusters)?
3. Does the clustering of deciduous woody species improve the growth and survival of those trees compared to single seedlings?
4. Does cluster planting support the establishment, maintenance and ingress of desirable native plant species?
5. Does cluster planting prevent or reduce the dominance of undesirable non-native plant species?

This project is replicated at two operating in-situ facilities: ConocoPhillips's Surmont facility (ConocoPhillips) and the CNOOC Long Lake facility (CNOOC). These operations are within 15 km of each other and approximately one hour southeast of Fort McMurray. The ConocoPhillips site is comprised of two recently reclaimed borrow pits: #1, reclaimed in the summer 2016; and #5, reclaimed in November 2016. The second study location, CNOOC, which is a 2.5 ha reclaimed sump, was reclaimed in November 2017. The ConocoPhillips site was largely level with some rolling features as this was a borrow pit cut from an existing hill and the CNOOC site was level; both sites were surrounded by young forest stands (as a result of forest harvesting and fires) and were adjacent to gravel roads. At the ConocoPhillips site, each treatment was replicated seven times for the cluster size factor and four times for the seedling spacing factor, while at the CNOOC site, each cluster size factor and seedling spacing factor was replicated five times. Treatment factors were randomly assigned within replicate blocks (where each block contained six clusters of each treatment combination) across each of the two study locations (refer to Figure 1 for examples of layout of a replicate block of each treatment combination).

Similar reclamation instructions were given to the earthworks crews at all three sites, to reclaim as per the site-specific reclamation commitments associated with each disposition with the additional request to make the surface soils on the sites rough and loose. Earthworks at borrow pit #1 occurred under wet conditions leading to a smoother and perhaps more compacted site than desired, whereas borrow pit #5 was completed under drier conditions which achieved slightly better surface roughness. At the CNOOC site, a dozer with a six-way blade furrowed the entire site where the individual furrows (25 cm to 50 cm in height) were spaced approximately two to three metres apart. The objective of furrowing was to create greater surface heterogeneity. Field establishment of seedlings occurred at the ConocoPhillips site in spring 2017 and at the CNOOC site in spring 2018. In addition, a pre-emergent herbicide was incorporated into the study design at the CNOOC site based on concerns regarding vegetation competition observed at the ConocoPhillips location.

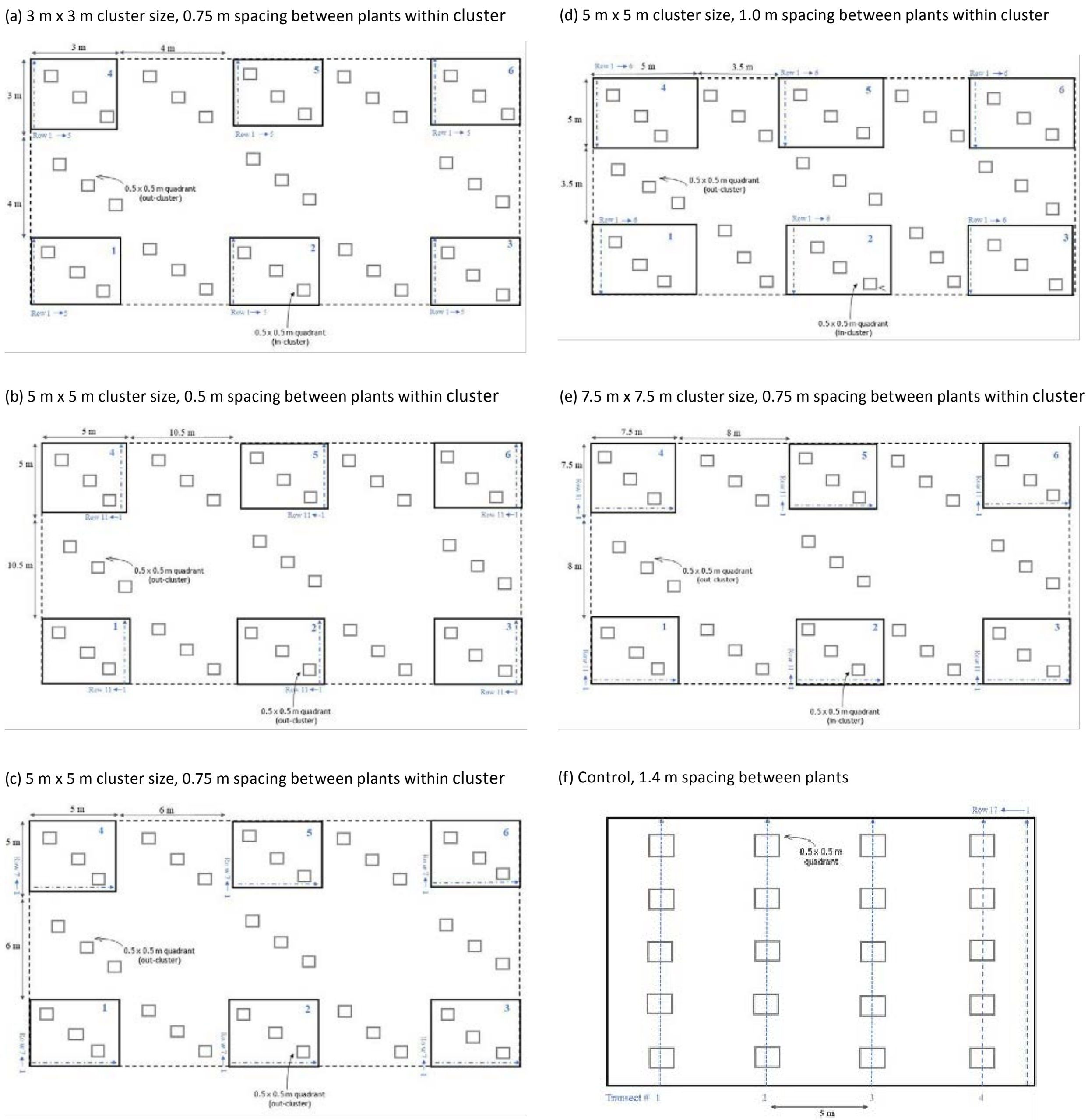

Figure 1: Diagram of an experimental plot. Example shows one experimental block representing each cluster size factor (individual clusters of seedlings are shown in black squares) and spacing factor. **(a)** 3 m x 3 m with 0.75 m spacing, **(b)** 5 m x 5 m plot with 0.5 m spacing, **(c)** 5 m x 5 m plot with 0.75 spacing, **(d)** 5 m x 5 m plot with 1 m spacing, **(e)** 7.5 m x 7.5 m plot with 0.75 m spacing, **(f)** control, conventionally planted seedlings (1.4 m between plants). Presence and total height of all seedlings within the treatment blocks were measured and this diagram illustrates individual vegetation survey points (0.5 m x 0.5 m quadrat) by grey squares.

PROGRESS AND ACHIEVEMENTS

The Year 3 measurements at the CNOOC study site were completed in August 2020 (the ConocoPhillips study site Year 3 measurements were completed in 2019). The results are still being processed. However, the following key observations are noted:

- Canopy closure has been observed in some (though not all) clustered plant treatments (Figure 2); this is closely tied to the growth rate of trees within individual clusters. It is notable that few instances of canopy closure were observed at the ConocoPhillips site in Year 3 (2019) and this is almost certainly attributable to differences in tree growth rates at these study sites.
- There is a high degree of variation in tree cluster growth across the CNOOC study site (Figure 3). As competition was not a contributing factor at the time of establishment (due to use of pre-emergent herbicide), these differences are more likely driven by soil properties. Project researchers are currently examining soil-based drivers on tree growth in this study.
- Researchers continue to observe that total height of all deciduous tree species at the CNOOC site has exceeded those at the ConocoPhillips site even though the ConocoPhillips site was planted one year earlier (Figure 4). These study sites are located less than 15 km apart, within the same seed zone (CM 3.1). Soil preparation activities and the timelines between site reclamation and planting were similar between the study sites. Soil bulk density from 0 cm to 30 cm depth was found to be similar between the sites. It is hypothesized that this marked difference is most likely due to reduced initial herbaceous plant competition (as the CNOOC site had a pre-emergent herbicide applied immediately prior to planting). However, the possibility of inherent differences in soil chemical parameters cannot be ruled out. Further study will be required to support or refute this hypothesis. (Study 2 of Project LJ0226 Interim Reclamation)

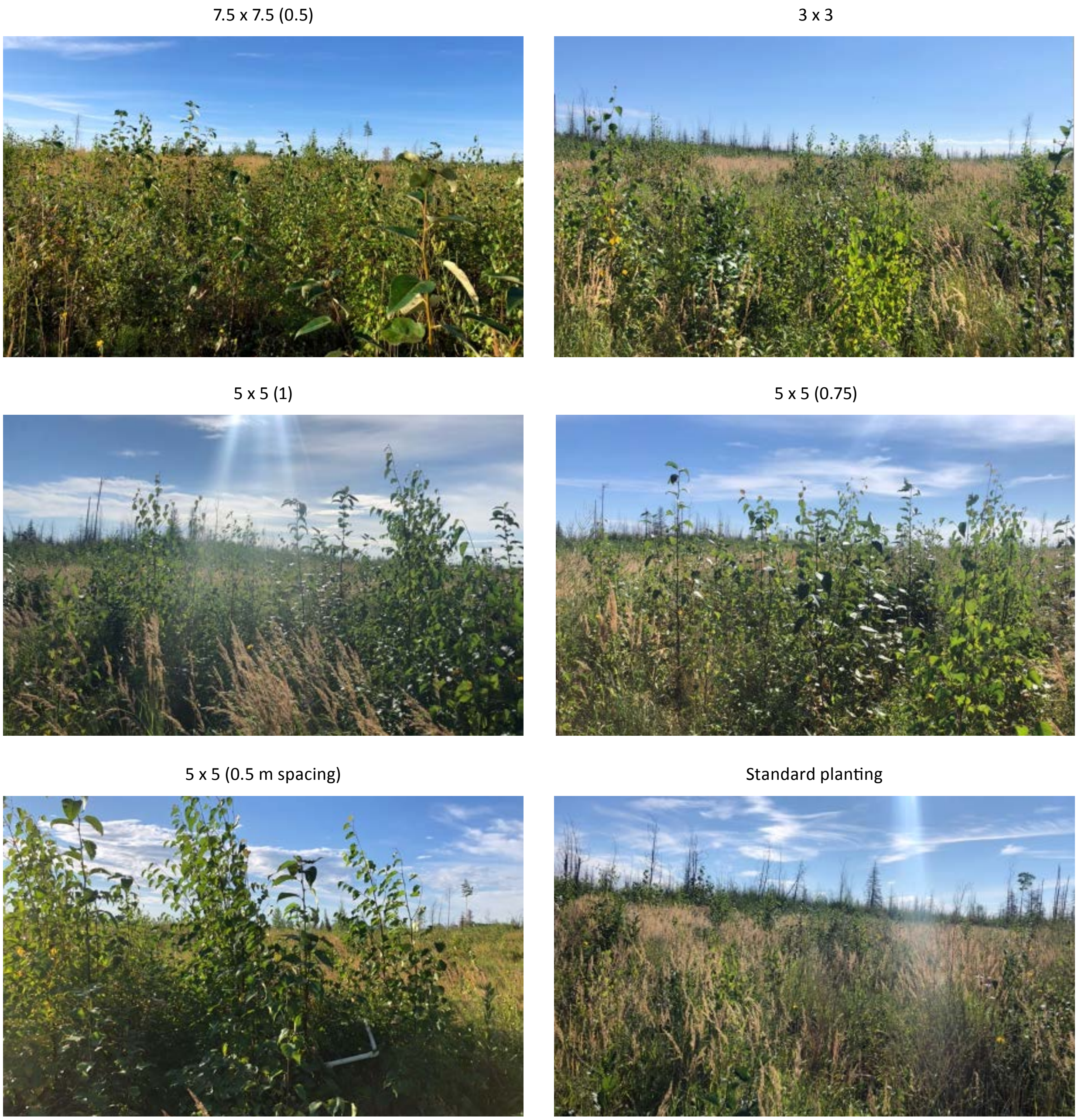

Figure 2: Images taken in August 2020 illustrating the cluster size treatments as well as conventionally planted treatments.

(a) (b)

Figure 3: Illustration of the variation in tree growth at the CNOOC study site in August 2020; both images illustrate a 7.5 m x 7.5 m sized cluster of planted deciduous trees. The blue arrow in (b) shows the boundary of the cluster of trees.

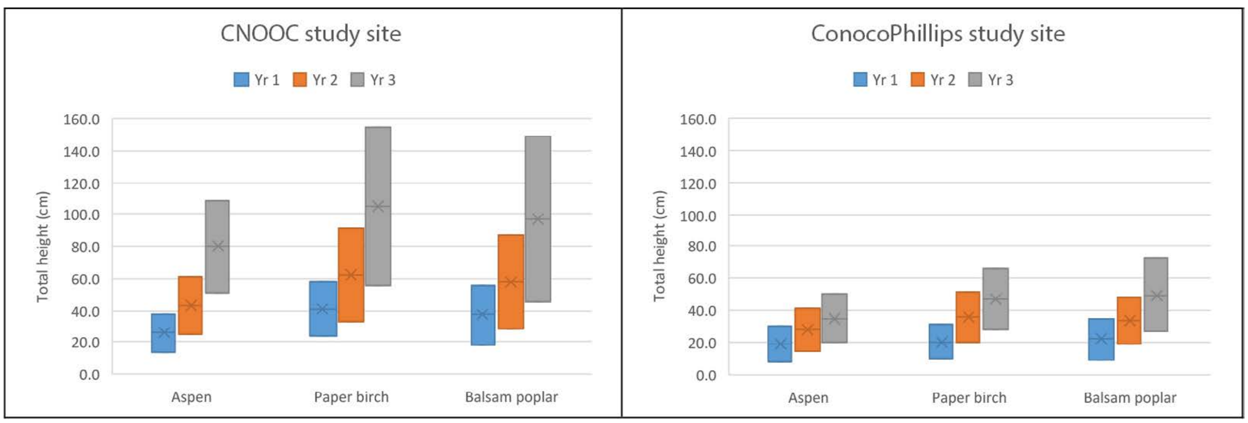

Figure 4: Boxplots showing descriptive statistics for the three deciduous tree species established at the CNOOC and ConocoPhillips study sites across three growing seasons (years). Mean values are shown by the crossed-line and one standard deviation of the mean is represented by the outer boundaries of the boxes (n = 1771-6437 individual tree heights).

LESSONS LEARNED

While recommendations regarding specific cluster-planting prescriptions cannot be made at this time, what this study has so far clearly demonstrated is the sizeable negative impact that competing herbaceous vegetation can have on rates of growth of the three deciduous tree species under evaluation. Reducing this initial competition has resulted in a doubling of total height for all species after only three years of growth.

PRESENTATIONS AND PUBLICATIONS

No presentations or publications in 2020.

RESEARCH TEAM AND COLLABORATORS

Institution: NAIT Centre for Boreal Research

Principal Investigator: Dr. Amanda Schoonmaker

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Dr. Mark Baah-Acheamfour	NAIT Centre for Boreal Research	Research Associate		
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Erin Laxton	NAIT Centre for Boreal Research	Student Research Assistant	2019	2021

Research Collaborators: Dr. Brad Pinno, University of Alberta (formerly Canadian Forest Service); Dr. Simon Landhäusser, University of Alberta

Improving Establishment Success and Early Growth of Trembling Aspen

COSIA Project Number: LJ0255

Research Provider: Canadian Forest Service, Natural Resources Canada

Industry Champion: Imperial

Status: Year 6 of 6

PROJECT SUMMARY

The purpose of this project is to address field observations that trembling aspen (*Populus tremuloides* Michx.) seedlings planted on newly reclaimed in situ oil sands sites often have poor survival after outplanting, and when they do survive, exhibit poor growth and form. It is hypothesized that the lack of appropriate soil fungi (mycorrhizae) could be contributing to these observations.

In the fall of 2015, the community of fungi associated with aspen roots at undisturbed (natural) and reclaimed sites (NN-Borrow and D-East Borrow) at Imperial's Cold Lake Operations was assessed using traditional culturing techniques, greenhouse studies and next-generation DNA sequencing. A total of 28 taxa of root associated fungi were cultured from aspen root systems, the majority of which were saprophytes (including seven species with known mycorrhizal properties). Ectomycorrhizal fungi were observed on the roots.

In 2016, a year following reclamation, the fungal communities present at the D-East Borrow site were studied along three transects that started 10 m inside the interior of undisturbed forest, crossed the forest edge and ended 40 m into the reclaimed area. Differences in fungal communities were observed at different points along the transects using Illumina DNA sequencing. Within the interior of the forest, ectomycorrhizal fungi were more common, while in the reclaimed areas arbuscular mycorrhizae and saprophytes were more common. These field assessments have demonstrated that soil fungal communities do exist within the root systems of aspen growing in reclaimed areas, that they may improve aspen survival, and that natural areas of adjacent undisturbed forest can act as a source of ectomycorrhizal fungi that can disperse into reclaimed areas.

In 2017, two greenhouse studies were conducted at the Northern Forestry Centre (NoFC) in Edmonton, Alberta. In each study, root-associated fungi that were collected at the Imperial Cold Lake site, as well as isolates from the NoFC culture collection, were inoculated onto aspen seedlings. In both studies the growth responses were highly variable, resulting in no statistically significant difference between treatments. However, observations suggested that the uninoculated controls did not survive or grow as well compared with the aspen that were inoculated, indicating that the fungi may improve survival following planting.

In 2018, a field trial was established at the D-East borrow site to assess the effect of root-associated fungi on aspen growth and survival. A total of 360 aspen seedlings were planted into three blocks of 120 seedlings, with 20 replicate aspen seedlings for each of the five different root-associated fungi plus 20 replicates of the uninoculated control. The seedlings were measured twice in 2018.

The focus of the 2019 research was the assessment of aspen growth and survival following field trial establishment in 2018. Aspen height, diameter at the root collar and survival were measured in May and September of 2019. Overall, aspen mortality was low as 29 of 360 replicates, or eight percent of the aspen seedlings, were dead at the September assessment. Mortality was spread relatively evenly across the treatments and the three blocks. Average growth of aspen seedlings that were inoculated by all five of the different fungal species was higher than the uninoculated control. The treatment that provided the best growth resulted in an average increase in aspen height of 26 cm and diameter of 3.4 mm, compared with the control treatment which resulted in average height increase of 16 cm and diameter of 2.8 mm. However, variability was high which resulted in no statistically significant difference between treatments in height or diameter growth. The results are encouraging and as the trial progresses statistically significant results may emerge. Monitoring and measurement of the trial continued in 2020.

PROGRESS AND ACHIEVEMENTS

In the spring of 2020 due to COVID-19 restrictions, researchers were unable to measure the changes in growth and survival of the aspen at the field trial site established in 2018. However, measurements were taken in September of 2020.

Analysis of the health, survival and growth data from September 2020 indicated that there were no significant differences between treatments or blocks. The trial was established with 20 replicates of each treatment per block, across three blocks. The variation was high, leading to the finding of no significant difference. The trees are still relatively small and as the experiment progresses significant differences may arise. Monitoring and measurement of the trial will continue in the future, with two measurements anticipated in 2021.

LESSONS LEARNED

Results are now published and available online for the 2016 survey that examined how the distance from the forest edge influences fungal communities colonizing a reclaimed soil borrow site in boreal mixedwood forest.

Results for field trial initiated in 2018, to assess the effect of root-associated fungi on aspen growth and survival, are preliminary. There are no lessons learned to share at this time.

PRESENTATIONS AND PUBLICATIONS

Journal Publications

Ramsfield T., Shay P-E., Trofymow T., Myrholm C., Tomm B., Gagné P., and Bérubé J., 2020. Distance from the forest edge influences soil fungal communities colonizing a reclaimed soil borrow site in boreal mixedwood forest. Forests 11, 427; doi:10.3390/f11040427

RESEARCH TEAM AND COLLABORATORS

Institution: Canadian Forest Service, Northern Forestry Centre

Principal Investigators: Tod Ramsfield and Richard Krygier

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Colin Myrholm	Canadian Forest Service	Technician		
Bradley Tomm	Canadian Forest Service	Technician		

Restoration of Native Tree and Shrub Species on Reclaimed Grassy Sites

COSIA Project Number: LJ0291

Research Provider: Natural Resources Canada, Canadian Forest Service

Industry Champion: Imperial

Status: Year 5 of 6

PROJECT SUMMARY

The objective of the study is to determine the most effective site treatment for oil sands legacy sites (20 to 30 years old) in the boreal forest that were reclaimed using non-native grass and herbaceous species. These sites were reclaimed to the standards of the day (standards in place at the time the reclamation was completed) and have grass as the only or predominant vegetation growing on the site. The intent is to establish desirable boreal tree and shrub species so that these sites can be placed on trajectory to becoming fully functioning forest ecosystems. Restoration of forest ecosystems on these sites will reduce the area of disturbed forest and forest fragmentation impacting woodland caribou and other wildlife species.

In the spring of 2016, a field study was designed to test a range of mechanical and chemical site preparation treatments on the establishment and growth of tree and shrub seedlings. The field study was established at D63 Borrow which is located at Imperial's Cold Lake Operations. The soil is a compacted sandy clay loam with a 2 cm to 5 cm thick LFH layer. Soil pH ranged between 6.4 and 7.8 and sodium adsorption ratio (SAR) between 0.5 and 1.1. Soil nutrient concentration was approximately 4 ppm of nitrogen, < 4 ppm of phosphorus and 77 ppm to 110 ppm of potassium. The site was divided into forty, 9 m x 30 m plots in two rows of twenty and oriented north/south along the short axis of the site. Treatments were assigned randomly to each plot.

The treatments (four site preparation techniques and an untreated control) being tested are:

1. Non-selective herbicide (glyphosate) 1 m x 2 m spot spray followed by planting the next year, installation of a 40 cm tall biodegradable waxed paper tree shelter supported by a wooden stake after planting, and an additional application of a non-selective herbicide (glyphosate) around the tree shelter if required;
2 Excavator mounding of soil (mounds 30 cm wide by 25 cm long), followed by planting;
3. Excavator mounding of soil followed by the application of a non-selective herbicide (glyphosate) only over the mound area in the year of treatment, followed by herbicide before planting if needed;
4. High-speed soil mixing (160 cm wide x 140 cm long patches) followed by the application of a non-selective herbicide (glyphosate) only over the mixed area in the year of treatment, followed by herbicide before planting if needed; and
5. Untreated control.

Given the poor nutrient availability, fertilizer tablets (Forestry Suppliers 20-10-5, 21 gram) were placed by each seedling/cutting in half of the plots (randomly selected) on each site treatment. There were four replications of each site treatment/fertilizer combination.

Eighteen seedlings of white spruce (*Picea glauca* Moench Voss.) and green alder (*Alnus viridis* [Chaix] DC.), and eighteen 20 cm long balsam poplar cuttings (*Populus balsamifera* L.) were planted in June of 2017 in each of the treatments. Seedlings/cuttings were planted on the top of the mounds or in the middle of the mixed bed. The planting spot was randomly assigned to each seedling.

In 2018, two additional study sites were developed at Cold Lake Operations (J10, P3). Treatments at these sites incorporated learnings from the D63 Borrow. In J10 and P3, the pre-emergent herbicide Torpedo™ was added to the tank mix with glyphosate in the treatments where herbicides were used. In addition, the fertilizer application protocol was modified. The fertilizer tablets were placed no closer than 10 cm from the stem of the seedling/cutting. Plants were site prepared in 2018 and planted in the spring of 2019.

PROGRESS AND ACHIEVEMENTS

Overwinter survival assessment for all blocks was not completed in spring 2020 due to COVID-19 travel restrictions. Analysis of the fall 2020 growth data is ongoing.

Over all the treatments, 2020 mortality was highest for poplar, ranging between 44% and 85%, and the lowest for white spruce, ranging between 3% and 44%.

Poplar mortality was significantly less ($p \leq 0.05$) in the mixing with fertilizer treatment when compared to the no site preparation plots, where the highest mortality occurred.

White spruce mortality was highest in the herbicide plus shelter treatment, the best treatment being the mounding plus herbicide treatment with fertilizer when compared to the no site preparation plots.

Alder mortality ranged between 29% and 71%. The mixing with herbicide treatment had significantly less ($p \leq 0.05$) mortality than the two no site preparation treatments which had the highest mortality.

Unlike earlier findings for D63 Borrow, for all species and within all site treatments there was no significant difference ($p \leq 0.05$) between the fertilizer and the no fertilizer treatments.

By the end of the 2020 growing season, any weed control benefits seen in 2019 from using the pre-emergent fertilizer Torpedo were largely gone. Data analysis on this aspect continues.

LESSONS LEARNED

Preliminary study findings to date:

- When using individual tree fertilization systems such as tablets, placement is critical. Results from blocks J10 and P3 show that tablets placed more than 5 cm from the tree stem caused no significant difference in mortality when compared to non-fertilizer treatments. This is unlike what was observed in previous years in block D63. Determination of growth impacts of fertilizer application are underway.
- For alder and poplar, direct planting into the established grass cover resulted in the highest mortality after two growing seasons. The best site treatment varied by species.

PRESENTATIONS AND PUBLICATIONS

No presentations or publications available for 2020.

RESEARCH TEAM AND COLLABORATORS

Institutions: Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre Centre, Edmonton

Principal Investigator: Richard Krygier

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
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Martin Blank	Canadian Wood Fibre Centre	Research Technician		

Interim Reclamation

COSIA Project Number: LJ0226

Research Provider: NAIT Centre for Boreal Research

Industry Champion: ConocoPhillips

Status: Year 7 of 10

PROJECT SUMMARY

This program of research encompasses study topics of: (1) interim reclamation (also known as temporary reclamation); as well as (2) final reclamation. Although, it should be recognized that much of the interim reclamation research is applicable to final reclamation. Each study (and projects therein) is described below:

Study 1: Interim Reclamation of a Facility Soil Stockpile

Industrial site disturbances, whether in the mining or oil and gas sector, typically result in the clearing of forests and stockpiling of surface soils during the development and operational phases. Ongoing management of these stockpiles is required until the site is decommissioned and final reclamation is undertaken. This is where the facilities are removed, the site is recontoured and stockpiled soils are spread. Historical and current practices include seeding stockpiled soils with grasses and the use of chemical herbicides to eradicate or control prohibited and noxious weeds. In principle, the temporary reforestation of soil stockpiles will provide: root and seed propagules; coarse woody materials; long-term soil erosion control; reduced noxious weed management; and increase biodiversity. Temporary reforestation of soil stockpiles is an alternative, though not widely utilized, practice that may better fit the fundamental long-term final reclamation goals in forested settings, which is to re-establish a functional boreal forest.

This temporary (or interim) reclamation project is situated on an eight-hectare topsoil and subsoil stockpile that is anticipated to be in place for more than 40 years. The intent of this study is to advance interim reclamation a step beyond historical recontouring and seeding practices to include the establishment of woody species on nonactive areas of an in situ project (e.g., soil stockpiles) during the life of the facility. It is hypothesized that this will speed establishment of forest cover and reduce the need for ongoing and repeated weed management. To date, this practice is not something that has been commonly implemented at in situ facilities in the oil sands region. This project provides an on-site demonstration of the effect of site preparation (dozer to create furrows and backhoe to mound on steeper slopes), varying planting densities (0, 2,500, 5,000 and 10,000 stems per hectare), and the use of coarse woody material as a reclamation material (present or absent). Rather than assessing one combination of interim reclamation techniques, the experimental trials have been structured to support the development of best practices that will have a high probability of success at final in situ specific reclamation and will be cost effective to implement.

This project is also designed to question assumptions about species suitability for use (in terms of the out-planting of different nursery stock species) in a reclamation context. Industrial disturbances do not necessarily follow the same early vegetation dynamics patterns found after fires or forest harvesting. Industrial disturbances require soil to be moved during construction and again during reclamation prior to the final revegetation. This “unnatural” soil handling forces the system into being a largely seed-based regeneration/revegetation system rather than root based. This has consequences for the native species being established and will actually favor those species that are able to tolerate competition as young seedlings. The project plots are situated on a big hill with soil and aspect variability which should help inform tolerance ranges for each of the planted species in a reclamation context.

While the long-term goal of this project is to initiate forest development, in the short term, three separate projects were initiated at this site in order to ask specific questions related to initial planting density, how to include desirable native herbaceous species, and alternative methods of planting deciduous trees.

Specific objectives and study questions for these projects are further described below.

Project 1: Site preparation and establishment density

1. Compare three densities of container stock planting (2,500, 5,000 and 10,000 stems per hectare) and monitor natural regeneration (within unplanted controls).
    a. Which native tree and shrub species will provide speedy establishment, produce viable seed within the time frame of facility life and have capacity to regenerate aggressively through root fragments following reclamation activities?
    b. Which species are best suited to different combinations of slope position and aspect on reclamation soils?
    c. Is natural regeneration a viable approach for forest plant establishment?
    d. How does the speed of canopy development and structure compare with different densities over time?
    e. Does the overstory density impact development of understory vegetation?
    f. Does aspect or slope position interact with plant establishment through these methods?
2. Compare use of soil adjustment to create a rough and heterogeneous soil surface against track-packed “smooth” reclamation approach.
    a. Does soil adjustment impact the growth and production of planted woody species?
    b. Does soil adjustment improve natural ingress and regeneration of desirable woody species?
3. Demonstrate the utility of coarse woody material in conjunction with soil treatments to create a rough and heterogeneous soil surface.
    a. Does coarse woody material impact growth and production of planted woody species?
    b. Does coarse woody material increase the stability of sloped soils and reduce erosion?
    c. Does coarse woody material improve the natural ingress and regeneration of desirable woody species?
4. Examine the impact of wildlife browsing (and presence) on establishment and development of planted woody species.
    a. Which species are preferentially browsed?
    b. What is the impact of browsing on plant performance?
    c. Does browsing significantly impact canopy development?

Project 2: Cover crop establishment through planting

5. Evaluate two methods of planting native forbs including: individual planting of container stock and co-planting native forbs with a woody species (produce plants in same plug).
    a. Does the forb develop (increase in vegetation cover) equally well with both approaches?
    b. Is there a positive, neutral or negative impact for the woody species which shares the plug initially?
6. Compare the effect of the addition of native forbs during the early phase of forest development.
    a. Do they facilitate ingress of other desirable species?
    b. Do they reduce ingress of undesirable species?
    c. Do they aid in soil stabilization?
    d. What is incremental cost of planting native forbs?
7. Optimize production of mixed-species container stock for three different woody species (green alder, willow and paper birch) each co-grown with fireweed.
    a. What is the best time to sow the forb into container with woody species?
    b. Is mixed-species container stock appropriate for all woody species or only for specific species?

Project 3: Aspen establishment through container stock, optimizing plant deployment through grouped planting

This study was conducted as a pilot project to further the concept of cluster planting of deciduous trees (see project Cluster Planting (page 18), 2018 COSIA Land EPA – In Situ Report).

8. The objective of this project was to compare localized cluster planting of aspen with conventional planting at uniform spacing. In this project, the question of how many plants are required for a "cluster" to positively impact survival and growth of aspen container stock will be addressed.

Study 2: Vegetation Management Solutions for Final Reclamation

Site occupancy with native plant species is a key objective of reclamation and reforestation of industrial sites. However, noxious weeds and other undesirable vegetation (e.g., sweet clover [*Melilotus* sp.], alsike clover [*Trifolium hybridum*], creeping red fescue [*Festuca rubra*], timothy [*Phleum pretense*] and smooth brome [*Bromus inermis*]) are transported to reclamation sites by a variety of mechanisms. These include historical presence in the soil seed bank from previous decades of utilization in cover crop mixes, contaminated equipment, wind, wildlife and in some cases intentional broadcasting. Collectively, these undesirable species present challenges to the development of forest plant communities. In northern Alberta, management of aggressive agronomic species is a significant issue to forest development and the certification of reclaimed wellsites (Bressler, 2008). Regulatory criteria and legislation clearly define the need to control and eradicate noxious weed species (Weed Control Act, 2010; Environment and Sustainable Resource Development, 2013), as well as undesirable species (Environment and Sustainable Resource Development, 2013). Site preparation, cultural control (cover crop establishment) and chemical management represent a range of approaches to control or eradicate undesirable species.

The objective of this study was to examine the ability of combinations of native plant cultural controls (cover crop) and herbicide-based approaches to reduce and eliminate undesirable plant ingress. In this study, approaches that are appropriate for use in the early stages of revegetation development following soil replacement will be evaluated.

Each of these approaches was initiated in the first year following reclamation with plans to monitor the study for three growing seasons. At the completion of the study, the following questions will be answered:

1. Which approaches are most effective at reducing the initial establishment of undesirable species?
2. By controlling ingress of undesirable plants, are there also differences in native plant establishment through natural ingress?
3. Is there a reduction in the growth and productivity of desirable native woody species when utilizing a treatment that is aimed at reducing undesirable plant development (i.e., a trade-off)?
4. What is the potential return on investment of the vegetation management approaches considering relative benefit/success at managing undesirable species?

PROGRESS AND ACHIEVEMENTS

Study 1: Interim Reclamation of a Facility Soil Stockpile

Overall, this study is progressing well. Creating surface heterogeneity either through furrowing, or rough and loose mounding (on steeper parts of the stockpile), has stimulated the emergence of a wide range of plant species from the soil seed and propagule bank. In the first four years of this investigation, 13 tree and shrub species, 36 native forbs, 23 graminoids and 18 non-native forbs were documented. Experiment-wide there has been a steady increase in woody vegetation development and in 2019 woody plants represented nearly 30% of all vegetation cover across the study area.

Project 1: Site preparation and establishment density

Three planting densities (2,500, 5,000 or 10,000 stems per hectare [sph]) and an unplanted control treatment were initiated in this trial in a randomized block design with fixed effect for planting density treatment and random effect for block. Vegetation surveys were not conducted on this trial in 2020. However, the following general field observations are noted:

1. As in 2019, a sharp decline in the occurrence of noxious weeds on this site was observed and this has occurred without conventional intervention practices (spot application of herbicide or hand picking).
2. It is abundantly clear that tree and shrub planting efforts are leading to visible differences in the vegetation community (Figure 1).
3. There is anecdotal evidence of balsam poplar spreading vegetatively on the subsoil part of the stockpile (Figure 2). This was observed as the presence of shorter balsam poplar saplings arising within one to four metres of taller plants that had been planted in 2016. These are distinguishable from seed-based natural recovery by the differing rate of terminal shoot growth.

A

B

Figure 1: Examples of planting treatments in Project 1 from August 2020: (a) 0 sph in foreground and 10,000 sph in background; and (b) untreated area in foreground, 2,500 sph on the right side of sign and 5,000 sph on left side of the sign.

Figure 2: Example of vegetative spread of balsam poplar on subsoil with suckering plants circled in red. The largest individual (red arrow) was planted in spring 2016. Photo taken in August 2020.

Project 2: Cover crop establishment through planting

The forest industry has planted tree plugs (small trees grown in nurseries) in commercial reforestation efforts for decades. Traditionally, these were commercial tree species containing one plant per plug. NAIT is developing 'hitchhiker' plugs that in addition to the tree include a herbaceous species such as fireweed. The hitchhiker plant provides shelter for the slower-growing tree and may prevent invasive weedy species, such as scentless chamomile, from taking hold. Adding a second species doubles the number of plants delivered to site, at much less than double the cost, and increases the plant diversity of the planted stock.

Final measurements for this project were completed in 2019 with compilation and final reporting nearing completion. Key findings after three years of growth in the field include:

1. Green alder (*Alnus viridis*) showed no difference in survival, total height or cover across the planting dates evaluated.
2. Paper birch (*Betula papyrifera*) was progressively taller with later planting dates relative to earlier planting dates — though neither cover, annual height increment nor survival were affected.
3. Bebb's willow (*Salix bebbiana*) was similar in total height, height increment, cover and survival amongst the three different planting dates tested after three years.
4. White spruce (*Picea glauca*) showed no differences in either growth or survival between the two planting dates tested in this study.

For fireweed grown with each of these species, total cover as well as occurrence around the tree or shrub was not statistically different amongst planting dates; though the mean probability of occurrence was consistently higher the earlier that fireweed was sown into a nursery container when it was co-grown with green alder, paper birch or Bebb's willow. At least some of the lack of observable differences may be attributable to the background presence of fireweed on these sites. In addition, as fireweed tends to egress away from its original planting location (study measurements focus on a 0.5 m area surrounding the woody plant), the full extent of spread and whether there are potential differences in the total quantity of aboveground plant biomass due to continual spread is not necessarily known.

Project 3: Aspen establishment through container stock, optimizing plant deployment through grouped planting

Aspen seedlings were clustered in groups of four, 10 or 20 plants (spaced approximately 25 cm apart within the cluster) or planted singly at a total density of 2,500 stems per hectare. Key observations from the summer 2020 include:

1. Survival of individual aspen seedlings appears to be more tightly tied to site conditions (degree of herbaceous competition) rather than clustering. In plots where seedlings were planted in topsoil, survival overall is 48%; whereas, on subsoil the survival increases to 62% on average, experiment wide. There also appears to be higher survival associated with the non-clustered seedlings and the lowest cluster group (four plants), compared with groups of 10 or 20 plants. This likely attributable to self-thinning as seedlings are averaging greater than 2.0 m in height after five years.
2. The aspen on this site were impacted by a number of other factors including browsing by wildlife, minor defoliation by insects, and most commonly, terminal shoot dieback as a result of shoot blight infection. While browsing and defoliation appeared more sporadic, terminal shoot blight was widespread and infected greater than 80% of the individual plants measured. This is the second time since planting in 2016 that this pathogen has been commonly observed (the first time was in 2017).

3. In general, it appears as though the other hardwood tree species concurrently established on this site in 2016 (*Populus balsamifera* and *Betula papyrifera*), are growing more vigorously (taller and with a greater quantity of leaf area) than aspen (Figure 3). While this is an anecdotal observation at this time, there will be an effort to quantify this observation in future monitoring.

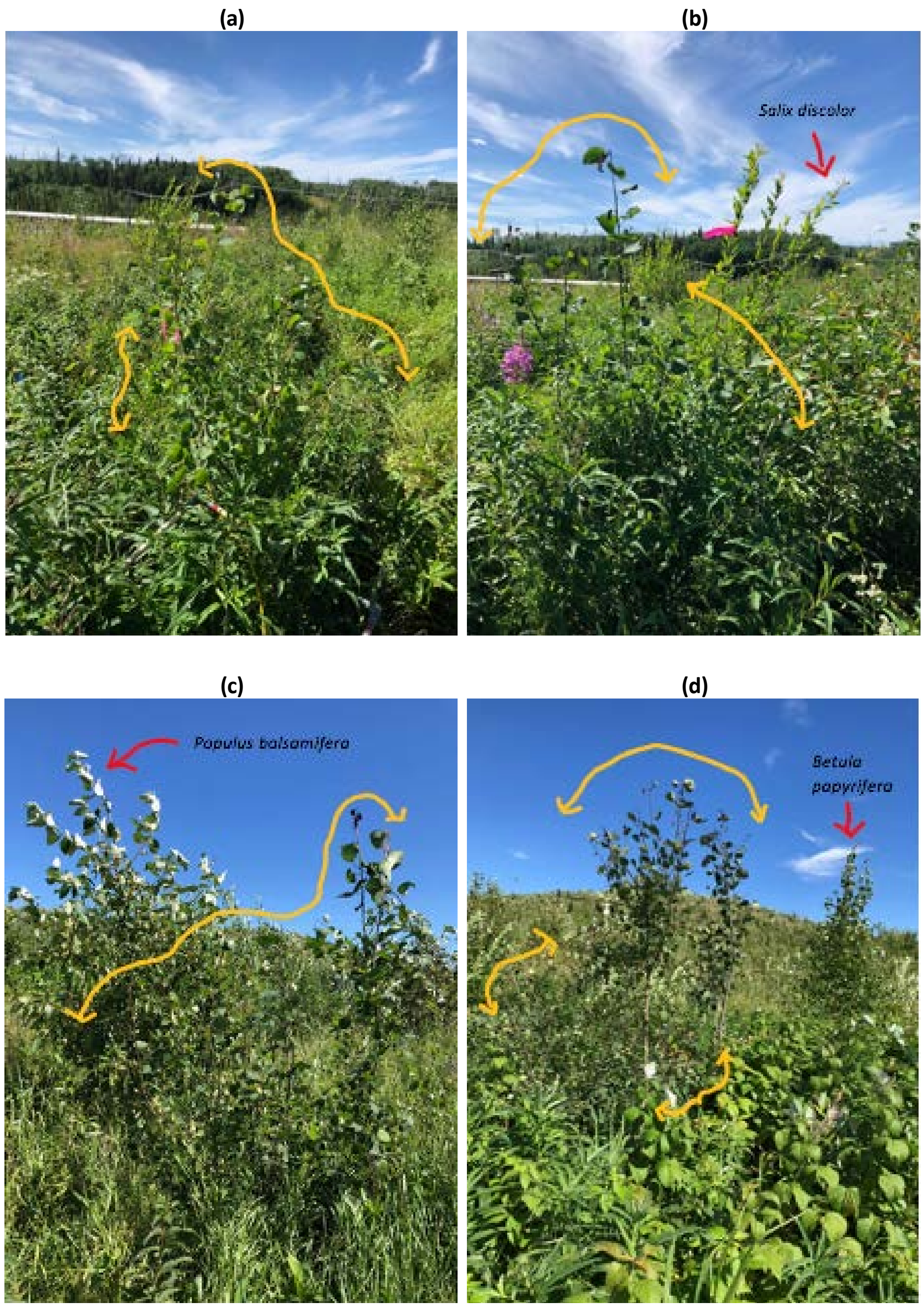

Figure 3: Example of different sizes of aspen seedling clusters growing on a topsoil pile taken five years after planting: (a) non-clustered, (b) cluster of four, (c) cluster of 10 and (d) cluster of 20 aspen seedlings. Yellow arrows indicate the location of aspen seedlings and red arrows indicate other tree or shrub species surrounding these clusters. Photos taken August 2020.

Study 2: Vegetation Management Solutions for Final Reclamation

No monitoring was conducted on this study in 2020 but a final Year 5 measurement is planned for summer 2021.

LESSONS LEARNED

Study 1: Interim Reclamation of a Facility Soil Stockpile

As only four seasons of growth and data collection have been completed and there are no quantitative results for Year 5, final conclusions about these studies and the overall approach of temporary reforestation are far from being made. However, this study has clearly demonstrated that creating surface heterogeneity (in this case using a dozer to create furrows and backhoe to mound on steeper slopes) can have a stimulating effect on native plant regeneration. In addition, declining dominance of noxious weeds on this study site continue to be observed, further supporting the idea that allowing for natural processes and vegetation dynamics to occur without human interventions may be a viable and certainly a more cost-effective strategy to reforestation of sites such as these.

Hitchhiking fireweed with deciduous woody species has proved challenging and even though substantial differences in the initial growth of both the woody plant and forb as a result of timing of forb introduction were observed, most of these differences have dissipated after three years. This suggests that there is some flexibility with forb introduction; nevertheless, the first year results strongly suggested that the earliest sow date (i.e., sowing the fireweed concurrent with sowing the woody species) was associated with higher rates of fireweed being observed near the woody plant and this was likely a function of relative vigor (size) of fireweed plants as well as the relative quantity of hitchhiker plugs that contained both species. Though the green alder, paper birch and Bebb's willow were smaller than their late sow date counterparts, these differences became progressively less important with time.

There are few differences in terms of plant growth (as seen in Figure 3 above) or vegetation development to suggest there is any short-term benefit to tight (25 cm spacing) clustering of aspen seedlings. However, continued monitoring of this study is required to quantify the potential effects of this alternate planting approach as perennial forest species are slow to develop and it is anticipated that there may be other factors that become important as this project ages (such as changes in vegetation development around aspen clusters).

Study 2: Vegetation Management Solutions for Final Reclamation

No new recommendations are included. From the data collected in the third growing season for this study, there is evidence that pre-emergent herbicides were both highly effective at controlling undesirable non-native herbaceous species (largely in the first two years with some maintenance of this effect into the third year) and that they have not negatively affected the survival and growth of planted woody species.

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PRESENTATIONS AND PUBLICATIONS

Conference Presentations/Posters

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Theses

Hudson, J. J. (2020) An evaluation of hitchhiker seedlings with native boreal species as a revegetation tool of industrially disturbed sites in Alberta, Canada. MSc thesis, University of Alberta. 171 pp. Available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj78ZmP-YzuAhXRJzQIHfQwCiUQFjAAegQIBRAC&url=https%3A%2F%2Fera.library.ualberta.ca%2Fitems%2Feb20aa22-9ba8-477c-a470-3b454819a6b4%2Fdownload%2Fbe826406-03de-4c24-86d2-d64dc31c8d13&usg=AOvVaw0U0egfbcMkICIWpJDfnZIG

RESEARCH TEAM AND COLLABORATORS

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Principal Investigator: Dr. Amanda Schoonmaker

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Derek Alcorn	NAIT Centre for Boreal Research	Student Research Assistant	2018	2020

Research Collaborators: Dr. Brad Pinno, University of Alberta (formerly Canadian Forest Service); Dr. Derek MacKenzie, University of Alberta cosia

Faster Forests

COSIA Project Number: LJ0019

Industry Champion: ConocoPhillips

Industry Collaborators: Canadian Natural, Cenovus, CNOOC Petroleum North America ULC, Husky, MEG Energy Corp., Suncor

Status: Year 4 of 5

PROJECT SUMMARY

Exploration activities required to locate subsurface energy resources result in the clearing of vegetation and levelling of a work surface on exploratory wellsites prior to development. Returning land on these wellsites to a functioning boreal ecosystem can take decades. Historic reclamation practices typically involved seeding disturbances with grass and allowing trees and shrubs to grow back on their own. Often these sites became ecologically stagnant with grasses impeding the establishment of shrubs and trees. The Faster Forests program has led to wider adoption of planting sites soon after disturbance, improved reclamation practices and the planting of local native trees and shrubs to accelerate site recovery.

A number of studies out of the University of Alberta have focused on understanding the factors affecting site recovery and recommended practices for construction and reclamation. ConocoPhillips, with Nexen Energy ULC., Statoil Canada, Suncor and Total E&P Canada Ltd. implemented recommendations from these studies to create Faster Forests in 2009.

Reclamation of in situ oil sands exploration (OSE) wells and access trails may include planting of tree and shrub seedlings (although some sites are able to recover naturally) in an effort to reduce the time it takes for these disturbances to recover. While the amount of land directly disturbed through OSE programs is a relatively small percentage of the total area, large contiguous patches of wildlife habitat are fragmented when the trees on these sites and associated access routes are cleared. There is a need to restore ecological structure and ecosystem functions at these sites within a shorter period of time. Construction practices (e.g., low or minimal disturbance, rough and loose surface soil placement in uplands, microtopography conservation in peatlands, etc.) have a strong influence on the reclamation outcomes on OSE sites.

The objective of Faster Forests is to accelerate OSE sites along a trajectory towards self-sustaining boreal forest ecosystems. This will be accomplished through promoting the best practices gained through research and knowledge sharing.

PROGRESS AND ACHIEVEMENTS

The Visual guide to planting (Osko and Pyper, 2019) was finalized, printed and distributed to Faster Forests member companies for use in their respective reclamation endeavours. The annual field tour was cancelled due to the COVID-19 pandemic.

LESSONS LEARNED

Satellite image analysis on 366 sites, using Normalized Differential Vegetation Index (NDVI) as a measure of revegetation progress, suggests that planting trees supports accelerated establishment of boreal forest vegetation in the driest ecosite types (b and c; as defined in *Field Guide to Ecosites of Northern Alberta*, Beckingham and Archibald) and wettest ecosite types (i and j) for which data were available. In comparing Oil Sands Exploration sites that were planted with those that were left to revegetate naturally, no significant differences were detected in adjusted NDVI scores for the more mesic ecosite types (d, e, f, g and h). With the understanding that the planted sites were determined to be sites that would not re-forest without purposely planting trees, these sites were statistically similar or had a greater vegetation index scores than those of sites that were deemed capable of re-foresting without tree planting. Therefore, it is strongly suggested that the Faster Forests program results in forests on these sites establishing faster than letting the sites revegetate on their own.

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PRESENTATIONS AND PUBLICATIONS

Reports and Other Publications

Faster Forests: A visual guide to planting (Prepared by: Terry Osko PhD, P.Ag., Circle T Consulting Ltd. and Matthew Pyper MSc, Fuse Consulting Ltd. Report Date: December 2019).

Oil sands producers team up to plant more than five million trees Dec 4, 2020. Jaremko, D. EnergyNow.ca: Retrieved from: https://energynow.ca/2020/12/oil-sands-producers-team-up-to-plant-more-than-five-million-trees/

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RESEARCH TEAM AND COLLABORATORS

Principal Investigator: Jon Hornung

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Dr. Terry Osko	Circle T Consulting Ltd.	Principal		
Matthew Pyper	Fuse Consulting Ltd.	Principal		

WILDLIFE RESEARCH AND MONITORING

Linear Restoration Project (LiDea) Plant, Animal, and Greenhouse Gas (GHG) Response to Treatment

COSIA Project Number: LJ0217

Research Provider: Cenovus, Wildlife Infometrics, Woodlands North, Alberta Biodiversity and Monitoring Institute

Industry Champion: Cenovus

Industry Collaborators: Canadian Natural

Status: Final Cumulative Summary

PROJECT SUMMARY

Caribou decline and climate change are accepted to be the biggest issues facing future oilsands development, and as such are priorities for performance improvement. Caribou declines are linked to habitat disturbance and specifically to linear disturbances such as road and seismic lines created by resource industries. The federal recovery strategy for woodlands caribou indicates that herds will not be self-sustaining unless the majority (about two thirds) of their native range is intact.

The linear deactivation project (LiDea) was established in 2013 to test plant and animal response to caribou habitat restoration treatment. In contrast to previous restoration work that had been completed to date, the LiDea project was conducted at landscape scale with a treatment area of 368 km^2. All features within the treatment area that were not already regenerated were treated for restoration. Mechanical treatments applied included site soil preparation in the form of mounding and scalping as well as recruitment of coarse woody material onto the disturbed line. Following mechanical treatment, sites were planted with conifer seedlings representative of the site type (black spruce and larch for lowlands; pine, black spruce and white spruce for uplands).

By way of experimental design, the treatment area was compared to a similarly sized reference area with non-treated linear disturbances as well as a natural area with no anthropogenic disturbance. Response monitoring was completed via a suite of sampling approaches including GPS collar relocations of wolves, moose and bears, remote camera traps, scat/pellet collection and analysis, predation site investigations, vegetation measurements and gas flux chamber measurements.

The practical, operational objectives of LiDea are:

1) Increase conifer abundance and growth rates
2) Restore species distribution
3) Reduce predator movement efficiency on restored features
4) Develop viable linear feature treatment methods
5) Continual improvement/adaptive management on a basis of evidence

The specific LiDea predictions (hypotheses) are organized into various scales including site, individual and population levels. With treatment, it was predicted:

Site level:

- Reduced use of treated features by large mammals
- Forest vegetation trending towards non-disturbed vegetation

Individual level:

- Reduced predator travel speed on linear features
- Reduced caribou encounter and kill rates
- Reduced percent of caribou in predator diet
- Improved caribou body condition

Population level:

- Reduced predator survival and recruitment
- Improved caribou survival and recruitment
- More caribou
- More moose until such time as forest cover is returned, after which less moose

To date, LiDea findings that have either been accepted for publication or are in preparation include: reduced use of treated linear features by wolves, reduced travel speed on treated linear features by all large mammals except for moose, increased conifer abundance and growth rates.

Effective habitat restoration is now understood to be an unavoidable requirement for caribou recovery. This LiDea research was an important milestone in this new paradigm, not only to for continual improvement in habitat restoration efforts, but also due diligence in response to a significant business risk.

PROGRESS AND ACHIEVEMENTS

In 2020 our work focused on data analysis, refinement of analysis and manuscript preparation. Both of the LiDea manuscripts submitted in 2020 have been accepted for publication and a third remains in preparation (see below).

LESSONS LEARNED

The results to be published on large mammal use of treated features include:

- Wolves, bear, moose and caribou were less likely to be present and travelled at reduced speed at treated versus non-treated sites.
- Many hypotheses of large mammal response were tested and assessed cumulatively according to a multiple lines of evidence approach. Animals responded more often than not in a manner consistent with predictions.

- Tree growth following restoration treatment and specifically following mounding and planting increased to a rate comparable to background forest rates and reduced carbon emission to atmosphere from disturbed peatlands.

Although not all of the original LiDea predictions have been tested, these results demonstrate that restoration treatments are working and that there are areas for continual improvement.

Bold, in-house, applied research may sometimes be needed in order to address industry's most pressing problems. Although multilateral collaboration is also needed, industry work can enjoy the benefit of timeliness and focus. However, in the current conditions, internal research budgets may never again be sufficient for unilateral work like this.

- Evidence was found that all of the mechanisms by which linear features are believed to contribute to caribou decline can be addressed through restoration treatment.
- Although there is evidence of early response by large mammals to restoration treatment, observations indicate that physical treatments change and diminish over time (erosion, decomposition, snow-press). There is a need to understand if treatment responses persist over longer time periods.
- There is evidence of multiple co-benefits associated with restoration treatment including emission reduction and carbon sequestration.
- Most of the responses reported are associated with a significant amount of variability and some were contrary to predictions. The lack of predicted response in all cases points to the complexity of the ecological system being manipulated, the need for monitoring at appropriate scale and statistical power, and ongoing research.
- Taken together, these lessons give the in-situ oilsands industry an opportunity to demonstrate a meaningful response to one of the most pressing environmental issues facing the sector and region. More broadly, they offer a rare opportunity to demonstrate world class stewardship.

PRESENTATIONS AND PUBLICATIONS

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RESEARCH TEAM AND COLLABORATORS

Institution: Cenovus

Principal Investigator: Michael Cody

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Geoff Sherman	GS Consulting	MSc		
Bruce Neilsen	Woodlands North	BSc		
Melanie Dickie	Alberta Biodiversity Monitoring Institute	MSc		

Regional Industry Caribou Collaboration (RICC)

COSIA Project Number: LJ0155

Research Provider: Alberta Biodiversity Monitoring Institute (ABMI)

Industry Champion: Canadian Natural

Industry Collaborators: Alberta-Pacific Forest Industries, Athabasca Oil Corporation, Cenovus, CNOOC Petroleum North America ULC, Imperial, MEG Energy, Suncor

Status: Ongoing, Annually

PROJECT SUMMARY

The main cause of caribou declines across most of their ranges is excessive predation, mostly by wolves. The current high predation rates are a result of many complex and interacting factors, including landscape level habitat changes (both natural and human caused). For any caribou recovery program to be successful, it has to address the full range of habitat and population factors impacting caribou, and it must be implemented at the broad-range scale to ultimately spur caribou population growth over time.

The Regional Industry Caribou Collaboration (RICC) is a group of resource companies operating in the oil sands region of northeast Alberta that are working together across their project boundaries to:

- Restore caribou habitat on legacy seismic lines
- Conduct research on caribou ecology and their relationships with other parts of the landscape
- Lead trials on restoration methods, effectiveness and how wildlife respond to restoration

Reversing the decline of caribou requires a focused, science-based strategy that involves multiple partners, including industry, government, academia and non-profit organizations. RICC brings these parties together to contribute to the recovery of boreal woodland caribou and their habitat.

More information about RICC can be found at: https://www.cosia.ca/initiatives/land/projects/regional-industry-caribou-collaboration

PROGRESS AND ACHIEVEMENTS

RICC is a multi-year program that includes many individual projects that also span multiple years. Achievements in 2020 include the following:

Large-Scale Habitat Restoration

In 2020, RICC members conducted over 46 km of seismic-line restoration treatments. Work conducted in 2020 brings the cumulative total to over 1,800 km of seismic lines with restoration treatments to date.

Caribou Ecology and Recovery Webinar Series

The COVID-19 pandemic resulted in the cancellation of numerous conferences, including the Alberta Chapter of the Wildlife Society and the North American Caribou Workshop. To facilitate sharing of information and maintaining communication between academics, government and industry, RICC sponsored the Caribou Ecology and Recovery Webinar Series, hosted by the Caribou Monitoring Unit and National Boreal Caribou Knowledge Consortium. Within the webinar series, Melanie Dickie, supported by RICC, presented preliminary research from Cenovus's Linear Deactivation (LiDea) mammal monitoring program. The series has successfully engaged the community, with local and international participants frequently attending webinars. Because of the success, the series will continue into the spring of 2021.

Ecosystem Monitoring Camera Program

In partnership with the Alberta Biodiversity Monitoring Institute's (ABMI) Caribou Monitoring Unit, the Government of Alberta and the University of Alberta, RICC continued deployment of wildlife cameras in Cold Lake, East Side Athabasca River (ESAR), West Side Athabasca River (WSAR) and Saskatchewan boreal plains caribou ranges. This project has monitored mammal (deer, moose, caribou, wolf, bear and mesocarnivores) response to i) wolf reduction program in Cold Lake and ESAR, and ii) the relative influence of anthropogenic habitat alteration and climatic factors since 2017. In 2020, RICC expanded the program to include the Richardson caribou range. The expansion of the program into Richardson addresses the relative influence of human disturbance (WSAR, ESAR and Cold Lake) in comparison to predominately fire disturbance (Richardson) on mammalian densities, and collects baseline ungulate and carnivore data while white-tailed deer expand into the Richardson range, which is at the northern limit of their range. Three clusters of 25 cameras were deployed across ESAR, WSAR, Richardson and Saskatchewan, for a total of 75 cameras in each range, as well as one cluster within Cenovus's Linear Deactivation (LiDea) area in Cold Lake.

Preliminary data showed that both deer and black bears exhibited a strong latitudinal gradient in the Alberta caribou ranges, with densities an order of magnitude larger in the southern portions of WSAR, ESAR and Saskatchewan compared to the northern portions. Multiple years of monitoring will be required to draw more meaningful conclusions.

LESSONS LEARNED

Wolves Contract Their Home Ranges in Areas of High Habitat Alteration

Previous research from RICC's program showed that wolves travel faster and farther on linear features such as seismic lines and roads, increasing hunting efficiency – but how does that influence wolf behavior and space-use at a larger scale? With the support of RICC, Melanie Dickie combined data from RICC and three other study areas spanning a range of linear feature densities from British Columbia, Alberta, and Saskatchewan. Results are still preliminary, but by doing so, it was learned that wolf home ranges are smaller in areas with higher linear feature densities. This suggests that in areas with more linear features, not only are wolves able to move faster and farther, but by being able to move around their home ranges more efficiently they can defend smaller home ranges. Smaller home ranges means that more home ranges can fit into a space. All else being equal, this links linear features to increased wolf densities. But here is an interesting twist – the effect of linear features was disproportionately strong in low-productivity habitats where prey resources are limited, suggesting that linear features provide a bigger benefit to wolves in areas where prey are scarcer. This may mean that restoring linear features in low-productivity habitat may have a higher impact on wolf predation by simultaneously reducing wolf hunting efficiency and increasing home range size. RICC members are excited to see how this research continues to unfold.

Mechanisms of Landscape Change on White-Tailed Deer

RICC supported research by the Caribou Monitoring Unit to evaluate the mechanisms driving white-tailed deer expansion into caribou range across Alberta. Increased deer presence and density within caribou range has been linked to increased predation on caribou populations by increasing predator densities. Furthermore, deer carry diseases such as Chronic Wasting Disease that can transfer to caribou, posing additional threats to these populations. Therefore, understanding deer abundance and distribution has important implications for management. Both increased anthropogenic habitat alteration, which provides browse and forage for deer, and less severe winters, which increases energetic demands and results in mortality, have been linked to deer expansions. Here, by using camera trap data from across the province of Alberta, it was learned that deer were more likely to be present at sites with shallower snow and increased habitat alteration, however habitat alteration increased deer presence in the northern portion of Alberta only. Winter deer densities were primarily driven by snow depth, and the effect of snow carried over into the spring such that spring densities were driven by both habitat alteration and the previous winter's snow depths. These results suggest that limiting future habitat alteration or restoring habitat can indeed alter deer distributions, but that climate must be considered while planning management actions. Furthermore, results of this study suggest that habitat restoration will be most effective in northern areas, where deer presence and abundance were more strongly impacted by habitat alteration.

PRESENTATIONS AND PUBLICATIONS

Dickie, M., McNay, R. S., Sutherland, Shermann, G., and M. Cody. 2020. Recovery actions for woodland caribou: Predicting and testing the efficacy of habitat restoration. Presented to the Caribou Ecology and Recovery Webinar Series.

Laurent, M., Dickie, M., Becker, M., Serrouya, R., Boutin, S., 2020. Evaluating the mechanisms of landscape change on white-tailed deer populations. J. Wildl. Manage. 85: 340-353. https://doi.org/10.1002/jwmg.21979

RESEARCH TEAM AND COLLABORATORS

Institution: Alberta Biodiversity Monitoring Institute (ABMI), Caribou Monitoring Unit

Principal Investigator: Dr. Rob Serrouya

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Melanie Dickie	Alberta Biodiversity Monitoring Institute (ABMI), Caribou Monitoring Unit	Research Analyst – PhD Student	2020	
Natasha Crossland	Alberta Biodiversity Monitoring Institute (ABMI), Caribou Monitoring Unit	Field Operations Coordinator		
Craig DeMars	Alberta Biodiversity Monitoring Institute (ABMI), Caribou Monitoring Unit	Research Analyst		

Research Collaborators: University of Alberta; Government of Alberta, Department of Environmental Protection; University of Calgary; Wildlife Infometrics Inc.

cosia

A Portable Testing Device For Conservation

COSIA Project Number: LJ0334

Research Provider: McMaster University, University of Calgary

Industry Champion: ConocoPhillips

Industry Collaborators: Imperial, Teck

Status: Year 1 of 4

PROJECT SUMMARY

The goal of this project is to develop an affordable (less than CAN$1.00 per assay), simple to use, paper-based device that is capable of extracting and identifying DNA from biological samples, in the field, in real time. Once developed, the device can be employed by non-specialist users without the need for access to laboratory facilities and has important applications. These include the detection of pathogenic bacteria in food and the analysis of biological samples (feces, skin and mucus) for real-time wildlife detection. For example, it can be used to identify species from fecal remains in the wild which will assist in wildlife monitoring activities and in the detection of illegal trafficking of wildlife parts.

This project builds on several technologies that have been and are continuing to be developed by the research teams. These technologies have proven to be effective in; extracting DNA directly onto paper; concentrating the DNA and linking it to a simple colour change; and the ability to print, dry and therefore stabilize reagents at any temperature. The challenge for this project is to integrate these technologies into a simple-to-use paper-based device that can detect species-specific DNA from non-invasively collected samples.

For proof-of-concept, we are using caribou (our test species), an elusive animal that can be difficult to survey and whose fecal pellets are sometimes indistinguishable from those of other ungulate species with which it shares its range. Caribou are considered a Species at Risk and are therefore highly relevant in the Canadian context, particularly for areas with a high development interest. However, the approach is easily transferrable to the identification of other species of elusive wildlife or to other species of conservation concern. This device offers a non-invasive and potentially cost-effective technology to monitor wildlife in reclamation areas in the Oil Sands region.

The overall objective of the proposed research is to engineer an all-in-one paper-based device for the detection of animal DNA in the field. We will pursue this objective with the following specific Aims:

> **Aim 1: Paper-based DNA extraction method -** to establish a simple and effective paper-based method to extract genomic DNA from fecal samples of caribou.
>
> **Aim 2: Paper-based amplification and detection method -** to develop a simple method capable of amplifying DNA and generating a visual signal in the presence of caribou-specific DNA sequence.
>
> **Aim 3: Device integration -** to combine the paper-based extraction and amplification systems above into a one paper device.

Aim 4: Device testing in lab setting - to test the device in the laboratory using caribou fecal samples that have been collected from the field and archived at University of Calgary.

Aim 5: Device optimization - to test the device in the field through consultation with COSIA stakeholders and optimize its field usability by non-specialists.

The device will provide researchers, environmental managers, indigenous communities, citizen scientists and industries with a cost-effective tool capable of producing real-time presence/absence data for species without the need for complex analytical processes. The direct output will be a highly useful device for targeted monitoring of a highly sensitive flagship species. The broader outcome will be a novel platform technology with the potential to make a transformational contribution to the field of conservation science internationally.

When the device is closer to deployment, workshops will be organized with COSIA members and public stakeholders to discuss the collaborative testing and implementation of this technology. These activities will therefore serve two purposes: to verify the technology can be easily used by both experts and non-experts alike, and ensure it can be implemented in the real-world.

PROGRESS AND ACHIEVEMENTS

This project officially started in 2020, however the COVID-19 pandemic has severely impaired the academic teams at McMaster University and the University of Calgary from making progress on the scientific objectives. Despite these restrictions, progress was made towards achieving the stated objectives in terms of funding, publications, presentations, a prototype design, acquiring personnel and securing samples. A summary of the progress made in 2020 is described below:

The McMaster team recently submitted a paper to the journal of Angewandte Chemie, reporting the results of preliminary research (2019) into creating a colorimetric biosensing platform using magnetic separation, rolling circle amplification (RCA) and a litmus test. This methodology is being trialed and tested for caribou detection, and offers promising results.

In 2020, using genomic approaches, Single Nucleotide Polymorphisms (SNPs) across caribou populations from western North America were examined. Population structure and genes under selection within each caribou group were detected. Leading to the determination of the DNA sequences (and their natural variation in nature) that are specific to the target species — the same sequences that will be amplified in the paper device under development. The findings of 2020 will also ensure that primers will be unique to caribou, as opposed to closely related species (such as white-tailed deer in the study area) that are often easily confused in the field.

Early in 2020, significant funding from Alberta Innovates was added to our funding pool. The additional funding allowed canvassing for another PhD student or post-doctoral fellow to join the McMaster team, which is expected to be confirmed shortly.

Considerable global interest in our paper-based species detection technology has been received for other endangered and threatened species as well as for other applications. Of most interest has been in using the technology as a monitoring tool for the illegal wildlife trade. As such, Geographical Magazine published an article on the potential of the technology in this arena to assist law enforcement officers. Dr Natalie Schmitt gave a talk at a Wildlife Crime webinar based in South Africa, and informal partnership agreements have been established with the South African

National Biodiversity Institute, Wildlife Conservation Society and the World Wildlife Fund to expand the technology beyond caribou. This creates an opportunity to advance a tool that could transform conservation on a global scale.

An engineering student in the Netherlands (Joey Liddard) has also been working on a preliminary prototype design to help the researchers envision how they might piece together all the methodological components. His design includes three repeat tests to help avoid false positive results and a digital display which may be useful for exploring fluorescent options for colour signalling (Figure 1).

Figure 1: Early protype design of our paper-based DNA species detection technology.

The McMaster team is in the final stages of selecting an initial PhD student to begin work with Dr Filipe and Dr Schmitt. An overwhelming 180 worldwide applications were received, which confirmed that the project has significant global interest in the fields of conservation and biosensor design research. Due to the uncertainty of the pandemic at the moment, it is difficult to predict when the student might start.

The University of Calgary welcomed an exceptional Post-doctoral fellow to the project, Dr Maria Cavedon who submitted her PhD thesis in September titled, *Ecological genomics and conservation of caribou in western North America.*

The device will only be as good as its performance in the field. As the project progresses, researchers need to ensure it has high sensitivity to low quantities of DNA and to potentially highly fragmented DNA in the collected fecal samples. Fecal sample collection, as opposed to collection of other tissues for the genetic analyses conducted in 2020, was deemed as a desirable approach for the COSIA-funded project due to nonintrusiveness and animal care considerations, as well as avoiding impacts on threatened caribou. For future work, research team will test the effectiveness of caribou-specific primers determined in 2020 for polymerase chain reaction(PCR) and rolling circle amplification (RCA) from fecal samples.

LESSONS LEARNED

This project is still in the beginning phase so there are no major lessons for 2020. However, some of the genes determined as under selection in 2020 (see above) were linked to morphological characteristics, migratory behaviour, habitat selection, and climatic and environmental factors impacting caribou. Researchers identified genes under selection and patterns of population structure that should be considered in conservation planning and management of caribou populations. This project has therefore led to the unexpected opportunity to use the paper device to target regions of DNA that are indicative of caribou characteristics that should be maintained by conservation programs. For example, various studies have indicated that caribou migration could be impacted by development, and the proportion of migrants in populations could decrease in the future. This device could potentially detect genetic correlates of these characteristics and help to manage their occurrence in nature.

PRESENTATIONS AND PUBLICATIONS

Published Theses

Cavedon, M. (2020). Ecological genomics and conservation of caribou in Western North America (Unpublished doctoral thesis). University of Calgary, Calgary, AB. Available at: https://prism.ucalgary.ca/handle/1880/112511

Journal Publications

Chang, D., Liu, M., Tram, K., Schmitt, N., Li, Y. In review. Ultra-sensitive colorimetric sensing using Rolling Circle Amplification and a urease-mediated litmus test. Angewandte Chemie.

Cavedon, M., vonHoldt, B., Hebblewhite, M., Hegel, T., Heppenheimer, E., Hervieux, D., Mariani, S., Schwantje, H., Steenweg, R., Theoret, J., Musiani, M. In review. Ancestry and genes determine migratory behavior in endangered caribou. Science Advances.

Conference Presentations/Posters

Schmitt, N. T., Li, Y., Musiani, M., Filipe, C. A innovative paper-based technology for species detection. North American Congress for Conservation Biology. Denver, Colorado, USA (virtual conference due to pandemic), 27-31 July 2020.

Reports and Other Publications

"DNA sequencing device could rapidly detect illegal wildlife products", Geographical Magazine (July 2020): Available at: https://geographical.co.uk/nature/wildlife/item/3760-dna-sequencing-device-could-rapidly-detect-illegal-wildlife-products

RESEARCH TEAM AND COLLABORATORS

Institution: McMaster University[1] and the University of Calgary[2]

Principal Investigator: Dr Carlos Filipe[1]

Co-Principal Investigators: Dr Marco Musiani[2] and Dr Yingfu Li[1]

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Natalie Schmitt	McMaster University	Post-Doctoral Fellow		
Maria Cavedon	University of Calgary	Post-Doctoral Fellow		

Genomics and eDNA Workshop

COSIA Project Number: LE0069

Workshop Facilitator: Hemmera

Industry Champion: Imperial

Industry Collaborators: Canadian Natural, Cenovus, ConocoPhillips, Husky, Suncor, Syncrude, Teck

Status: Complete

PROJECT SUMMARY

With the rapid advances in sequencing technologies and data analysis, environmental genomics can offer a variety of tools that can be used to obtain comprehensive biological information. These tools include the collection of environmental DNA (eDNA) for use in species and community assessment. This is emerging as a promising method for biodiversity monitoring and is expected to help improve environmental performance and management in the oil sands industry.

In November 2020, the COSIA Genomics and eDNA Workshop was held with the goal of exploring more sustainable and cost effective monitoring methods for the assessment of biodiversity and reclamation trajectories within the oil sands industry.

The main objectives of the workshop were to:

- Share current research and to gain knowledge about leading edge research in environmental genomics and its applications in reclamation.
- Identify specific applications, limitations, and knowledge gaps of genomics and eDNA tools as they relate to oil sands reclamation and biodiversity monitoring.
- Encourage new research collaborations among industry, academia and consultants.

PROGRESS AND ACHIEVEMENTS

Due to COVID-19 restrictions, the Genomics and eDNA Workshop was held online using Microsoft Teams on November 4th and 5th, 2020. Up to 66 attendees from across North America participated in the workshops each day. They included respresentatives from environmental government organizations, consulting agencies, the oil and gas industry, and academia.

The workshop was organized into two main sessions; eDNA for Species Monitoring (day one); and Genomics for Community Assessment (day two). Each session consisted of a keynote presentation followed by various presentations from speakers in academia, consulting, industry, and government. The keynote speakers were Dr. Caren Helbing from the University of Victoria (day one) and Dr. Merhdad Hajibabaei from the University of Guelph (day two). At the end of each day, a discussion session was carried out to debate prepared themes, as well as emerging questions from the participants. In addition, participation was encouraged through the use of survey questions that were sent to attendees (via POPin platform).

After the completion of the workshop, a report was prepared by Hemmera to summarize the main highlights and any emerging themes.

LESSONS LEARNED

The main topics and highlights discussed during the workshop are summarized below:

- There is an increasing amount of eDNA research and pilot project work being conducted in the oil sands region related to environmental monitoring – much of this is conducted through the collaborative efforts of academic researchers, industry managers and consulting scientists.
- In general, eDNA assessment surveys have been compared with traditional sampling methods for a variety of targeted species and broader ecosystem characterization studies. A strong alignment between the methods has been observed.
- The general consensus is that eDNA analysis has great potential as an additional tool in the environmental assessment toolbox.
- Identified advantages of using eDNA methods compared to traditional methods include: reduced cost, ability to assess ecosystem taxa and community-level ecosystem health more comprehensively, potential reduction of sampling frequency, and less destructive sampling methods.
- Current challenges with using eDNA methods include: the limited availability of adequately validated assays for some species and taxonomic groups, and issues in some studies with false positives and/or false negatives, the current lack of standardized testing methods contributes to end users having reduced confidence in the results, and there is limited eDNA lab capacity beyond academic research institutions.
- Next steps needed to advance these methods were recognized. These included the standardization of sampling design, analytical methodology, and quality assurance/control protocols. A national working group that includes academics, researchers, government bodies and consulting firms has been formed to advance standardization through the Canadian Standards Association.

PRESENTATIONS AND PUBLICATIONS

Workshop

2020 COSIA Genomics and eDNA Virtual Workshop Summary Report. Availabe at: https://cosia.ca/sites/default/files/attachments/Genomics_eDNAworkshop_Report_FINAL_Mar9.pdf

WORKSHOP FACILITATION TEAM AND KEY SPEAKERS

Facilitators: Hemmera

Workshop Facilitation and Report Preparation: Kate Witte, Doug Bright, and Desiree Hartshorn

Workshop Speakers:

Name	Institution or Company	Job Title
Keynote Speakers		
Dr. Caren Helbing	University of Victoria	Professor
Dr. Merhdad Hajibabaei	University of Guelph	Associate Professor
Invited Speakers		
Dr. Natalie Schmitt	McMaster University	Post-Doctoral Fellow
Dr. Brian Lanoil	University of Alberta	Associate Professor
Dr. Christine Martineau	Canadian Forest Services	Research Scientist
Sherry Walker	Fisheries and Oceans Canada	National Manager of Biotechnology and Genomics Program
Dr. Ryan Mercer	Genome Alberta	Manager of Program and Business development
Dr. Jordan Angle	ExxonMobil	Environ. Genomics Lead
Dr. Mary Murdoch	Stantec and Canadian Natural	Senior Aquatic Biologist
Dr. Steve Crookes and Dr. Mario Thomas	Precision Biomonitoring	Co-founders
Dr. Brian Eaton and Susan Koziel	InnoTech Alberta and Canadian Natural	Manager of Environ. Impacts Team and Research Technologist
Kenneth Clogg-Wright	Canadian Standards Association	Project Manager

ENVIRONMENTAL RESEARCH AND MONITORING

Testing an Electromechanical Seismic Source to Achieve Reduced Acquisition Footprint

COSIA Project Number: LJ0337

Research Provider: Full Force Geophysical Ltd.

Industry Champion: Suncor

Status: Year 1 of 2

PROJECT SUMMARY

As part of the COSIA Land Challenge, Suncor is collaborating with member companies and industry to identify new and improved seismic exploration technologies that may lead towards less disturbance from exploration activities. One new seismic approach, called electric vibroseis from Full Force (Evibe), has the potential to meet this challenge.

Safe and successful resource recovery requires detailed information about the location and quality of the underground oil resource, and seismic exploration is an important industry activity for gathering this information. Seismic exploration involves the generation, collection and subsequent analysis of energy waves that propagate into and reflect back from the subsurface. This data is then used to generate a model of subsurface geological features, required for optimal development of an oil sands reservoir underlying a lease. The energy waves are often generated during the winter months (January to March) for optimal ground conditions. There are two primary methods used to generate the energy waves; 1) dynamite charges placed and detonated in shallow holes (shot holes) in the earth; or 2) using vibroseis, which is a truck-mounted device that generates and propagates elastic acoustic energy into the earth. Corridors are cleared for dynamite and vibroseis equipment and to provide human access through the boreal forest. These cut lines are needed for low impact seismic equipment to be deployed and to ensure safe access routes. Current industry standards for seismic exploration approaches use seismic cut lines that are up to 3 m wide and hundreds of kiliometres in length (this is dependant on the depth of the subsurface target).

Full Force has developed a smaller impact source by generating the acoustic energy via linear synchronous motors, a novel approach that can be attached to a smaller unit (ATV), which allows for a reduced environmental footprint. Although the Evibe unit is a smaller seismic unit, it can generate a broader bandwidth of frequency data (1 Hz to 250 Hz) as compared to traditional vibroseis (5 Hz to 180 Hz) mounted to a truck. Therefore, it requires narrower cut lines than regular vibroseis units but has the potential to produce seismic datasets of equal or even superior technical quality. Evibe source lines would only need to be approximately 1 m wide, compared to the 2 m to 3 m wide lines required for traditional vibroseis vehicles. There is the potential to reduce the overall seismic exploration footprint by up to 30%, which has the potential to directly contribute to: 1) the aim of the COSIA Land Challenge to approach zero footprint seismic exploration; 2) conservation of a species at risk, the boreal woodland caribou (*Rangier tarandus caribou*); 3) overall boreal forest biodiversity conservation; and 4) reduced greenhouse gas emissions during seismic exploration (Lovitt et al., 2018).

The goal of this study is to conduct a small proof of concept test that compares Evibe to conventional seismic data. Performance of Evibe will be evaluated against traditional low-impact seismic in relation to the COSIA Land Challenge performance metrics, which includes disturbance footprint, reservoir data needs and safety. An additional performance metric is cost relative to traditional vibroseis. The test plan is a 2D (two-dimensional) and 4D (four-dimensional) baseline seismic survey at an oil sands in situ site in the Athabasca Oil Sands.

PROGRESS AND ACHIEVEMENTS

- Experimental design and associated planning for a 2D and 4D baseline test at an oil sands in situ site commenced in the third quarter of 2019 and continued into the first quarter of 2020.
- Hazard identification and mitigation of the test plan occurred in preparation for a safe winter 2020 test.
- The Evibe approach recorded a 2D and 4D baseline geophysical program without incident.
- Data process was completed in 2020.

LESSONS LEARNED

This project is in early stages so there are no emerging outcomes or lessons learned available for 2020.

LITERATURE CITED

COSIA (2020). COSIA Challenge, Transforming seismic exploration to approach zero land disturbance. Available at: https://www.cosia.ca/sites/default/files/attachments/COSIA%20Challenge%20Land%20-%20Approaching%20Zero%20Land%20Disturbance%20Exploration_0_3.pdf

Lovitt J., Rahman M. M., Saraswati S., McDermid G. J., Strack M., Xu B. (2018). UAV remote sensing can reveal the effects of low-impact seismic lines on surface morphology, hydrology, and methane (CH4) release in a boreal treed bog. Journal of Geophysical Research: Biogeosciences, 123, 1117–1129. https://doi.org/10.1002/2017JG004232

PRESENTATIONS AND PUBLICATIONS

Nycz J, de Kunder R. 2020. E-Vibes: Achieving significant reduction in land disturbance while improving seismic data quality when compared to traditional methods. In: Exploration Tools 2020; 2020 November 17-18; Calgary (AB). Calgary: Canadian Oil Sands Innovation Alliance.

RESEARCH TEAM AND COLLABORATORS

Institution: Full Force Geophysical Ltd.

Principal Investigator: Jason Nycz

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Tim Little	Full Force Geophysical Ltd.	President		
Richard de Kunder	Full Force Geophysical Ltd.	Chief Operating Officer		

Osx™ ClearWave™ - Optimization of Low-Impact Seismic Source Towards Zero Footprint

COSIA Project Number: LJ0336

Research Provider: Orica

Industry Champion: Suncor

Status: Final Cumulative Summary

PROJECT SUMMARY

As part of the COSIA Land Challenge, Suncor is collaborating with member companies and industry to identify new and improved seismic exploration technologies that may lead towards less disturbance from exploration activities. One new seismic approach, called Osx™ ClearWave™ has the potential to meet this challenge.

Osx™ ClearWave™ is a pentolite seismic source technology that is placed in a charge shaping device and can be deployed at shallow soil depths (approximately 0.6 m to 1.2 m) using a hand drill instead of at approximately 6 m to 9 m depth using drilling equipment — which is the current practice with Low Impact Seismic (LIS; i.e., today's seismic standard). Thus, relative to LIS, the Osx™ ClearWave™ source can be deployed on narrower or even non-mulched lines if executed at higher densities in order to compensate for the weaker source signal and using the charge shaping device which optimizes energy focus into the ground. There is the potential to reduce the overall seismic exploration footprint by up to 50%, which directly contributes to: 1) the aim of the COSIA Land Challenge to approach zero footprint seismic exploration; and 2) conservation of a species at risk, the boreal woodland caribou (*Rangifer tarandus caribou*). Another environmental benefit to reducing the seismic line footprint is a reduction in greenhouse gas emissions produced during exploration and seismic line recovery. Additionally, relative to LIS, the removal of drilling equipment may translate into cost savings, potentially making this new technology of similar or lower cost to execute.

A "proof of concept" seismic acquisition test of the Osx™ ClearWave™ technology was executed at an oil sands in situ site in the first quarter of 2020 as part of a joint industry project to support the COSIA Land Challenge. This test examined the seismic data quality of a smaller seismic source with the potential to be deployed with a reduced surface footprint. The test line survey was a 2D (two-dimensional) and 4D (four-dimensional) baseline. The objective of the test was to compare the geo-technical capability of Osx™ ClearWave™ to LIS along a 2D line, and as a Osx™ ClearWave™ 4D baseline. The 2D test line was 5.3 km in length. Osx™ ClearWave™ sources were spaced at 2.5 m and receivers were spaced at 5 m. In contrast, LIS sources were placed at 15 m densities and LIS receivers were spaced at 5 m.

Data processing and analysis occurred in the first and second quarters of 2020 and the seismic data was reviewed in June 2020.The promising initial results led to a plan to continue de-risking the technology to address remaining technical, safety, environment and cost unknowns (i.e., the COSIA Land Challenge performance metrics). This is the final cumulative summary for the current stage of development.

PROGRESS AND ACHIEVEMENTS

Geotechnology performance metrics were outlined at the outset of the project to effectively evaluate the Osx™ ClearWave™ and LIS survey data and included the following:

- Imaging through thick Quaternary
- Imaging a deep reservoir and disposal targets (> 300 m deep)
- Imaging near operating infrastructure
- Imaging steam chambers
- Near offset quality and continuity of reflectors compared to LIS baseline
- Far offsets/angles and usable signal ranges compared to LIS baseline
- Frequency content

The processed Osx™ ClearWave™ and LIS datasets were compared within the following categories: geological structure, image resolution, data frequency, gathers and data acquisition. Results are described below.

Geological Structure

- Time structures were similar between the two sources with visible and comparable features present in both.

Data Frequency

- Frequency spectrum between LIS and Osx™ ClearWave™ source were comparable.
- Overall, the LIS has a higher frequency content in the shallow portions of the examined geology, which is expected as it is a larger source charge.

Gathers

- Near and far offset gathers were comparable.
- Similar minimum and maximum usable angles and offset were observed.

LESSONS LEARNED

Overall, this proof of concept seismic acquisition test demonstrated that the low energy near surface Osx™ ClearWave™ source imaged the subsurface well relative to LIS. Consequently, this study demonstrated the potential for the Osx™ ClearWave™ source to aid in seismic footprint reduction in the oil sands industry. Further research is required to close some remaining knowledge gaps for this new technology. The knowledge gaps are related to the COSIA Land Challenge performance metrics, which include technical, safety, and environmental footprint considerations. An additional unknown is the cost of this technology when its applied at a large, commercial-scale relative to LIS.

LITERATURE CITED

COSIA (2020). COSIA Challenge, Transforming seismic exploration to approach zero land disturbance. Available at: https://www.cosia.ca/sites/default/files/attachments/COSIA%20Challenge%20Land%20-%20Approaching%20Zero%20Land%20Disturbance%20Exploration_0_3.pdf

PRESENTATIONS AND PUBLICATIONS

Conference Presentations/Posters

Miranda J, Kotsonis S. 2020. Osx Clearwave smart solution to seismic challenges. In: Exploration Tools 2020; 2020 November 17-18; Calgary (AB). Calgary: Canadian Oil Sands Innovation Alliance.

RESEARCH TEAM AND COLLABORATORS

Institution: Orica

Principal Investigator: Steven Kotsonis

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Juan Miranda	Orica	Global Commercial Oil and Gas Manager		
Eddie Petrovic	Orica	Lead Technology		
Clint Brearley	Orica	Lead Technology		
Mike Tarnowski	Orica	Account Manager Canada		
Steve MacLeod	Orica	Business Development Lead -Canada		

Boreal Ecosystem Recovery and Assessment

COSIA Project Number: LJ0220

Research Provider: University of Calgary

Industry Champion: ConocoPhillips

Industry Collaborators: Cenovus, Canadian Natural, Imperial

Status: Year 6 of 6 (1-year extension from NSERC due to COVID-19)

PROJECT SUMMARY

The boreal-forest regions of Alberta are under increasing pressure from human development related to natural resource extraction. Roads, seismic lines, well sites, cut blocks, mines, pipelines and other elements of human footprint exert cumulative environmental effects that can harm biodiversity, water quality and the habitat of threatened species such as woodland caribou. In order to mitigate these effects, resource extraction companies and provincial regulators are working to develop monitoring initiatives that track the amount of human footprint present in a given area and measure the rate and quality at which previously disturbed areas are being restored.

The Natural Sciences and Engineering Research Council of Canada (NSERC) Collaborative Research and Development (CRD) Boreal Ecological Recovery and Assessment project (BERA, http://www.bera-project.org) brings researchers, government, stakeholders, and industry together to mitigate the effects of nonpermanent industrial activities, such as the construction of seismic lines, access roads, and well pads, on the boreal forest. The team, led by research experts from the University of Calgary, University of Alberta, Trent University (Waterloo University added in 2019) and Natural Resources Canada, aims to develop cutting-edge technologies and techniques that can help to measure, monitor and predict the recovery of vegetation and some animal uses after temporary human disturbance by industrial activity.

The Technology

The research program uses advanced geospatial technologies and modelling techniques to aid in the process of measuring, monitoring and predicting vegetation recovery on nonpermanent (i.e., to be reclaimed) human footprint features (i.e., seismic lines, roads, etc.).

The BERA project previously included three research areas: remote sensing, sensor networks and ecology. In 2019, a fourth research area was added: soils and ecohydrology.

Objectives

The research project addresses five specific research objectives:

1. Map human footprint features using advanced remote-sensing devices;
2. Assign descriptive attributes to human-footprint features that can be tracked through time in a monitoring program;

3. Develop low-cost ground-sensor networks that can track the physical condition and human or animal use of human-footprint features;
4. Develop statistical models that can predict the rate of vegetation recovery in human-footprint features across the boreal forest; and
5. Deliver a rapid verification protocol designed to assess the reclamation status areas disturbed by humans.

Potential/Actual Environmental Benefits

By discovering new ways to monitor and measure how humans impact the boreal forest and predict how vegetation can return to areas of temporary disturbance, the oil sands and forest industries can improve how they manage reclamation efforts across their areas of operation.

Outcomes

Innovative approaches to mapping the extent and condition of temporary footprint, monitoring vegetation recovery, and the efficacy of habitat restoration activities in the boreal forest are key to effective land reclamation.

Remote sensing technologies offer a credible and defensible way to map and monitor recovery of vegetation on disturbed sites. BERA's research supports industry efforts to develop timely land-reclamation practices. Novel geosensor technology can aid in better understanding the use of recovering temporary disturbances, by both humans and boreal forest dwellers, which is an important factor determining future recovery success.

Arriving at a set of unambiguous scientifically defensible criteria determining vegetation recovery success and future success trajectories will aid in prioritizing areas for treatment as well as inform regulatory requirements for effective boreal forest reclamation.

PROGRESS AND ACHIEVEMENTS

2020 was a transitional year for BERA. The first phase of BERA (BERA 1 from 2015 to 2020) came to an end and funding for a second phase of BERA (BERA 2 from 2021 to 2026) was secured. This transition was complicated by the COVID-19 pandemic, which delayed the start of Phase 2. As a result, a one year extension was sought and granted from NSERC on BERA 1.

LESSONS LEARNED

Lessons learned from BERA 1 are as follows.

Key Outcome 1: The Forest Line Mapper (FLM) is a powerful, semi-automated tool for delineating and attributing linear disturbances in Alberta forests.

Why it is important: Most existing linear-feature inventories are suitable for cartographic purposes but lack the fine spatial details and multiple attributes required for more demanding analytical applications like restoration assessment. The FLM reliably predicts both the center line (polyline) and footprint (extent polygons) of a variety of linear-feature types including roads, pipelines, seismic lines, and power lines. FLM outputs are consistently more accurate than publicly available datasets produced by human photo-interpreters and can be reliably deployed across large application areas.

Implications: The FLM is open-source and freely available (see http://flm.bera-project.org) and is aimed to assist researchers and land managers working in forested environments everywhere. It requires seed points from lines digitized at approximately 1:20,000 and a LiDAR-derived (light detection and ranging) canopy height model, both of which are widely available in Alberta. The FLM is the first of an envisioned suite of free, open-source tools to support large-area forest-restoration planning and monitoring.

Relevant Publication: Lopez-Queiroz et al., 2020

Key Outcome 2: Airborne remote sensing can detect establishment-aged evergreen seedlings (eight to 10 years old; > 60 cm tall) on seismic lines. Leaf-off imagery and 5 cm pixels are required.

Why it is important: The Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta calls for establishment monitoring two to five years (survivability assessment) and eight to 10 years (establishment survey) after treatment. With many kilometres of seismic lines to be assessed, this work establishes the conditions required for performing remote stocking assessments on an operational basis.

Implications: With existing technology, establishment monitoring of eight to 10+ year-old evergreen seedlings is likely feasible on an operational basis, though further testing is required.

Relevant Publication: McDermid et al., in prep

Key Outcome 3: Growth trajectory models predict site and landscape patterns.

Even when trees establish on seismic lines, there is evidence that different characteristics of seismic lines affect their growth rates. Here we predict, in a spatially-explicit manner, density and growth rates of trees on seismic lines within the Lower Athabasca region using site factors to model tree abundance and recovery dynamics.

Why it is important: This outcome will provide government and industry a set of models, maps, and tools to quickly and easily assess locations in northeastern Alberta where leave-for-natural regeneration strategies are suitable and where reclamation efforts are most needed.

Implications: Trajectory maps and models can be used to prioritize future seismic line restoration efforts.

Relevant Publications: Filicetti and Nielsen, in prep.

Key Outcome 4: Mounding promotes tree regeneration on seismic lines.

Comparisons of treated lines (approximately four years post-mounding and planting) to untreated lines (22 years post-disturbance) in peatlands demonstrated that mounding increased tree densities over untreated lines by a factor of 1.6 times, but there is still high uncertainty in responses to tree survival and growth.

Why it is important: Bog, poor fen, rich fen, and poor mesic peatland had tree-regeneration densities on untreated seismic lines averaging 7,680 stems/ha. This suggests that natural regeneration is ongoing at most peatland sites, although tree growth may be limited by site factors and thus ameliorated with mounding. Increased tree densities (12,290 stems/ha) were observed on treated lines in bog, rich fen, and poor mesic sites, but not significantly in poor fens suggesting this ecosite isn't responsive to boosting tree density with current restoration practices. As tree densities on treated lines were much higher than planting densities, the observed increases in tree recruitment can be attributed to structural changes in the line's topography (mounding).

Implications: In peatlands (except poor fens) mounding can increase tree density.

Relevant Publications: Filicetti et al., 2019

Key Outcome 5: Soil disturbance on seismic lines leads to higher bulk density, wetter conditions and organic matter loss.

Seismic line disturbances resulted in a significant increase in bulk density and soil moisture on the line at both ecosites. We found an almost 40% reduction in organic matter on the line compared to natural areas at the poor mesic site, implying changes to carbon cycling, increased mineralization rates and carbon loss from the system. There was also $\delta^{13}C$ and $\delta^{15}N$ enrichment and narrower C:N ratios on the line, indicating increased decomposition state. We also found evidence of increased decomposition state on the mounds created after restoration at the treed fen.

Why it is important: The large reduction in organic matter found in poor mesic sites has major implications for carbon cycling across these sites, indicating increased rates of mineralization. The mounding technique used for restoration of these lines also causes some disturbance to soil properties through increased decomposition and higher bulk density.

Implications: Although long term evidence for carbon stocks is required, it has to be questioned whether mounding these lines is a trade-off between disturbing the landscape to encourage tree regeneration and enhancing organic matter decomposition leading to increased carbon losses from the system, at least in the short term. As mounding has been successfully used to improve tree regeneration in other ecosite types, future work should involve investigating alternative mounding techniques to ensure both tree recovery and minimal impact to the ground layer vegetation in wetland systems.

Relevant Publications: Davidson et al., 2020.

Key Outcome 6: Mounding alters nutrient cycling in peatlands that may change competition.

The objective of the current mounding technique of inverting the soil profile is to change soil physical and chemical properties to improve tree growth. Although mounds may serve to create drier microsites for trees, current mounding methods may decrease soil quality by exposing older, more decomposed peat.

Why it is important: It is important to optimize treatment techniques to promote black spruce and larch growth over other species. Without proper establishment of black spruce and other tree species, mounding will not be fully successful in restoring seismic lines.

Implications: Although mounding is already tailored to the recovery of trees, changes may be needed to support tree establishment and survival. Further research will be required to fully understand how local soil property change caused by mounding treatments affect growth of key species, especially to identify situations when tree planting is necessary.

Relevant Publications: Kleinke et al., 2021 in prep.

Key Outcome 7: Fire promotes tree regeneration in lowlands and uplands.

Wildfires facilitate and speed tree recovery on seismic lines across both lowland and upland ecosites with most ecosites averaging tree regeneration densities of at least twice the rate of unburned lines and all being higher than current restoration standards.

Why it is important: Since the fire return interval in Alberta's boreal forest is quite high, seismic lines that haven't burned will burn at some point in the next number of decades. Natural recovery (passive restoration) is expected post-fire when measured against regeneration standards of tree density.

Implications: Active restoration practices may not be needed for places that do not require immediate conservation actions (e.g., caribou recovery), although existing inhibitory factors, such as loss of microtopography, may affect other traits like tree height and growth.

Relevant Publications: Filicetti and Nielsen, 2018; Filicetti and Nielsen, 2020; Filicetti and Nielsen, in prep.

Key Outcome 8: Drones have emerged as a powerful complement to traditional field work and can be trusted to perform a variety of vegetation-mensuration tasks.

Why it is important: If the vegetation target is large enough (approximately 30 cm seems to be the lower limit) and distinct enough (we prefer the shoulder seasons where living targets stand out on senesced backgrounds) then significant efficiencies and cost-savings can be achieved. Environmental conditions and Transport Canada regulations remain the largest considerations for drone operations.

Implications: Drones can reduce (not replace) the need for field surveys of vegetation, leading to cheaper/faster ground operations. Detection, count, and measurement of trees, saplings, and larger seedlings are currently feasible and can likely proceed under operational conditions.

Relevant Publications: Ahmed et al., 2017; Chen et al., 2017; Franklin et al., 2017; Franklin et al., 2017; Hird et al., 2017; Williams et al., 2017; Feduck et al., 2018; Franklin et al., 2018; Castilla et al., 2020

Key Outcome 9: Autonomous Recording Units (ARUs) decrease costs of monitoring wildlife use of small-scale energy disturbances.

Why it is important: To understand the effectiveness of natural regeneration and reclamation for mitigating energy impacts on wildlife requires we measure where they spend time. The development of new techniques using Autonomous Recording Units, which can be set up and left in the field to record sounds for months at a time, allows the non-invasive and precise measurements of habitat use by birds on small energy sector disturbances (i.e., seismic lines and exploration well pads).

Implications: Birds are excellent indicators of the effects of forest fragmentation. Our techniques allow anyone to cost-effectively monitor hundreds of species responses to restoration practices and share that data with others through WildTrax. Such information is crucial for being able to ensure the functional habitat quality is maintained for species and is pivotal when assessing if threshold levels of quality habitat remain available as development proceeds.

Relevant Publications: Hedley et al., 2020.

Key Outcome 10: Multi-source remote sensing improves bird-habitat models.

We evaluated different types of spatial data (AVI, satellite imagery, LiDAR) on their capacity to predict bird abundance in the boreal forest. For most analyzed species, composite models drawing on multi-source data worked better.

Why it is important: There are pros and cons to every type of spatial data set out there, and researchers and managers constantly question their relative values. Our work shows all three types of data to be complementary, with LiDAR being perhaps the most important.

Implications: To effectively assess the overall state of the oilsands region for birds, a regular and standardized collection of LiDAR is needed.

Relevant Publications: Leston et al., in prep.

Key Outcome 11: LiDAR and optical remote sensing are essential and complementary datasets for forest monitoring and restoration.

Why it is important: Light detection and ranging (LiDAR) is the de-facto standard for measuring three-dimensional (3D) terrain and forest structure, but digital aerial photogrammetry (DAP) from optical data has emerged as a viable and economical alternative. Our assessments show that the two technologies remain complementary. Optical data are the best source for land-cover mapping and change detection, but DAP's sensitivity to occlusions and mismatched tie points make it a poor alternative to LiDAR for most detailed 3D mapping.

Implications: Accurate characterization of vegetation and surface terrain are necessary for a host of workflows associated with forest monitoring and restoration planning. LiDAR and optical datasets are complementary and essential, even in a cost-constrained environment. We recommend continued investment in both.

Relevant Publications: Rahman et al., 2017; Dietmaier et al., 2019; Lopez-Queiroz et al., 2019; Lopez-Queiroz et al., 2020; Losada, in prep.

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Korsah, P. 2020. Seismic line disturbances change rates of peatland carbon cycling. BERA 1 Final Synthesis Webinar. April 30, 2020.

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Ojagh, S. 2020. A geospatial web portal for visualizing and analyzing. BERA 1 Final Synthesis Webinar. April 30, 2020.

Saeedi, S. 2020. Spatio-temporal analytics for IoT observations. BERA 1 Final Synthesis Webinar. April 30, 2020.

AWARDS

NSERC Alliance Grant, Boreal Ecosystem Recovery and Assessment (BERA) Project, Phase 2, with Alberta-Pacific Forest Industries Inc., Natural Resources Canada, Canadian Natural, ConocoPhillips, Cenovus, Alberta Biodiversity Monitoring Institute, and Imperial.

RESEARCH TEAM AND COLLABORATORS

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WASTE REDUCTION

Camp Food Waste Reduction

COSIA Project Number: LJ0330

Research Provider: Eco-Growth Environmental Inc.

Industry Champion: ConocoPhillips

Status: Year 2 of 2

PROJECT SUMMARY

In situ camp facilities generate a variety of waste streams that typically need to be trucked long distances to landfills for disposal. In the summer of 2017 ConocoPhillips formed the Operations Waste and Liability Strategy (OWLS) team to review and assess various waste streams and develop solutions to reduce costs and environmental impacts.

One of the identified waste streams was camp food waste. Building on the COSIA Environmental Priority Area (EPA) led study LE0040 *Composting and compost utilization with organic residuals from oilsands camps and operations* the OWLS team investigated several options to address the problem and eventually identified the Eco-Growth Organic Reactor as the best option for the Surmont facility. Prior to this pilot project the equipment had only been deployed at two locations. At the Alberta Treasury Branch (ATB) in Calgary where food waste is converted to dry biomass and trucked to Eco-Growth facilities where it is combusted in a boiler. And at the YMCA in Regina where it converts food waste into a feedstock for an on-site integrated boiler that heats the water for the pool. The manufacturer needed to make several adaptations and modifications to enable the system work at the Surmont facility.

The primary objective of this project was to reduce the amount of food waste being trucked to the landfill while also reducing costs and greenhouse gas (GHG) emissions.

PROGRESS AND ACHIEVEMENTS

Initiated in 2018 the project took a little over a year to confirm the potential for a food waste diversion system, review options, select the best option, design/build/adapt and install a fit for purpose system for the Surmont camp. A key aspect to the success of the system was the development and roll out of a waste separation system suited to the Surmont Camp. This involved multiple channels of communicating expectations and the rationale for depositing the various waste streams into the appropriate bins in the main dining area at the camp. Reducing single use packaging and plastics in the camp was another strategy to keep waste streams free of contaminants, but this hit a bit of a setback with the pandemic as safety is now paramount. More single use individually wrapped options have been reintroduced which has led to some ongoing challenges with keeping plastics out of the food waste stream. Issues that were resolved in the pilot phase included calibrating the auger system to move the waste through at the right pace, adding a platform to ensure good ergonomics for the loading process, and installing highly visible easy to use emergency shut down buttons.

A safe and reliable camp food waste reduction system is now in place at Surmont. It includes the separation of waste at source by camp residents for input into customized Eco-Growth Organic Reactors. The process has reduced the camp food waste stream by approximately 80% by weight. Additionally, instead of trucking approximately 235 tonnes of waste per year to the landfill, the camp food waste stream is now utilized at site as a bulking agent in other waste streams. The resultant product could also be used as Category A (unrestricted use) compost, as it complies with the Canadian Council of Ministers of the Environment criteria, or it could be used as an input to a modular boiler system to produce heat and hot water.

A knowledge sharing session held in the second quarter of 2020 with a number of COSIA member companies (Canadian Natural, Cenovus and Imperial) resulted in them expressing interest in adopting the system developed through this project for use at their facilities. Adoption has been slowed due to the pandemic but interest remains high especially as progress is made towards having the option to connect a modular boiler system to combust the camp food waste stream to heat water at the camp.

LESSONS LEARNED

The formation of the diverse Operations Waste and Liability Strategy (OWLS) team with representation from Site Operations, Surmont Regional Residence, Environmental Operations and local contractors led to innovative solutions to reduce costs and environmental impacts related to waste streams at the Surmont facility.

Nothing ever works the first time. This pilot project required several iterations to adapt the equipment to meet safety and throughput capacity requirements to service the Surmont Regional Residence which typically houses and feeds several hundred people every day.

To ensure uncontaminated waste streams at camp facilities, clear signage and ongoing communications are required.

PRESENTATIONS AND PUBLICATIONS

Reports and Other Publications

Waste Not, Want Not. 2020. ConocoPhillips Canada web article available at: https://www.conocophillips.ca/sustainable-development/environment/waste-management/

Energy Excellence Awards: Companies earn high marks for efforts to shrink the land footprint in the oilsands. April 27, 2020. JWNEnergy.com web article available at: https://www.jwnenergy.com/article/2020/4/27/energy-excellence-awards-companies-earn-high-marks/

ConocoPhillips on-site waste management reduce more than garbage. Dec 23, 2019. CAPP Context web article available at: https://context.capp.ca/articles/2019/feature_conoco-on-site-waste-management

AWARDS

The Alberta Emerald Foundation awarded this project an Emerald award in the Small Business category in 2020. Waste to Energy Project (ConocoPhillips Surmont Plant) | Alberta Emerald Foundation. Available at: https://emeraldfoundation.ca/aef_awards/ecogrowthenvironmental/

RESEARCH TEAM AND COLLABORATORS

Institution: ConocoPhillips

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Collaborators: Eco-Growth Environmental Inc., Fort McMurray Lodge Services and Collective Waste