

2025 COSIA LAND EPA

Mine & In Situ Research Report



Oil Sands
Alliance



cosia®

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Introduction

COSIA is the innovation arm of Oil Sands Alliance* which represents five of Canada's major oil sands producers — Canadian Natural, Cenovus, ConocoPhillips Canada, Imperial, and Suncor. It is the collective voice of its oil sands members for communicating with Canadians and engaging all levels of government. Our members understand the power of innovation and collaboration. For over a decade they have been working together as **COSIA**, to help advance environmental technologies and innovation. Through **COSIA**, **Oil Sands Alliance** continues to serve as the epicentre of collaboration between members to advance technologies and achieve shared goals, especially in the environmental priority areas of land, tailings, water and greenhouse gas emissions.

This report is funded by members of COSIA's Land Environmental Priority Area (EPA):

Canadian Natural

Cenovus Energy Inc. (Cenovus)

ConocoPhillips Canada Resources Corp. (ConocoPhillips)

Imperial Oil Resources Limited (Imperial)

Suncor Energy Inc. (Suncor)

Syncrude Canada Ltd. (Syncrude)**

This 2025 report summarizes progress for Land EPA projects related to both in situ and mine reclamation. The project summaries included in this report do not include all projects completed under the Land EPA. Projects have been conducted by external researchers. More information about the Land Environmental Priority Area is available on the Oil Sands Alliance website: www.oilsandsalliance.ca.

Please contact the Industry Champion identified for each research project if any additional information is needed.

* In February 2026, Pathways Alliance was renamed Oil Sands Alliance.

** Suncor Energy assumed operatorship of the Syncrude Joint venture in October of 2021, however Syncrude Research and Development remained a full member of COSIA until December 2025.

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Project Index by Topic and Report (Combined Mine and In Situ, Mine, In Situ) 2014 to 2025

The projects included in this index cover the period from 2014 to 2025 and do not include all projects completed under the Land EPA. More information about the Land EPA is available on the Oil Sands Alliance website: www.oilsandsalliance.ca. Please contact the Industry Champion identified for each research project if any additional information is needed.

Beginning in 2022, COSIA published a single combined research report, COSIA Land EPA — Mine and In Situ Research Report. Prior to 2022, COSIA published two separate annual reports: COSIA Land EPA — Mine Research Report and COSIA Land EPA — In Situ Research Report (first published 2018).

COSIA LAND EPA — MINE AND IN SITU RESEARCH REPORT (2022 TO 2025)

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2022	2023	2024	2025
WETLANDS						
Removing the Wellsite Footprint (iFROG)	LJ0126	ConocoPhillips	X	X		
Assessing the Ecological Potential of Wetlands and Surrounding Reclaimed Pads Field Plot	LE0078	COSIA	X	X		
Boreal Wetlands Reclamation Assessment Project (BWRAP): Industrial Research Chair in Oil Sands Wetland Reclamation	LE0037	COSIA	X	X	X	
Evaluating the Success of Fen Creation — Phase 2	LJ0098	Suncor	X			
Quantifying the Effect of In Situ Oil Sands Development on Wetland Function	LJ0349	Imperial			X	X
SOILS AND RECLAMATION MATERIALS						
Topsoil Replacement Depth Study	LJ0335	ConocoPhillips	X	X	X	X
DNA-Based Technologies to Evaluate Reclamation Success (Final Cumulative Summary)	LJ0294	Imperial	X			
Shrub and Perennial Outplanting Study	LJ0322	Syncrude	X			
High Quality Shrub Seedlings	LE0087	COSIA		X		
Development of Soft Tailings Reclamation Technologies to Create Stable and Sustainable Boreal Landscapes	LJ0341	Imperial		X		
REVEGETATION						
Restoration of Native Tree and Shrub Species on Reclaimed Grassy Sites	LJ0291	Imperial	X		X	

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2 0 2 2	2 0 2 3	2 0 2 4	2 0 2 5
Hitchhiker Field Trial at Kearl Operations (Final Cumulative Summary)	LJ0324	Imperial	X			
Interim Reclamation	LJ0226	ConocoPhillips	X	X		
Surmont Boreal Forest Reclamation	LJ0226	ConocoPhillips			X	X
Oil Sands Vegetation Cooperative (Renamed COSIA Vegetation Research Committee in 2024)	LE0014	COSIA	X	X	X	X
The Use of Carbon Nanomaterials to Improve Seed Germination Seedling Vigour and Growth	LE0067	COSIA	X			
NSERC - Industrial Research Chair in Terrestrial Restoration Ecology (Final Cumulative Summary)	LE0034	COSIA	X			
Syncrude Upland Vegetation Monitoring Program	LJ0343	Syncrude	X	X		
Improving Establishment Success and Early Growth of Trembling Aspen on In-Situ Reclamation Sites in the Athabasca Oil Sands	LJ0225	Imperial				X
Prioritizing Zones for Buried Pipeline Revegetation in Caribou Habitat	LE0093	Canadian Natural				X
WILDLIFE RESEARCH AND MONITORING						
Regional Industry Caribou Collaboration (RICC)	LJ0155	Canadian Natural	X			
A Portable Testing Device for Wildlife Conservation	LJ0334	ConocoPhillips	X	X	X	
Johne's Disease in Bison	LJ0342	Syncrude	X	X	X	
Early Successional Wildlife Dynamics Program (Final Cumulative Summary: Supplemental Year 1)	LJ0013	Canadian Natural	X			
Early Successional Wildlife Dynamics Study	LJ0013	Canadian Natural			X	X
Canadian Toad (<i>Anaxyrus hemiophrys</i>) Monitoring on Canadian Natural's Horizon Oil Sands	LJ0325	Canadian Natural	X	X		
Canadian Toad (<i>Anaxyrus hemiophrys</i>) Habitat Suitability Index Model Update and Validation	LJ0326	Canadian Natural	X	X		
Canadian Toad (<i>Anaxyrus hemiophrys</i>) Mitigation, Monitoring, and Habitat Suitability Index Modeling	LJ0325 and LJ0326	Canadian Natural			X	X
Alberta Biodiversity Conservation (ABC) Research Program — Phase 2	LE0056	COSIA	X			
Wildlife Monitoring – Horizon Oil Sands	LJ0186	Canadian Natural		X		
Caribou Detection in Boreal Forest Environments	LE0075	COSIA		X	X	X
Early Successional Wildlife Dynamics Study	LJ0013	Canadian Natural			X	
ENVIRONMENTAL RESEARCH AND MONITORING						
Boreal Ecosystem Recovery and Assessment — Phase 2	LJ0220	ConocoPhillips	X	X	X	X
EcoSeis Phase 1 (Final Cumulative Summary)	LJ0340	Suncor	X			
EcoSeis Phase 2	LJ0344	Imperial		X	X	
Edge Effects of Seismic Footprint in the Lowland Boreal Ecosystems of Alberta	LE0081	COSIA	X	X		
COSIA Fall Filed Tour 2024	LE0091	COSIA			X	

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2 0 2 2	2 0 2 3	2 0 2 4	2 0 2 5
2025 COSIA Land EPA Symposium	LE0100	COSIA				X
Restoration Lessons and Future Guidance Workshop	LE0096	COSIA				X
EQUIPMENT						
Restoration Equipment Modernization	LJ0345	Cenovus	X			X

COSIA LAND EPA — MINE RESEARCH REPORT (2014 TO 2021)

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2 0 1 4	2 0 1 5	2 0 1 6	2 0 1 7	2 0 1 8	2 0 1 9	2 0 2 0	2 0 2 1
INSTRUMENTED WATERSHEDS										
Applying Natural Analogues to Constructing and Assessing Long-Term Hydrologic Response of Oil Sands Reclaimed Landscapes (HEAD3)	LJ0215	Syncrude	X	X	X	X	X	X		
Aurora Soil Capping Study: Program Overview	LJ0201	Syncrude	X	X	X	X	X	X		
Aurora Soil Capping Study: Evaluation and Modelling of Soil Water Dynamics to Determine Land Capability of Coarse Textured, Hydrocarbon-Affected Reclamation Soils	LJ0099	Syncrude	X	X	X	X	X			
Aurora Soil Capping Study: Hydrocarbon Degradation and Mobility	LJ0219	Syncrude	X	X	X	X				
Aurora Soil Capping Study: Re-Establishment of Forest Ecosystem Plants, Microbes and Soil Processes in Coarse Textured Reclamation Soils	LJ0201	Syncrude	X	X	X	X	X			
Aurora Soil Capping Study: The Roots of Succession: Relations Among Plants, Soils and Mycorrhizal Fungi in a Reclaimed Site	LJ0100	Syncrude	X	X	X	X	X			
Aurora Soil Capping Study: Soil Carbon Dynamics and Nutrient Retention in Reconstructed Sandy Soils	LJ0201	Syncrude	X	X	X	X	X			
Aurora Soil Capping Study: Water and Carbon Isotope Methods Development	LJ0201	Syncrude	X	X						
Coal Watershed Research and Development Program	LJ0160	Teck Resources Ltd	X	X	X	X				
Developing a Functional Approach to Assessment of Equivalent Capability: Utilizing Ecosystem Water, Carbon and Nutrient Fluxes as Integrated Measures of Reclamation Performance	LJ0127	Syncrude	X	X						
Evaluating the Success of Fen Creation	LJ0098	Suncor	X	X	X	X		X		
Evaluating the Success of Fen Creation (Phase II)	LJ0098	Suncor					X		X	X

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2 0 1 4	2 0 1 5	2 0 1 6	2 0 1 7	2 0 1 8	2 0 1 9	2 0 2 0	2 0 2 1
FORWARD III: Modelling to Contribute to Cumulative Effects Management in the Canadian Boreal Forest	LJ0009	Canadian Natural	X	X	X	X				
NSERC Long-Term Watershed Response to Climate: Industrial Research Chair in Hydrogeological Characterization of Oil Sands Mine Closure Landforms	LJ0210	Syncrude	X	X	X	X				
NSERC Long-Term Watershed Response to Climate: Industrial Research Chair in Mine Closure Geochemistry	LJ0292	Syncrude	X	X	X	X	X	X		
Sandhill Fen: Research Watershed Program Overview	LJ0204	Syncrude	X	X	X	X	X	X	X	
Sandhill Fen: Biogeochemical Investigation in Sandhill Fen	LJ0204	Syncrude	X							
Sandhill Fen: Early Community Development of Invertebrates in Sandhill and Reference Fens - Local Effects of Vegetation, Substrate, and Water Quality	LJ0204	Syncrude	X	X	X	X				
Sandhill Fen: The Early Development of Sandhill Fen: Plant Establishment, Community Stabilization and Ecosystem Development	LJ0204	Syncrude	X	X	X					
Sandhill Fen: Forest Reconstruction on Upland Sites in the Sandhill Fen Watershed	LJ0204	Syncrude	X	X	X	X	X			
Sandhill Fen: Geospatial Metadata and Mapping System	LJ0204	Syncrude	X		X					
Sandhill Fen: Hydrogeologic Investigation of Sandhill Fen and Perched Analogues	LJ0204	Syncrude	X	X	X	X	X	X		
Sandhill Fen: Influence of Peat Depth, Hydrology and Planting Material on Reclamation Success within a Created Fen-Like Setting	LJ0204	Syncrude	X	X	X					
Sandhill Fen: Water and Carbon Balance in the Constructed Fen	LJ0204	Syncrude	X	X	X	X	X			
Sandhill Fen: Assessing the Sodium Buffering Capacity of Reclamation Materials in Sandhill Fen	LJ0204	Syncrude			X					
South Bison Hill Instrumented Research Watershed (Clearwater Overburden) Soil Capping Research Synthesis	LJ0293 and LJ0312	Syncrude				X				
SOILS AND RECLAMATION MATERIALS										
Multiple Years of Biosolids Performance Data and Method Development	LJ0166	Teck Resources Ltd	X							
Nutrient Biogeochemistry 2: Tracking Nutrient Fluxes Through Reconstructed Soils	LJ0120	Syncrude	X	X	X	X	X			

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2 0 1 4	2 0 1 5	2 0 1 6	2 0 1 7	2 0 1 8	2 0 1 9	2 0 2 0	2 0 2 1
Salt Migration and Salinity Exposure to Plants in Reclamation	LJ0132	Total E&P Canada Ltd.: Contact COSIA	X							
Kearl Stockpile Study	LJ0254	Imperial		X						
Surface Soil Stockpiling Research	LJ0264	Imperial			X	X	X	X	X	X
Potential Limitation of Stockpiled Soils – A Case Study	LJ0300	Canadian Natural			X	X		X		
Limitations of Stockpiled Soil	LJ0300	Canadian Natural					X			
The GERI (Genomics Enhanced Reclamation Index) Stockpile Project: Creating Ecologically Viable Soil Stockpiles for Future Reclamation	LJ0299	Canadian Natural			X	X	X	X		
Reclamation Soils Index of Biological Integrity (IBI)	LJ0296	Canadian Natural			X	X	X	X		
Lean Oil Sand Soil Capping Synthesis and Risk Assessment	LJ0305	Canadian Natural				X		X		
Reclamation Material Stockpiling Opportunity and Gap Assessment	LE0043	COSIA						X		
Shrub and Perennial Outplanting Study	LJ0332	Syncrude							X	X
REVEGETATION										
Environmental Influences of Salinity Resistance in Forest Plants	LJ0133	Total E&P Canada Ltd.: Contact COSIA	X							
A Forest Fertilization Trial in a Mildred Lake Jack Pine Stand	LJ0209	Syncrude	X	X	X	X				
Improving Seed Longevity of Native Shrubs During Storage for Reclamation of Oil Sands Mines	LJ0195	Shell Canada Energy	X	X						
NSERC - Industrial Research Chair in Forest Land Reclamation	LE0012	COSIA	X	X	X	X	X	X	X	
Native Balsam Poplar Clones for Use in Reclamation of Salt-Impacted Sites	LJ0202	Syncrude	X	X	X	X	X	X	X	
Native Plant Establishment	LJ0053	Imperial and Syncrude	X							
Nutrient Loading of Seedlings to Improve Growth and Land Reclamation Success	LJ0141	Total E&P Canada Ltd.: Contact COSIA	X		X					
Oil Sands Vegetation Cooperative	LE0014	COSIA	X	X	X	X	X	X		X
Point Intercept Vegetation Monitoring	LJ0168	Teck Resources Ltd	X							
Selected Willow Clones for Use in Reclaimed Ecosystems Impacted by Elevated Salt Levels	LJ0203	Syncrude	X	X	X	X				
Terrestrial Mesocosm as a Model System for Evaluating Ecological Responses to OSPW Exposure	LJ0135	Total E&P Canada Ltd.: Contact COSIA	X							

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2 0 1 4	2 0 1 5	2 0 1 6	2 0 1 7	2 0 1 8	2 0 1 9	2 0 2 0	2 0 2 1
Trembling Aspen Seedling Establishment, Survival and Growth Related to Soil Properties on Reclaimed Sites	LJ0007	Canadian Natural	X	X	X					
Understory Plant Community Development on Reclaimed and Natural Sites	LJ0005	Canadian Natural	X	X	X					
Developing a Functional Approach to Assessment of Equivalent Capability: Utilizing Ecosystem Water, Carbon and Nutrient Fluxes as Integrated Measures of Reclamation Performance	LJ0127	Syncrude		X	X	X	X			
Fertilizer Dose Response Studies	LJ0141	Suncor		X						
Plant Community Succession of Oil Sands Reclamation	LJ0129	Shell Canada Energy: Contact Canadian Natural		X	X	X				
NSERC Terrestrial Restoration Ecology Industrial Research Chair	LE0034	COSIA			X	X	X	X	X	
Jack Pine Establishment	LJ0263	Imperial			X	X	X	X	X	
Establishment of Ericoid Mycorrhizal Associated Shrub Species (Blueberry, Labrador Tea And Lingonberry) in Oil Sands Reclamation Soils	LJ0128	Canadian Natural			X	X	X	X		
Effects of Non-Segregated Tailings (NST) on Growth of Oil Sands Reclamation Plants	LJ0303	Canadian Natural			X	X	X	X	X	X
Long-Term Plot Network	LJ0295	Canadian Natural			X	X	X	X		
Optimizing Weed Control	LJ0295	ConocoPhillips					X			
Bioengineering and Conventional Erosion and Sediment Control	LE0041	COSIA					X			
Hitchhiker Field Trial at Kearl Operations	LJ0324	Imperial						X	X	X
The Use of Carbon Nanomaterials to Improve Seed Germination, Seedling Vigour and Growth	LE0067	COSIA								X
WILDLIFE RESEARCH AND MONITORING										
Horizon Oil Sands Early Successional Wildlife Monitoring Program	LJ0186	Canadian Natural	X							
Early Successional Wildlife Monitoring of Reclaimed Habitat on Active Oil Sands Leases – Phase 1	LJ0186	Canadian Natural		X					X	
Wildlife Monitoring – Horizon Oil Sands	LJ0186	Canadian Natural			X	X	X	X	X	
Using Bighorn Sheep from Mined Land to Re-Establish Herds in Historic Ranges	LJ0161	Teck Resources Ltd	X							

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2014	2015	2016	2017	2018	2019	2020	2021
Wildlife Habitat Effectiveness and Connectivity Program	LJ0144	Shell Canada Energy: Contact Canadian Natural	X	X						
Wildlife Observation Database	LJ0163	Teck Resources Ltd	X							
Monitoring Avian Productivity and Survivorship in the Oil Sands Region (Boreal MAPS)	LJ0214	Syncrude		X	X	X	X	X		
Bison Research, Mitigation and Monitoring	LJ0266	Teck Resources Ltd.		X	X	X	X	X	X	X
Human & Wildlife Risk Assessment of Oil Sands Reclamation & Closure Landscapes Scenarios	LJ0272	Suncor			X	X	X			
Early Successional Wildlife Dynamics Program	LJ0013	Canadian Natural			X	X	X	X	X	
Environmental DNA (eDNA) for Canadian Toad, Burbot and Arctic Grayling	LJ0327	Canadian Natural						X		
Canadian Toad (<i>Anaxyrus hemiophrys</i>) Habitat Suitability Index Model Update	LJ0326	Canadian Natural						X		
Canadian Toad (<i>Anaxyrus hemiophrys</i>) Monitoring on Canadian Natural's Horizon Oil Sands	LJ0325	Canadian Natural						X	X	
Genomics and eDNA Workshop	LE0069	COSIA							X	
Johne's Disease in Bison	LJ0342	Syncrude								X
ENVIRONMENTAL RESEARCH AND MONITORING										
Horizon Lake Monitoring	LJ0011	Canadian Natural	X	X						
Swamp Reclamation in the Oil Sands Region: Investigation into Swamp Reclamation and Revegetation	LJ0114	Suncor	X							
Boreal Swamp Reclamation (Phase 2: Addressing Knowledge Gaps)	LJ0114	Suncor		X						
Shell Albian Sands Mine Reclamation Monitoring Using High Resolution Data from Unmanned Aerial Systems	LJ0193	Shell Canada Energy: Contact Canadian Natural		X	X					
Early Community Development in Reclaimed Landscapes of the Wapisiw Lookout Riparian Zone and Associated Wetlands	LJ0112	Suncor		X						
Criteria to Assess the Ecological Function of the STP Wetlands Complex and Diversion Channel	LJ0227	Suncor		X						
Fisheries Sustainable Habitat Committee: Refinement of Fish Habitat Pre-Disturbance Models	LJ0225	Suncor		X						
Compensation Lake Studies	LJ0260	Imperial		X						

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2014	2015	2016	2017	2018	2019	2020	2021
Reclamation Carbon Life Cycle Analysis	LJ0271	Suncor			X	X	X			
Biological Control of Scentless Chamomile	LJ0301	Canadian Natural			X	X				
Habitat Equivalency Analysis	LJ0306	Suncor				X				
WETLANDS										
Wapisiw Wetland Early Ecological Succession Monitoring	LJ0112	Suncor			X					
Criteria to Assess the Ecological Function of the STP Wetlands Complex and Diversion Channel	LJ0227	Suncor			X	X	X			
Peatland Restoration within the Suncor Millennium Mine (Phase One): Southeast Dump Wetland Hydrologic and Vegetation Monitoring Program	LJ0221	Suncor			X					
Ecohydrogeologic Investigation of Opportunistic and Constructed Wetlands on Syncrude's Mildred Lake Lease	LJ0275	Syncrude			X	X	X			
Coke Wetland Research	LJ0212	Syncrude			X					
Peatland Reclamation Markers of Success	LJ0273	Syncrude			X	X	X	X	X	
Reclamation Wetlands Index of Biotic Integrity (IBI)	LJ0297	Canadian Natural			X	X	X			
Wetland Inventory of Permanently Reclaimed Sites at Suncor Oil Sands Base Plant	LJ0304	Suncor				X				
Raised Bogs: Western and Traditional Knowledge Review	LJ0323	Suncor						X		
Boreal Wetland Reclamation Assessment Program (BWRAP): Industrial Research Chair in Oil Sands Wetland Reclamation	LE0037	COSIA							X	X
COSIA Swamp and Bog Reclamation Workshop: Investigating Innovation Opportunities for Reclaiming In Situ and Mining Developments in the Alberta Oil Sands Region	LE0062	COSIA							X	
COMPENSATION LAKES AND AQUATICS										
Horizon Lake Fisheries Monitoring	LJ0011	Canadian Natural			X	X	X	X	X	
Compensation Lake Studies	LJ0260	Imperial			X	X	X	X		
Fisheries Sustainable Habitat Committee: Refinement of Fish Habitat Pre-Disturbance Models	LJ0225	Suncor			X	X	X			
Assessing the Role of Habitat in Determining Age and Growth Relationships of Fish	LJ0170	Canadian Natural			X	X	X	X		
Assessing the Productive Capacity of Compensation Lakes	LJ0171	Canadian Natural			X	X	X	X		

COSIA LAND EPA — IN SITU RESEARCH REPORT (2018 TO 2021)

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2018	2019	2020	2021
WETLANDS						
H38 Wetland Carbon Flux Research Project	LJ0290	Imperial	X	X		
Removing the Wellsite Footprint (iFrog)	LJ0216	ConocoPhillips	X	X	X	X
Assessment of Relevant Indicators for the Monitoring of Reclaimed Sites in Peatlands	LJ0328	Canadian Natural		X	X	X
Boreal Wetland Reclamation Assessment Program (BWRAP): Industrial Research Chair in Oil Sands Wetland Reclamation	LE0037	COSIA			X	X
COSIA Swamp and Bog Reclamation Workshop: Investigating Innovation Opportunities for Reclaiming In Situ and Mining Developments in the Alberta Oil Sands Region	LE0062	COSIA			X	
SOILS AND RECLAMATION MATERIALS						
Cold Lake Topsoil Depth Experiment	LJ0208	Imperial	X	X		
DNA-Based Technologies to Evaluate Successful Reclamation	LJ0294	Imperial		X		X
Topsoil Depth Replacement Study	LJ0335	ConocoPhillips			X	X
REVEGETATION						
Cluster Planting	LJ0314	ConocoPhillips	X	X	X	
Optimizing Weed Control	LE0044	COSIA	X			
Improving Establishment Success and Early Growth of Trembling Aspen		Imperial	X	X	X	
Restoration of Native Tree and Shrub Species on Reclaimed Grassy Sites	LJ0291	Imperial	X	X	X	X
Mounding 2.0: Quantifying Plant Response to Silviculture Treatment	LJ0183	Cenovus	X			
Interim Reclamation	LJ0226	ConocoPhillips	X	X	X	X
Creating and Commercializing a Predictive EcoSite Mapping Platform for Alberta	LJ0188	ConocoPhillips	X			
Faster Forests	LJ0019	ConocoPhillips	X	X	X	
Oil Sands Vegetation Cooperative	LE0014	COSIA	X	X		X
Bioengineering and Conventional Erosion and Sediment Control	LE0041	COSIA	X			
Hitchhiker Field Trial at Kearl Operations	LJ0324	Imperial				X
The Use of Carbon Nanomaterials to Improve Seed Germination Seedling Vigour and Growth	LE0067	COSIA				X
WILDLIFE RESEARCH AND MONITORING						
South LiDea Restoration Area Project	LJ0182/LJ0307	Cenovus	X			
Regional Industry Caribou Collaboration (RICC)	LJ0155	Devon: Contact COSIA	X	X	X	X
Assessing Wildfire Risks to Caribou Recovery Projects in Northeast Alberta	LE0035	COSIA	X			
Migratory Connectivity Project	LJ0276	ConocoPhillips	X	X		

PROJECT SUMMARY TITLE	COSIA PROJECT NUMBER	INDUSTRY CHAMPION	2 0 1 8	2 0 1 9	2 0 2 0	2 0 2 1
Monitoring Avian Productivity and Survivorship in the Oil Sands Region (Boreal MAPS)	LJ0214	Suncor	X	X		
Linear Restoration Project (LiDEA): Plant, Animal and Greenhouse Gas (GHG) Response to Restoration Treatment	LJ0217	Cenovus			X	
A Portable Testing Device for Conservation	LJ0334	ConocoPhillips			X	X
Genomics and eDNA Workshop	LE0069	COSIA			X	
ENVIRONMENTAL RESEARCH AND MONITORING						
Approaching Zero Footprint Seismic – Pinpoint Pilot	LJ0320	Suncor	X			
A Multiple Lines of Evidence Approach for the Ecological Risk Assessment of an Accidental Bitumen Release from a Steam Assisted Gravity Drainage (SAGD) Well in the Athabasca Oil Sands Region	LJ0267	Devon: Contact COSIA	X			
Boreal Ecosystem Recovery and Assessment (formerly known as Geospatial Technologies for Monitoring Vegetation Recovery on Human Disturbance Features in Alberta's Boreal Forest)	LJ0220	ConocoPhillips	X	X	X	X
Prioritizing Zones for Caribou Habitat Restoration in the Canada's Oil Sands Innovation Alliance (COSIA) Area. Version 3.0	LE0049	COSIA		X		
Amphibious Restoration Equipment Efficacy Assessment	LJ0329	Cenovus		X		
Restoration Innovation Roadmap Phase 2	LE0059	COSIA		X		
Reclamation Carbon Life Cycle Analysis	LJ0271	Suncor		X		
Testing an Electromechanical Seismic Source to Achieve Reduced Acquisition Footprint	LJ0337	Suncor			X	
Osx™ ClearWave™ - Optimization of Low-Impact Seismic Source Towards Zero Footprint	LJ0336	Suncor			X	
WASTE REDUCTION						
Camp Food Waste Reduction	LJ0330	ConocoPhillips			X	

Featured Projects: Visual Summaries



LJ0294

Harnessing eDNA Technologies to Evaluate Land Reclamation Progress

CHALLENGE

Determine whether environmental DNA (eDNA) analysis can be used to assess the recovery of reclaimed sites and evaluate its potential as a cost-effective monitoring tool.

APPROACH

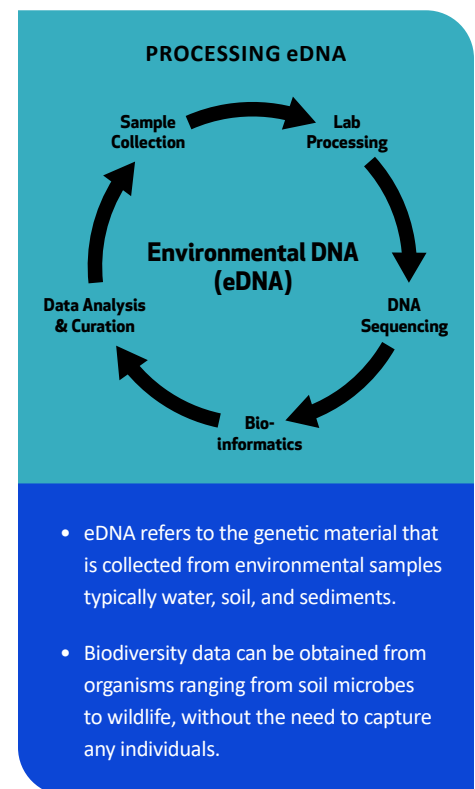
- Soil samples were collected from three reclamation sites (T13, NN and D63) with varying reclamation practices and three adjacent undisturbed reference sites at Cold Lake in-situ operations.
- D63 was a legacy grassy site and T13 and NN were sites using a combination of new practices (e.g., planting trees and shrubs). However, T13 had improved practices over the NN site.
- eDNA and soil analyses assessed biological (fungi, bacteria, microorganisms) and plant communities, alongside routine soil parameters.
- R programming was used to evaluate biodiversity, community composition, and ecological indicators.

KEY FINDINGS

- eDNA of selected biological communities provides valuable insights into biodiversity, species composition, and ecological function in reclaimed soils.
- Diversity (richness) of fungi and plants were not different between reclamation sites and reference sites, while for microbes, diversity was lower in reclaimed sites.
- Ecologically important fungal and microbial species found in reference sites were also present in reclaimed sites, particularly in T13, indicating successful recolonization.
- T13 showed the highest similarity to reference sites in terms of community composition and ecological indicators, suggesting a more advanced reclamation trajectory.
- Biodiversity indices and presence of indicator species further support T13's ecological alignment with undisturbed conditions.

WHY IT MATTERS

This is one of the first studies to use eDNA to assess reclaimed land, demonstrating its potential as a sensitive and cost-effective monitoring tool. Results, especially from the T13 site, highlight the value of integrating eDNA into reclamation monitoring and its exploration in newer reclamation sites.



LJ0226

Growing Forests on Soil Stockpiles: Nature as a Management Tool

CHALLENGE

Soil stockpiles from mining and oil/gas operations are prone to erosion, weed invasion, and long term degradation under grass seeding and herbicide application management approaches.

A more sustainable, interim approach such as temporary reforestation is needed to protect soil and accelerate forest recovery.

APPROACH

- Evaluated temporary reforestation on an 8-ha soil stockpile containing mixed topsoil and subsoil.
- Planted a mixed community of trees and shrubs (2 coniferous, 3 deciduous, 2 shrub species).
- Tested four planting densities to assess establishment responses.
- Applied site-wide decompaction treatments to counter prior track-packing and hydroseeding.
- Used rough-and-loose mounding or furrowing with coarse woody material to reduce grass cover, create microsites, and mitigate erosion.
- Implemented planting in June 2016 following site preparation.
- Conducted repeated vegetation surveys over eight years (years 1–4, 6, and 8) to track planted species performance and natural species ingress.

KEY FINDINGS

- Weed suppression: Early noxious weeds largely eliminated without herbicides.
- Forest establishment: Functional forests successfully developed across planting densities and soil types; no difference in stem density at year 8 between 2,500 and 5,000 stems/ha.
- Timely forest cover: Planting accelerates forested state compared to passive regeneration.
- Biodiversity gains: Plant and animal diversity increased from a handful to several dozen species.
- Scalable potential: Technique shows promise but requires replication across broader reclamation landscapes.

WHY IT MATTERS

This approach reduces long-term chemical inputs and overall management costs while improving soil conservation and final reclamation outcomes. It could also support biodiversity and habitats while providing operationally feasible solutions to manage soil stockpiles.



LE0014

From Seeds to Forests: COSIA Vegetation Research Committee

CHALLENGE

The challenge is to address knowledge gaps in oil sands reclamation vegetation and to support research that optimizes seed harvest, storage, propagation, and field establishment.

APPROACH

This project started as a means to encourage operators to cooperate in annual seed harvests, ensuring a consistent, genetically diverse supply of quality seeds. It has evolved over the past 16 years to optimize use of this valuable seed resource.

- A knowledge gap analysis is ongoing to identify challenges along the supply chain for individual species – from seed harvest, to extraction, storage, germination, seedling production and eventual field deployment.
- Research is designed to fully explore challenges and develop reliable solutions, often in cooperation with outside partners.
- Operational seed harvests are assessed to ensure quality and facilitate sharing among members.
- Operational monitoring of planted seedlings is ongoing to identify establishment concerns.

KEY FINDINGS

- Refined seed harvesting and handling methods for individual species are key to ensuring robust seedling production and eventual deployment success
- Cooperative harvesting has resulted in a relatively consistent, genetically diverse supply of quality seeds available for both research and deployment.
- Based on an ongoing knowledge gap analysis, members have prioritized key species for closer evaluation of specific supply chain concerns — most recently lowbush cranberry, green alder, dwarf blueberry and Labrador tea.

WHY IT MATTERS

Establishment of individual species is the foundation for reclaiming to a diverse, functional forest community.



LE0075

Caribou from the Clouds: High-Altitude Imaging for Wildlife Monitoring in Alberta

CHALLENGE

Monitoring wildlife is difficult in the vast, remote, and heavily forested regions of Alberta. Helicopter surveys are costly, can disturb animals, and pose safety risks to crews. For species like boreal caribou and other boreal wildlife, which are infrequently surveyed by direct observation, there is a need for new means of estimating abundance.

APPROACH

Using a TK-7 aerial imaging system mounted on a fixed-wing aircraft to survey large areas with minimal disturbance. The system collects both colour and thermal images from a high altitude.

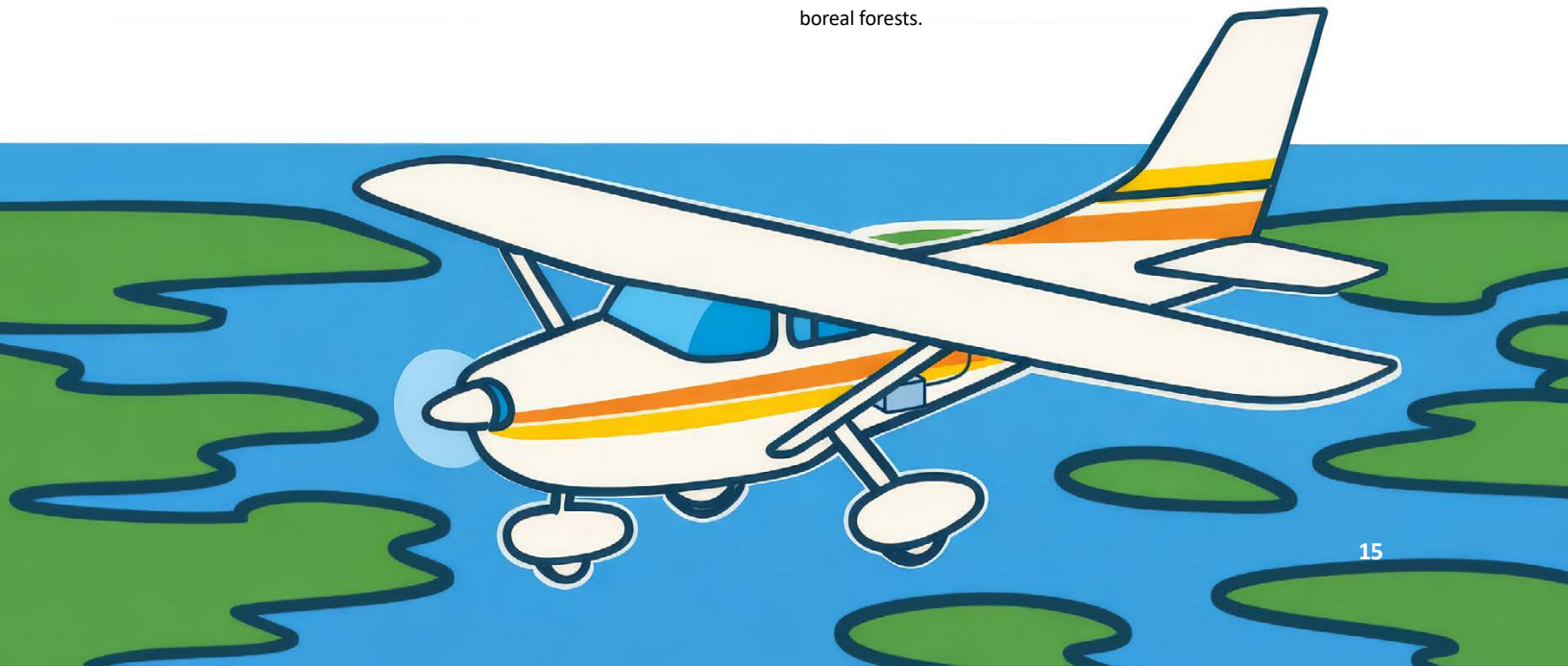
- Hi-res colour imagery is used to help identify species.
- Thermal images detect animals by heat.
- Machine-learning tools are being developed to find, identify, and count animals.
- Imagery is combined with GPS-based resource selection models to predict where wildlife are likely to be, even when the animals are not visible.
- Ongoing research focuses on easily seen species, such as feral horses and bison, to build AI training datasets that can also detect rarer species like boreal caribou and moose. Beaver lodges, deer, and waterfowl can also be observed.

KEY FINDINGS

- AI machine-learning models get better as more data is collected.
- Work with feral horses and bison has helped refine detection methods and built the foundation for caribou-focused detection.
- Integrating imagery with ecological modelling is a key innovation.
- By combining machine-learning detection with habitat models from GPS data, researchers can estimate where caribou are likely to occur, even when direct detection is limited.
- The project has contributed to new computer science publications, linking AI, remote sensing, and wildlife ecology.

WHY IT MATTERS

Despite ongoing detection challenges, this work is helping to build a scalable, non-invasive system to monitor caribou and other wildlife. It will support conservation, Indigenous stewardship, and land-use planning across Alberta's boreal forests.



LJ0325 & LJ0326

Hopping with Tech: Monitoring Canadian Toads

CHALLENGE

Assess Canadian Toad (*Anaxyrus hemiophrys*) wetland occupancy, the occurrence and characterization of suitable overwintering habitat, and whether they can be relocated from areas that are being mined to suitable receptor ponds.

APPROACH

Researchers monitored and relocated Canadian Toads to protect them.

This work included:

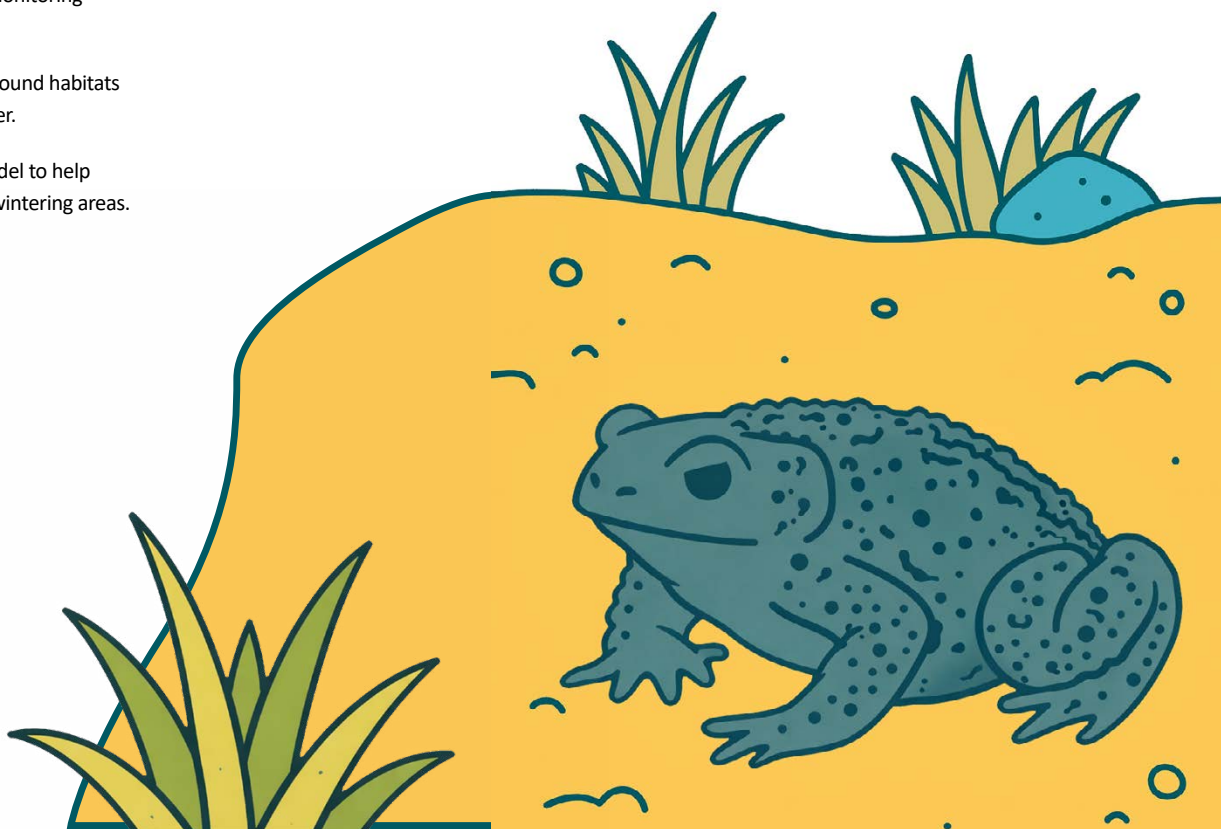
- Using Automated Recording Units (ARUs) to determine toad occupancy by listening for calling males and searching for toads during the day.
- Testing toads for diseases before moving them, to avoid spreading infections between wetlands.
- Relocating toads from areas at high risk of disturbance to safer ponds and monitoring survival rates.
- Finding and studying the underground habitats the toads use to survive the winter.
- Improving a habitat-mapping model to help identify good breeding and overwintering areas.

KEY FINDINGS

- Canadian Toad mitigation has occurred since 2018 with thousands of tadpoles, toadlets, and adults relocated to habitats that are not likely be affected by future mining activities.
- The distribution of breeding and wintering habitat has been assessed and mapped to support ongoing mitigation work.
- Various types of research, including telemetry studies, are providing regionally relevant data on toad habitat use.

WHY IT MATTERS

This work has contributed to a better understanding of the habitat required by toads for breeding and overwintering. Impacts to toads have been mitigated, and the updated habitat maps have provided information on the occurrence and distribution of suitable toad habitat.



LJ0347

Fishing Without Fishing: Using eDNA to Characterize Fish Communities

CHALLENGE

Develop a more efficient and effective way to monitor fish by replacing conventional methods that are time-intensive, require a lot of gear and effort, and can negatively impact the species they are meant to detect.

APPROACH

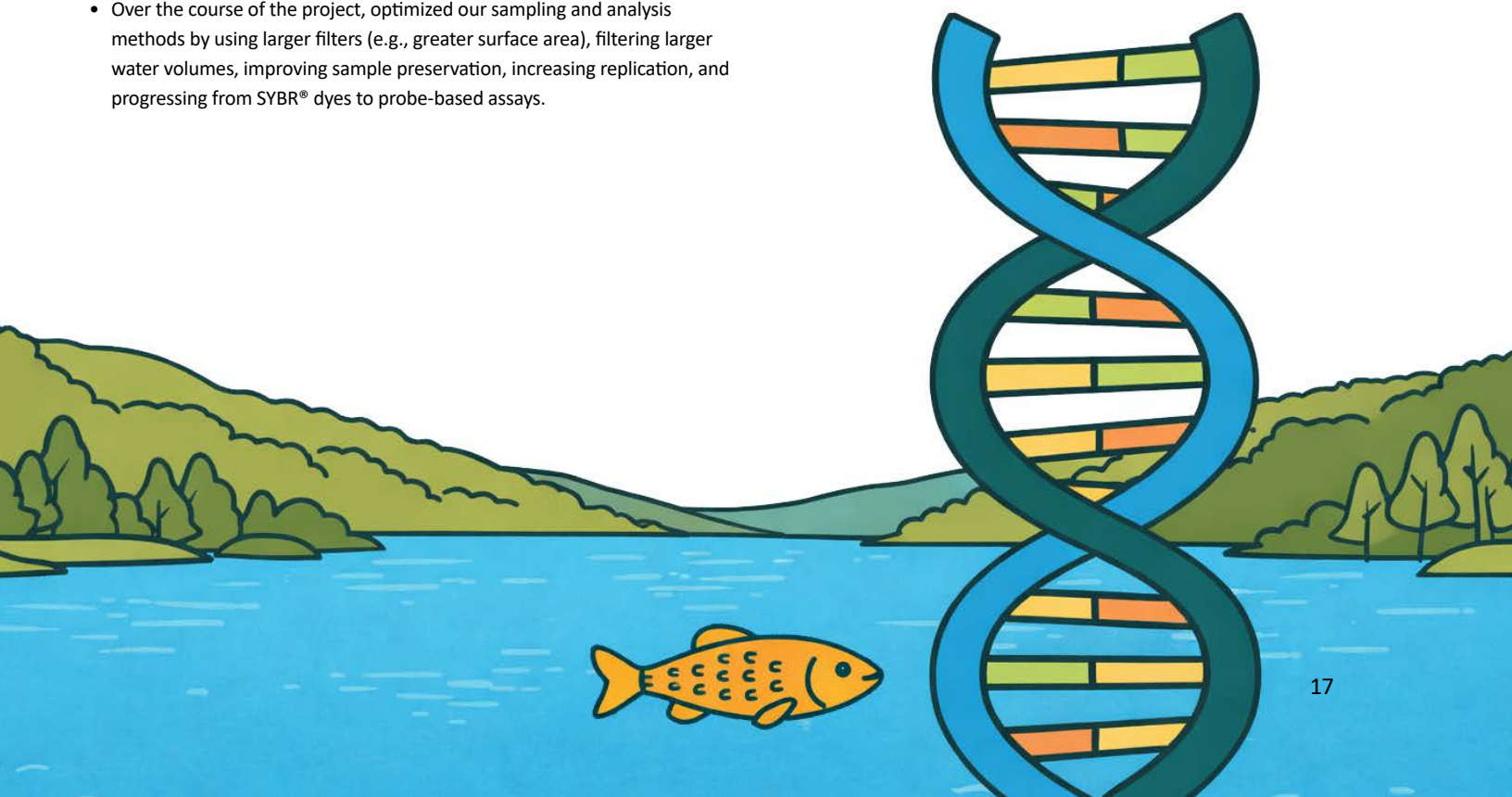
- Developed and validated species-specific primers for 13 target fish species.
- Developed an optimized water filtration system for collecting environmental DNA (eDNA) samples.
- Collected water samples from compensation lakes, nearby streams and rivers, and a diversion channel to characterize local fish communities.
- Used eDNA analysis to detect target fish species by quantitative polymerase chain reaction (qPCR).
- Compared eDNA results with conventional sampling methods (e.g., Gee minnow trap) for field validation.
- Over the course of the project, optimized our sampling and analysis methods by using larger filters (e.g., greater surface area), filtering larger water volumes, improving sample preservation, increasing replication, and progressing from SYBR® dyes to probe-based assays.

KEY FINDINGS

- eDNA detected one to 11 fish species per site, including species missed by conventional methods.
- Most target fish species were broadly present across sampled lakes and rivers.
- eDNA results were broadly consistent with conventional sampling.
- Understanding the sampling context and local hydrological systems is key to interpreting eDNA data.

WHY IT MATTERS

eDNA provides a fast, cost-effective, and sensitive way to monitor fish communities, reduce fish and habitat disturbance, and guide restoration and management decisions. Additionally, eDNA data can be used to demonstrate compliance with regulatory conditions related to fish habitat offsetting.



LJ0013

Where the Wildlife Are: Reclamation Monitoring in the Oil Sands

CHALLENGE

Assess whether areas rebuilt as upland forests after mining can support a variety of species — such as mammals, birds and amphibians — and study how the animals are using these reclaimed spaces.

APPROACH

Two phases guide the work:

- **Baseline Data Collection:** Collect baseline data on wildlife occurrence and distribution across reclaimed and natural habitats, including new in situ sites.
- **New and Future Analyses:** Assess how well reclaimed areas function by studying food sources, habitat structure, and year-round wildlife use.

Key activities:

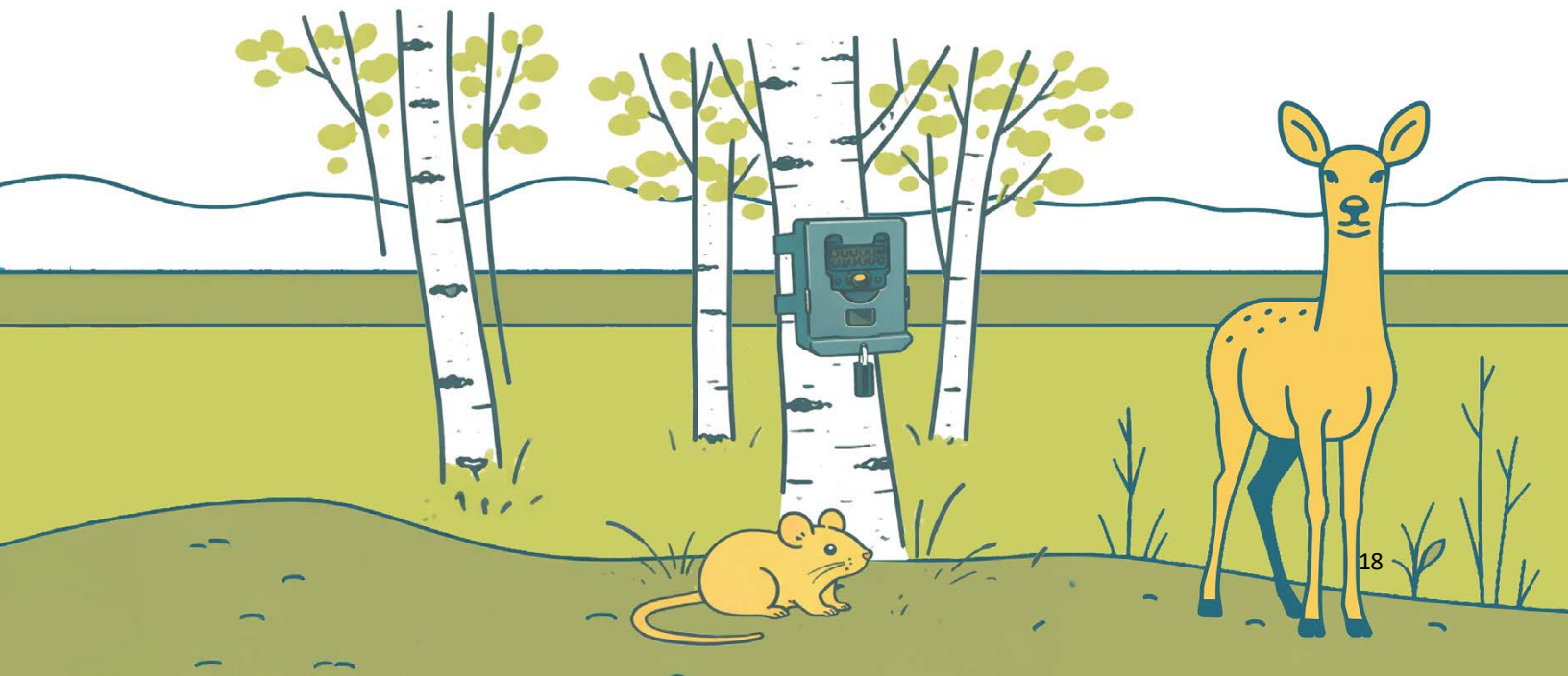
- Wildlife surveys across the region.
- Insect sampling to understand food availability and track ecological recovery.
- Habitat assessments for small mammals and their predators.
- Remote sensing with wildlife cameras and acoustic recorders for year-round monitoring.
- Long-term data analysis to compare reclaimed sites with reference habitats.
- A new winter bird program launched in 2024.

KEY FINDINGS

- Reclamation in the mined areas of the Athabasca Oil Sands region is helping to create upland boreal forests and reduce the impacts of mining.
- By studying how wildlife responds to these reclaimed areas, researchers are gaining valuable insights that can guide future reclamation efforts and improve the chances of creating healthy, productive habitats for wildlife.
- Reclaimed forests aren't expected to be exactly like natural ones, but early results suggest they can provide similar ecological benefits. More research is needed to see how well they support wildlife habitat.

WHY IT MATTERS

This monitoring program won't just show how well reclamation is working, but will also help shape better strategies for creating reclaimed wildlife habitats in the future.



LJ0344

Testing Low-Impact Seismic Technology to Reduce Land and Environmental Footprint

CHALLENGE

Conventional seismic surveys often require clearing wide linear corridors through forests and wetlands. These cleared lines disturb vegetation, fragment wildlife habitat, and can leave long-lasting impacts on sensitive landscapes. There is a need for a way to collect high-quality seismic data while reducing land disturbance and environmental impact.

APPROACH

- Validated Eco-Seis™, a low-impact way of carrying out seismic surveys that uses fewer linear survey layouts and reduces the amount of land clearing required.
- Conducted field trials comparing an EcoSeis™ program with a conventional 3D seismic program.
- Measured land disturbance and greenhouse gas emissions, including impacts from line clearing, fuel use, and methane from peatlands.
- Assessed vegetation regrowth on low-impact seismic cut lines versus wildfire recovery areas and undisturbed forest.
- Developed a software tool to evaluate and plan seismic acquisition parameters.

KEY FINDINGS

- 42% reduction in the length of cleared seismic lines compared to conventional methods.
- 37% reduction in total land disturbance area achieved in the field trial.
- Strong vegetation recovery observed on low-impact seismic lines cut 18 to 20 years ago.
- Demonstrated that the technology results in the same high-quality seismic data as compared to conventional methods.

WHY IT MATTERS

Low impact seismic line technologies such as EcoSeis™ can reduce land disturbance by minimizing the length of corridors needed to acquire seismic data. These approaches can help reduce vegetation loss and overall land footprint, lower data acquisition costs, and eventually reduce reclamation costs.



LJ0345

Innovation in Action: Restoration Equipment Modernization

CHALLENGE

Restoring wetlands and peatlands with conventional excavators is slow, costly and of limited quality. There is a need for alternative equipment and approaches that produce faster, higher-quality results.

APPROACH

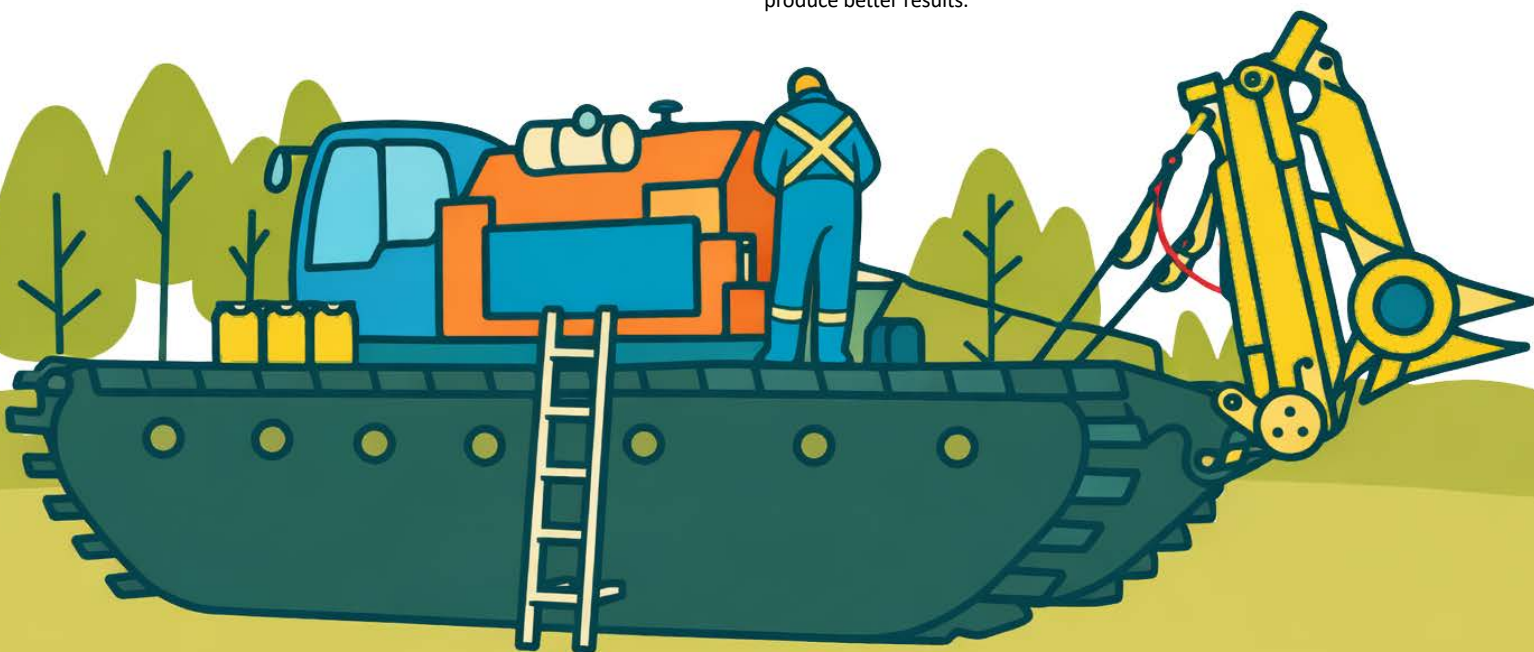
- Modern low ground pressure and amphibious equipment was used to access sites during non-frozen conditions.
- Employed site preparation (cultivation) implements, such as the Bracke™ moulder, under non-frozen conditions.
- Used excavators on amphibious undercarriages to enable multiple treatment types, including live transplantation, upright mounding and hummock transfers.
- Drawn implements were used to achieve up to a 10-fold increase in productivity.

KEY FINDINGS

- An approximate 10-fold increase in treatment productivity.
- Bracke™ moulder produced microsites with high quality and integrity.
- Upright mounds have high integrity and limited shrinkage.
- Transplanted trees and saplings had acceptable survival rates.
- Bracke™ mounds supported positive growth and controlled competing vegetation.
- Tree growth improved in most active treatments.

WHY IT MATTERS

Restoring Alberta's 120,000+ km of linear features — roads, pipelines, and seismic lines — is a big challenge for government and industry in Alberta. Silvicultural treatment costs for linear restoration using conventional equipment are 10 to 20 times greater on a per hectare basis than silviculture costs for typical boreal forest management in Canada. Alternative methods for linear restoration can significantly improve efficiency, reduce costs and produce better results.



Wetlands



Quantifying the Effect of In Situ Oil Sands Development on Wetland Function

COSIA Project Number: LJ0349

In Situ

Research Provider: Athabasca University, University of Waterloo, University of Calgary

Industry Champion: Imperial

Status: Year 3 of 5

PROJECT SUMMARY

Much of the bitumen in Alberta Oil Sands (AOS) is too deep for surface mining and must be extracted using in situ techniques, the latter involves construction of well pads interconnected by roads and pipelines distributed across the landscape. Although the area of any given installation is relatively small (e.g., well pads are generally one to four hectares (ha) in size), knowing the effects on wetland ecosystems beyond the direct footprint of the infrastructure will contribute to a successful site closure. On average, 30% of Canada's boreal region is covered by peatland (Natural Regions Committee, 2006), with areas in the AOS having between 50% to 100% peatland cover, accounting for most wetlands in the region (Vitt et al., 2000). Therefore, in situ oil sands developments can affect large wetland areas directly, and indirectly through changes in local hydrological and chemical conditions. The overall goal of the research program is to quantify the impact of in situ oil sands infrastructure on wetland ecohydrological and carbon accumulation function and evaluate activities that can help mitigate this impact.

The **main objectives** of this research project are to:

1. Determine the effect of in situ infrastructure (roads, well pads) on wetland hydrology, and how this varies among wetland types.
2. Relate the observed hydrological changes to wetland carbon (C) dynamics and plant community composition, productivity and peat accumulation rates.
3. Evaluate the timing of the ecohydrological response to infrastructure construction.
4. Determine best management practices for stockpiled peat and the effect of different stockpiling practices on greenhouse gas (GHG) emissions.

To address these objectives, project researchers have instrumented a peatland complex bisected by a mineral access road at the primary research site in Northern Alberta (Imperial's Aspen Lease). These ongoing, intensive measurements from this site are complemented by eight additional 'synoptic' wetland study sites impacted by infrastructure to capture the range in variation of ecohydrological response. These additional sites (four established in 2024; three more established in 2025) allow for the inclusion of a range of wetland types, across a larger geographical area (i.e., beyond the Aspen Lease) to encompass a broader range of ecosites, hydrogeological settings and responses. The synoptic sites have been instrumented with logging measurements and are visited less frequently than the primary site.

The general approaches used to address the project objectives are:

- 1. Infrastructure and wetland hydrology.** This project studies the interactions of the components of the water budget (including evapotranspiration using eddy covariance instrumentation; EC) in two main wetland types bisected by the road at the primary site (wooded coniferous fen and shrubby fen). Parallel measurements on the up and down-gradient sides of the road will be used to evaluate the magnitude and distribution of hydrological changes.
- 2. Wetland plant communities and carbon.** Shifts in plant community composition, productivity and carbon exchange are being evaluated at the Aspen Lease site. In parallel with objective 1, the EC towers also measure CO₂ exchange at ecosystem scale, and fluxes on both sides of the road will be compared and supplemented by chamber measurements. At the synoptic wetland sites, vegetation surveys and allometric equations will be used to determine biomass and productivity following road construction among wetland types.
- 3. Timing of wetland response.** The project team is using geospatial datasets collected from a remotely piloted aircraft system (RPAS) equipped with LiDAR (Light Detection and Ranging), thermal and optical sensors to evaluate ecosystem structural changes, including vegetation height and composition, microtopography and water table position, and evaluate its timing along a space-for-time continuum.
- 4. Stockpiled peat.** Stockpile management and planting practice treatments are underway, alongside complementary chamber-based carbon flux measurements to evaluate the effect of environmental conditions (e.g., soil moisture, temperature and plant cover) on stockpiled peat decomposition rates.

The **anticipated key outcomes** of this research project will inform industry development decisions and reclamation practices to help minimize and mitigate impacts to wetlands (avoid sensitive wetland types) and contribute to successful land closure. This includes advancing geospatial capacity to evaluate impacts during in situ oil sands operations and adjusting infrastructure designs based on ecosystem monitoring. Data collection for this project is taking place at Imperial's in-situ sites in Northern Alberta.

PROGRESS AND ACHIEVEMENTS

Significant progress was made in 2025 toward achieving the project objectives through continued field measurements, expanded site instrumentation, and acquisition of high-resolution geospatial and ecological datasets.

Activities in 2025 focused on advancing hydrological and carbon monitoring at the primary research site, expanding synoptic site coverage, and generating new quantitative datasets related to vegetation dynamics, stockpiled peat performance, and infrastructure-related disturbance.

Infrastructure and wetland hydrology

At the primary research site, both five-metre eddy covariance (EC) towers operated continuously from May through September 2025, providing a full growing-season dataset for ecosystem-scale evapotranspiration (ET) and carbon exchange on the up- and down-gradient sides of the main access road.

In August 2025, sapflow sensors were installed on trees adjacent to the EC towers to evaluate the relative importance of tree transpiration to total ecosystem ET. This addition addressed discrepancies between EC-based ET estimates and understory lysimeter measurements, whereby understory layer ET was greater on the upgradient side of the road, particularly in hollows, while ecosystem-scale ET measured by EC was greater on the downgradient side, especially during the late growing season. Processing of sapflow and EC datasets is ongoing, with EC footprint analyses finalized in 2025 as a critical step toward flux interpretation.

Hydrological monitoring was expanded through the establishment of stream gauging stations at six road culverts, at the outlet of the road-affected catchment, and at beaver impoundments within the same catchment. These stations provide quantitative discharge data to support comparisons of runoff dynamics associated with road infrastructure and natural streamflow alterations caused by beavers. Continuous measurements of water table depth and lysimeter-based soil water fluxes were maintained throughout 2025, extending the existing hydrological time series. In addition, in situ measurements were conducted throughout the piezometer network to quantify a depth-profile of saturated hydraulic conductivity within the peat soils across the study area.

Wetland plant communities and carbon

Vegetation surveys (conducted in 2024, analyzed in 2025) adjacent to the main access road showed that plant community composition varied between sides of the road and topographic position. Graminoid- and cattail-dominated communities were more prevalent in upstream and lowland areas, while downstream and transitional locations supported a greater proportion of woody species and mosses. Standing water was only observed in upstream-lowland positions, accounting for 13% of ground surface cover by area.

Vegetation surveys and biomass sampling continued across synoptic wetland sites in 2025, expanding the dataset used to assess post-disturbance plant community composition and productivity across wetland types. At the Aspen Lease Main Access Road site, chamber-based carbon flux measurements were continued in 2025, complemented by the ecosystem-scale measurements at the EC tower. Ecosystem-scale carbon flux measurements indicated that, over the 2024 monitoring period, the downgradient side of the road generally exhibited lower ecosystem respiration (R_{eco}) and gross primary productivity (GPP) compared to the upgradient side, resulting in lower net ecosystem exchange (NEE). However, late in the growing season GPP was slightly greater on the downgradient side.

Tree core samples were collected in 2025 to quantify annual growth rates and support assessments of longer-term vegetation response to infrastructure. In addition, sampling of dust deposition was initiated at locations spaced at multiple distances from the road, generating a new dataset to quantify spatial gradients in particulate deposition associated with mineral access roads.

Timing of wetland response

Progress toward evaluating the timing of wetland ecohydrological response was achieved through expansion of synoptic sites in 2025, increasing the spatial extent available for space-for-time analyses. Remotely piloted aircraft system (RPAS) missions were conducted at the Aspen Lease (including road- and stockpile-affected areas) and at synoptic sites. These missions generated high-resolution LiDAR, thermal, and optical imagery datasets, providing quantitative information on surface elevation, vegetation structure, and thermal patterns across disturbed and reference wetlands, with analyses of these datasets ongoing.

Stockpiled peat

Monitoring of the peat stockpile continued in 2025, with quantitative observations of erosion and vegetation growth. Erosion assessments indicate that the mean material loss of stockpile was 22.5 tonnes per ha, significantly lower than in 2023 (46.5 tonnes per ha). However, the soil loss remains high, ranging from 22 to 33 tonnes per ha per year (according to the soil loss classification proposed by Lobb et al., [2024]). Multi-year results indicated that soil erosion varied significantly by year and by the sides of the stockpile. In 2024, the west side lost 112 tonnes per ha, while the east and west sides gained 43.4 and 41.4 tonnes per ha, respectively. The high soil loss on the west side may be linked to the high soil gain on the east and south sides in 2024, as soil eroded from the west could be transported and partially deposited there by wind. In 2025, soil loss decreased significantly on the west side but increased on the east and south sides. As results, there were no significant differences in soil loss between sides in 2025. Reduced soil erosion on the west side could limit soil deposition by wind on the east and south sides, potentially increasing total soil loss on those sides in 2025 (Table 1).

Table 1: Summary of stockpile erosion in tonnes per hectare (t/ha) by year and position. Positive values indicate soil loss, while negative values indicate soil gain.

Erosion (t/ha)			
Side	2023	2024	2025
East	20.5 ± 3.3	-43.4 ± 7.9	29.4 ± 5.9
North	24.2 ± 2.7	0.1 ± 5.0	15.2 ± 4.6
South	9.1 ± 2.2	-41.6 ± 7.5	13.2 ± 6.6
Top	44.2 ± 4.1	32.3 ± 5.8	32.2 ± 7.3
West	131.8 ± 18.8	112.0 ± 18.5	22.7 ± 13.9
Mean	45.9 ± 6.2	11.8 ± 8.9	22.5 ± 7.7

Vegetation monitoring showed strong overall growth of planted tree and shrub species. Species-specific patterns in growth were observed, with jack pine (*Pinus banksiana*) and black spruce (*Picea mariana*) exhibiting the greatest increase in growth from previous years (Figure 1). Spatial divergence in growth also became more pronounced in 2025.

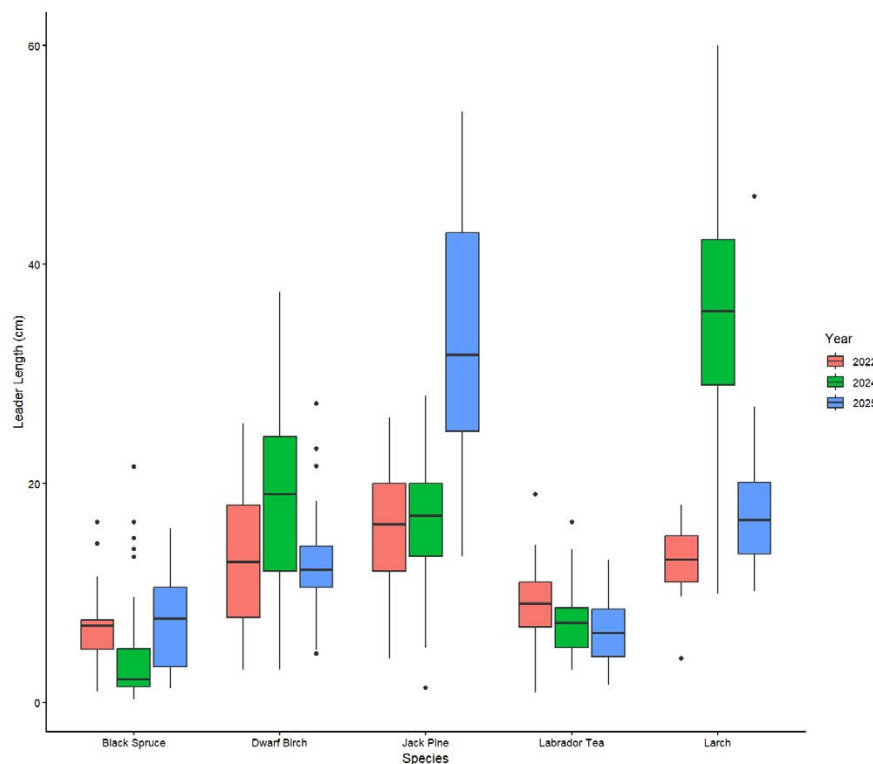


Figure 1: Leader length (cm) of tree and shrub species planted on the top of the stockpile. Species were planted in June 2022, and measurements were taken in August 2022, 2024, and 2025.

Chamber-based greenhouse gas flux measurements conducted on the stockpile in 2024 were analyzed in 2025. Results indicate that the stockpiled peat functioned as a substantial carbon source of approximately $539 \text{ g C m}^{-2} \text{ yr}^{-1}$ (Figure 2, 3). Future work in 2026 includes investigation of the hydrology and soil-water dynamics of the peat stockpile, in response to field-based observations of perched wetland conditions on the stockpile.

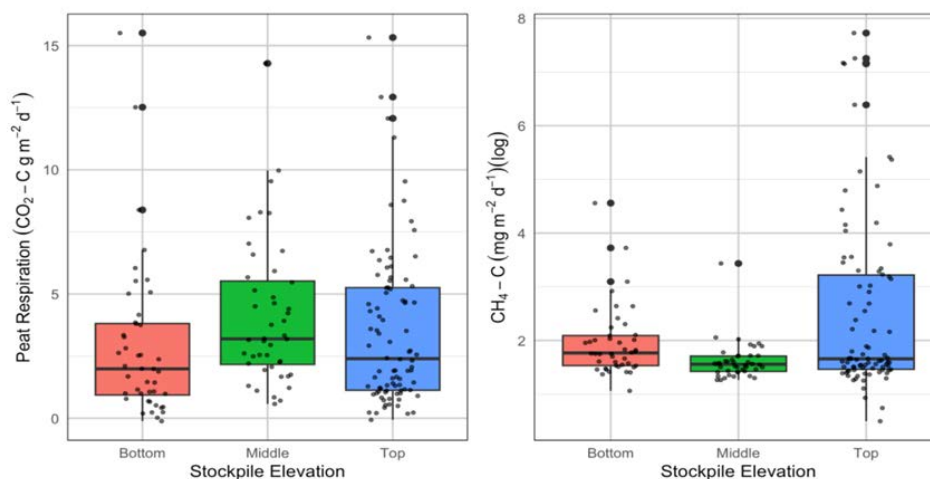


Figure 2: Boxplots depicting peat respiration (left) and methane flux (right) among stockpile elevations (bottom, middle, and top of stockpile).

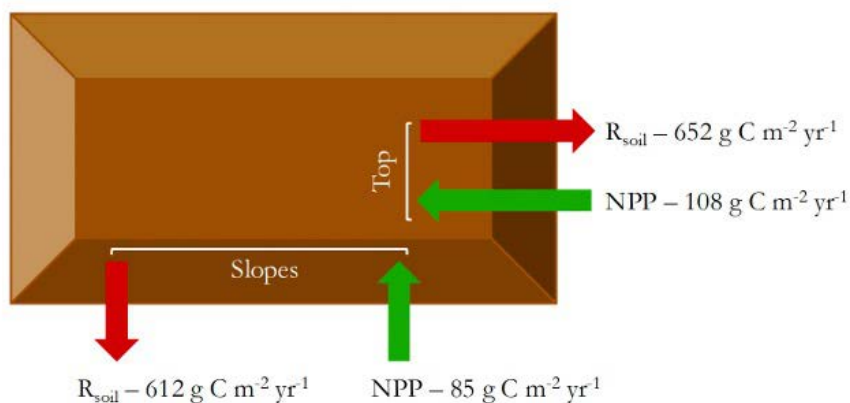


Figure 3: Conceptual diagram summarizing the different carbon fluxes on each part of the stockpile.

LESSONS LEARNED

Analysis of hydrological data at the main access road in 2025 revealed that the downgradient side of the road exhibited greater water table variability than the upgradient side. These differences were most pronounced during dry conditions and were evident across both seasonal and annual timescales, suggesting that groundwater transmissivity across the road is restricted. Preliminary results also indicate that horizontal hydraulic gradients are steeper across the road than the surrounding areas, but this observation is mitigated to some extent near culverts. Increased variability under dry conditions suggests that hydrological effects may be amplified during periods of climatic stress, which is relevant for understanding infrastructure–wetland interactions under a range of operating conditions.

The upgradient side of the road is generally wetter, which supports higher GPP, NEE and water use efficiency (WUE). In the late growing season, however, GPP, ET and WUE are greater on the downgradient side. This is consistent with visual observations of earlier senescence on the upgradient side of the road. Patterns revealed by the vegetation surveys to-date indicate that road-related hydrological gradients and landscape position are associated with measurable shifts in wetland vegetation structure, highlighting the importance of considering both flow direction and local topography when assessing and managing vegetation responses near mineral access roads.

Regarding the peat stockpile, results from 2025 monitoring indicate the successful establishment of boreal woody tree and shrub species, including black spruce, larch, pine, and dwarf birch, with additional natural ingress of willow and aspen observed. However, hitchhiker plug planting did not measurably increase species richness, and some species—particularly lingonberry—showed poor performance under high competition from graminoid cover crops. Vegetation observations showed that trees on the top of the stockpile are beginning to emerge above the grass canopy, indicating that woody species can persist despite early dominance by graminoid cover. In addition, surface depressions on the stockpile retained moisture and supported fen-like vegetation communities, including mosses, highlighting the interest in studying the hydrologic conditions of this stockpile.

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Principal Investigator: Dr. Scott Ketcheson

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Soils and Reclamation Material



Topsoil Replacement Depth Study

COSIA Project Number: LJ0335

In Situ

Research Provider: NAIT Centre for Boreal Research

Industry Champion: ConocoPhillips

Industry Collaborators: CNOOC Petroleum North America ULC

Status: Year 5 of 15

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 to pre-disturbance native soil depth 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, however, heterogeneity in placement depth is more desirable and 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. In addition, depending on the target forest ecosystem and plant community desired, a thick placement of topsoil may be counterproductive as individual species may be more, or less well suited to richer soil conditions. Ongoing work on an interim reclamation study of subsoil and topsoil supports this notion ([COSIA, 2024: LJ0226 Surmont Boreal Forest Reclamation pages 52-65](#)).

There has been significant interest in cover soil 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 allowed 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 comparatively evaluates three topsoil capping depth targets (no topsoil, shallow [5 cm] and standard [15 cm]) in a randomized complete block design. Recognizing that there will be variation around these targets, a ground survey was also conducted to confirm realized placement depths.

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 were planted (at a density of 4,800 stems per hectare) to evaluate species-specific survival and growth responses. In addition, intentional planting of native forbs specifically was accomplished 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. Hitchhiking, in the plant context, is a nursery stock production treatment whereby two plant species are co-grown in the same nursery container. This approach has been tested previously with white spruce and multiple native forbs (Mathison 2018, Hudson 2020) and this study applied the same principles in terms of seedling production (timing of sowing the forb after the conifer) to hitchhiking Jack pine and white spruce with native forbs.

The second approach was an operational-scale test of a pre-emergent herbicide that was applied in strips as a split-plot treatment within each capping depth plot replicate. This treatment is anticipated to 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 outplanting (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 ([COSIA, 2024: LJ0226 Surmont Boreal Forest Reclamation pages 52-65](#)), 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 was initiated 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 were 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 outplanting 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

Final results for Trial 3 were included in the [2024 COSIA Land EPA — Mine & In Situ Research Report](#), pages 18 to 43.

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 utilized the former approach as it was more practical from the perspective of seed emergence and in reducing issues with mosses and liverwort colonization.

The goal of this trial is to comparatively evaluate ericaceous shrubs grown singly, as well as hitchhiked shrubs (co-grown with one of two conifer species) and will also test the effect of soil inoculation on plant survival and growth. These seedlings were outplanted at the capping depth extremes (no topsoil versus standard 15 cm topsoil placement) to evaluate the conditions that are conducive to the healthy growth and persistence of these combinations of species. In this trial we will address the following questions:

1. Does hitchhiking have a negative, positive, or neutral effect on tree and shrub survival and growth?
2. Does topsoil addition benefit individual species in terms of survival or growth in the field?
3. Does a bio-stimulant provide a survival or growth advantage to individual species?
4. Does inoculation of seedlings during nursery production offer any survival or growth benefits after outplanting?

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., enables the use of 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

For 2025, this summary will focus on the findings related to Trial 4 – Hitchhiking ericaceous shrubs with conifers, as the final data collection and analyses for this trial has now been completed.

Key methodological details important to understanding and interpreting these findings:

1. Seedling stock was produced at the greenhouse facility at NAIT CBR (Peace River, AB) in 2021. Stock types were grown as single-cavity seedlings in 412A styroblock™ containers (125 mL) or as hitchhiker stock types of six basic species mixtures (shrub x tree): 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*]). All hitchhiker stock types were produced in 512A styroblock™ containers (220 mL).
2. Since ericaceous shrubs are also known to host a unique assortment of ericoid mycorrhizae, this trial tests whether inoculating nursery seedlings with field soil, during nursery production, promotes growth and survival in the field.
3. Both species, stock type (1) and inoculation (2) were randomized in blocked replicates within replicate plots that either had topsoil present at the standard application rate or entirely absent. As this trial was initiated one year following soil placement, all plots were established in herbicide-treated areas of the site to reduce competing ruderal vegetation effects on stock types.
4. Lastly, this experiment tests the potential for a bio-stimulant to compensate the lack of nutrients in the no-topsoil treatment. The bio-stimulant used was arGrow® from Arevo (Sweden), which is based on the amino acid arginine and acts as an organic nitrogen source that plants absorb efficiently through dedicated uptake pathways. This treatment was applied to seedlings across an entire plot.
5. In May 2022, seedlings were established into two treatment combinations within the main experimental design (four block replicates): no topsoil and standard topsoil depth treatments within herbicide treated plots where each replicate treatment plot contained 12 seedlings of each stock type combination. For each woody species group of stock types, all stock types were planted in groups of three plants along lines with each line replicated four times. Lines were paired and, in each pair, one line reflected seedlings that received inoculation in the greenhouse and the other line did not.
6. Planted tree and shrub seedlings surveys were conducted annually between 2022 thru 2025 to assess growth and survival of individual seedlings.
7. In the final year of the study (2025), vegetation was surveyed in three circular plots at each site. and Two soil samples were collected per plot: one from 0 cm to 15 cm depth and one from 15 cm to 30 cm depth (data not shown as samples are still being processed in the lab). Vegetation was assessed using three 50 cm x 50 cm quadrats randomly placed within each plot, and the cover of all species in each quadrat was recorded.
8. All statistical analyses were conducted in R (R core team 2025). Details regarding the modelling approaches employed and statistical model output are summarized in [Tables 1-6](#) (at the end of the photo panels).

Conoco Ericaceous Shrub Trial

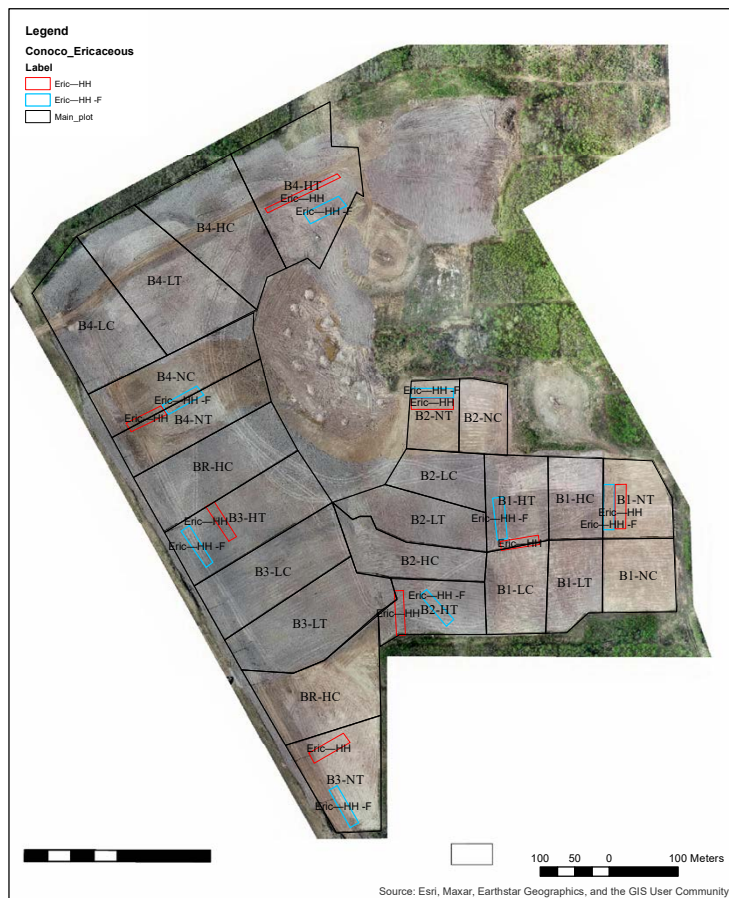


Figure 1: Overview of treatment plot layout showing the topsoil placement and pre-emergent herbicide treatments with hitchhiker plots nested inside main trial replicate plots. Treatment notations are as follows: B1-B4 refer to replicate blocks, H/L/C refer to the standard (H), shallow (L) or no-topsoil treatment (N) and T/C refer to treatment with pre-emergent herbicide (T) or untreated (C). Individual red (standard planting, no bio-stimulant) and blue rectangles (all seedlings were treated with a bio-stimulant) indicate ericaceous shrub trial plot locations within the larger experiment.

This was a complex trial with several factors with statistically significant model results ([Table 1-6](#)). However, upon closer examination, the effect size (magnitude of the difference among treatment means) for several factors were small. As such, this discussion and associated graphs focus on the primary drivers of survival and growth with respect to each species tested, rather than on some of the more nuanced factor levels that may have had statistical significance though the biological impact was arguably minor. The findings are discussed by addressing the following questions:

Question 1: Does hitchhiking have a negative, positive, or neutral effect on tree and shrub survival and growth?

- For white spruce, survival and growth was similar among singly grown and hitchhiked stock types (not shown).
- For Jack pine, survival was largely similar among singly grown and hitchhiked stock types with the exception of when it was hitchhiked with bog cranberry and inoculated with field soil in the greenhouse ([Figure 2e](#)) where Jack pine survival was lower. Growth of Jack pine was similar among hitchhiker and singly grown stock types (not shown).

- Common blueberry hitchhiked with white spruce and Jack pine had similar survival rates to singly grown seedlings in the standard topsoil treatment; in the no-topsoil treatment, hitchhiking improved blueberry proportional survival from 0.65 for singly grown seedlings to 0.85 with white spruce and 0.90 with Jack pine ([Figure 3a](#)). In contrast, vegetative cover was significantly higher for singly grown blueberry plants relative to hitchhiked plants across topsoil treatments – effectively showing that blueberry plants were larger when not growing directly under the conifer seedlings ([Figure 3e](#)).
- Bog cranberry survival showed a modest increase in survival when hitchhiked with white spruce compared with either Jack pine or singly grown seedlings; nevertheless, survival was very high for this species overall ([Figure 4a](#)). However, singly grown bog cranberry vegetative cover doubled, on average, relative to hitchhiked bog cranberry ([Figure 4d](#)).
- Labrador tea hitchhiked with white spruce or Jack pine showed similar (or slightly improved) rates of survival compared with singly grown Labrador tea ([Figure 5a](#)). Similar to the other shrub species, hitchhiking resulted in reduced vegetative cover compared with singly grown seedlings though this effect tended to be relatively modest with Jack pine ([Figure 5d](#)).

Question 2: Does topsoil addition benefit individual species in terms of survival or growth in the field?

- White spruce survival was similar among topsoil treatments provided understory tree cover was less than 30%. At cover values exceeding this, the presence of topsoil resulted in a sharp decline in survival compared with no topsoil ([Figure 2a](#)). Growth of white spruce also declined with increasing native forb cover and tree counts (higher tree densities) in the standard topsoil treatment ([Figure 2b](#)). For seedlings growing without topsoil, similar height growth was observed over the same range of native forb cover and tree counts ([Figure 2c](#)).
- Jack pine survival was also similar among topsoil treatments (not shown) and it was generally taller in the standard topsoil treatment relative to no-topsoil ([Figure 2h](#)) though the magnitude of this effect interacted with native forb and understory shrub cover ([Figure 2f-g](#)).
- In general, common blueberry illustrated mixed effects that were dependent on other stock treatment factors, in terms of survival ([Figure 3a-b](#)). Survival rates averaged approximately 0.80 across all blueberry stock types in the no-topsoil treatment and increased steadily with increasing understory tree cover in the standard topsoil treatment ([Figure 3c](#)). The same effect was observed for blueberry vegetative cover ([Figure 3f](#)). The net effect of this interaction was for blueberry to have similar survival rates in both topsoil treatments when tree cover was greater than 5% and similar cover development among topsoil treatments when tree cover was less than 4%.
- For bog cranberry there was no difference in survival among topsoil treatments (not shown). Except where understory tree cover was very low (less than 3%), bog cranberry vegetative cover was substantially greater in the standard topsoil treatment compared with no-topsoil ([Figure 4e](#)).
- For Labrador tea, topsoil treatments showed similar survival rates provided the vegetative cover of non-native forbs was less than 30%; while survival declined for Labrador tea as non-native forb cover increased beyond this, the magnitude of the decline was greater for seedlings in the standard topsoil treatment ([Figure 5b](#)). In general, the standard topsoil treatment resulted in greater vegetative cover compared with the no-topsoil treatment ([Figure 5e](#)); however, the magnitude of this effect was negatively influenced by increasing non-native forb cover and tree stem densities ([Figure 5f-g](#)).

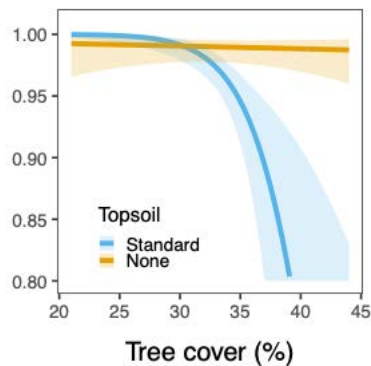
Question 3: Does a bio-stimulant provide a survival or growth advantage to individual species?

- For white spruce, Jack pine and common blueberry, application of bio-stimulant had no effect on survival (not shown).
- White spruce benefitted the most from bio-stimulant when it was applied to seedlings growing in the standard topsoil treatment with mean heights of approximately 90 cm as compared with 65 cm. In the no-topsoil treatment, while the trend was similar, the magnitude of the effect was minor with only a five cm difference between the means ([Figure 2d](#)).
- A similar effect was also observed for Jack pine where seedlings in the topsoil treatment were on average nearly 150 cm when they received bio-stimulant and 120 cm, on average without it; in contrast, bio-stimulant had no effect on Jack pine seedlings growing in the no-topsoil treatment ([Figure 2h](#)).
- In general, bio-stimulant had a negative effect on vegetative cover of blueberry ([Figure 3g-h](#)).
- Bio-stimulant improved bog cranberry survival by about 10% (Figure 4b) though it often reduced vegetative cover for this species ([Figure 4f-g](#)).
- While bio-stimulant had no effect on the absolute growth of Labrador tea (not shown) it improved survival under increasingly competitive conditions with non-native forbs. While survival tended to decline with increasing non-native forb cover, it was a modest drop for plants that received bio-stimulant while in the absence of bio-stimulant, survival of Labrador tea declined sharply with increasing non-native forb cover ([Figure 5c](#)).

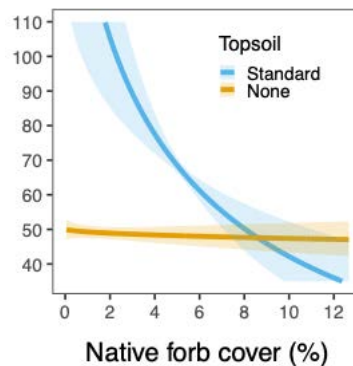
Question 4: Does inoculation of seedlings during nursery production offer any survival or growth benefits after outplanting?

- White spruce and common blueberry were not affected, in terms of growth or survival, by the inclusion of greenhouse soil inoculation (not shown).
- Soil inoculation had no effect on the growth of Jack pine seedlings though there was a 10% drop in survival (from 0.95 to 0.85) for bog-cranberry hitchhiked Jack pine seedlings that had received soil inoculation ([Figure 2e](#)).
- Bog cranberry survival showed a modest decline when it received a greenhouse field soil inoculation treatment with proportional survival rates of 0.82 compared with 0.90 ([Figure 4c](#)).
- Labrador tea survival was not affected by soil inoculation though it tended to show a modest benefit for singly grown seedlings and seedling hitchhiked with Jack pine (Figure 5d); this effect appeared most advantageous for seedlings in the standard topsoil treatment though no difference was observed for seedlings in the no-topsoil treatment ([Figure 5e](#)).

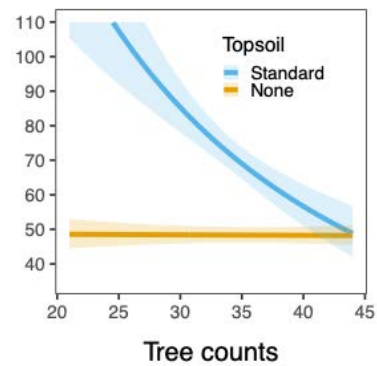
A. Spruce survival (proportion) as a function of tree cover (quadrat based)



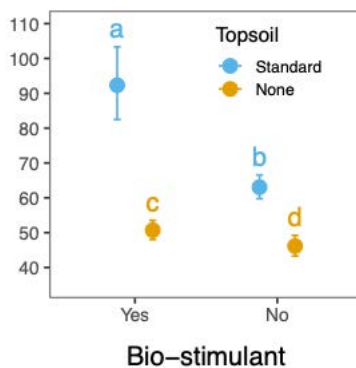
B. Spruce height (cm) as a function of native forb cover (%) and topsoil treatment



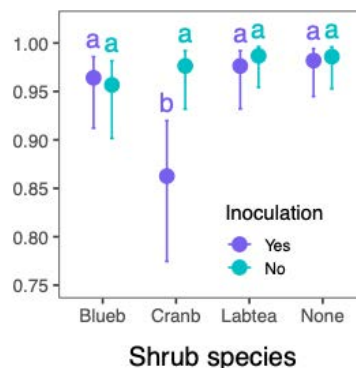
C. Spruce height (cm) as a function of tree stem counts and topsoil treatment



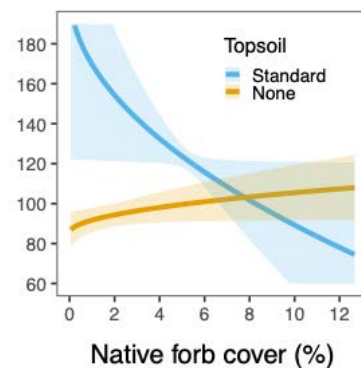
D. Spruce height (cm) as a function of topsoil treatment and bio-stimulant application



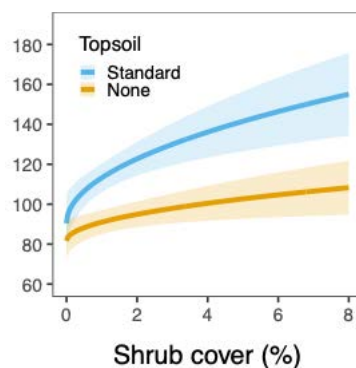
E. Pine survival (proportion) as a function of hitchhiker stock type and greenhouse soil inoculation



F. Pine height (cm) as a function of native forb cover (%) and topsoil treatment



G. Pine height (cm) as a function of shrub cover and topsoil treatment



H. Pine height (cm) as a function of topsoil treatment and bio-stimulant application

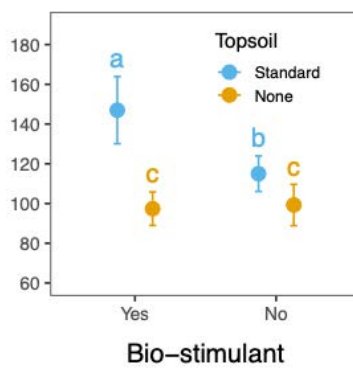
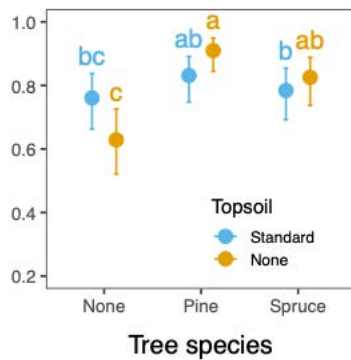
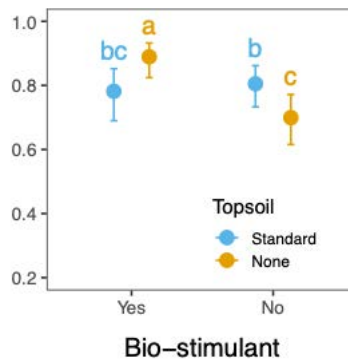


Figure 2: Significant effects of treatments and associated vegetation on the survival and height of white spruce and Jack pine at the end of the experiment (2025). Error bars and ribbons represent the 95% confidence intervals. Letters indicate significant difference between means ($\alpha < 0.05$).

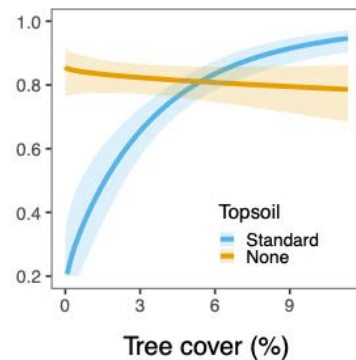
A. Blueberry survival (proportion) as a function of hitchhiked species and topsoil treatment



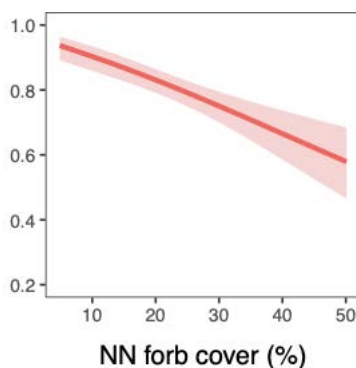
B. Blueberry survival (proportion) as a function of presence/absence of bio-stimulant and topsoil treatment



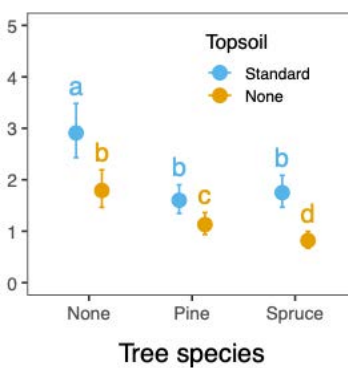
C. Blueberry survival (proportion) as a function of understory tree cover and topsoil treatment



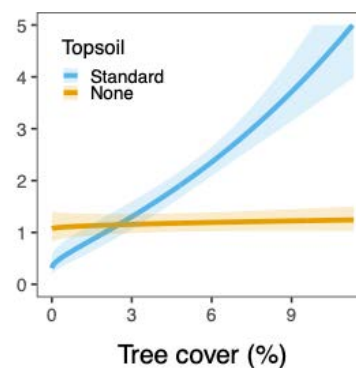
D. Blueberry survival (proportion) as a function of non-native forb cover



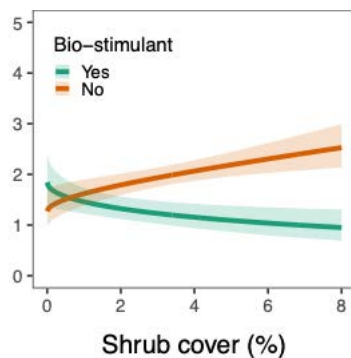
E. Blueberry cover (%) as a function of hitchhiked species and topsoil treatment



F. Blueberry cover (%) as a function of understory tree cover and topsoil treatment



G. Blueberry cover (%) as a function of understory shrub cover and presence/absence of bio-stimulant



H. Blueberry cover (%) as a function of grass cover and presence/absence of bio-stimulant

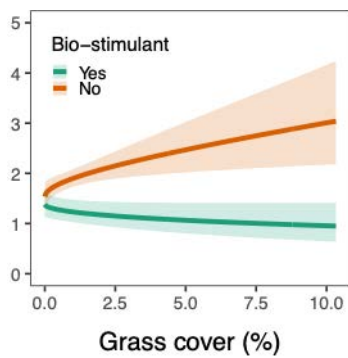
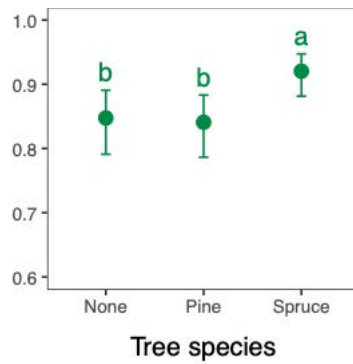
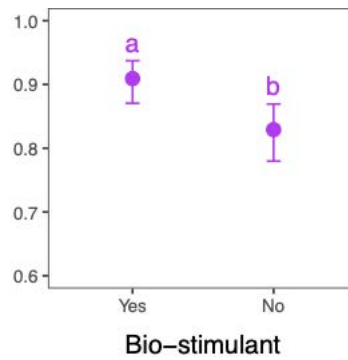


Figure 3: Significant effects of treatments and associated vegetation on the **survival and cover of common blueberry** at the end of the experiment (2025). Error bars and ribbons represent the 95% confidence intervals. Letters indicate significant difference between means ($\alpha < 0.05$).

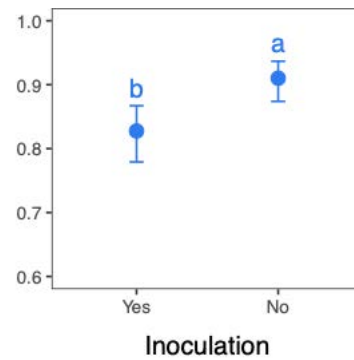
A. Cranberry survival (proportion) as a function of hitchhiked species



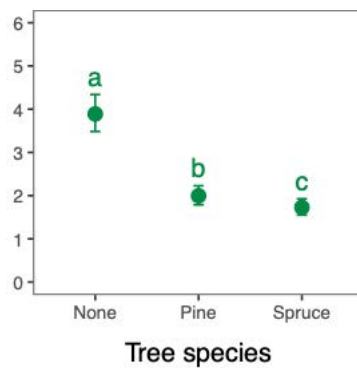
B. Cranberry survival (proportion) as a function of presence/absence of bio-stimulant



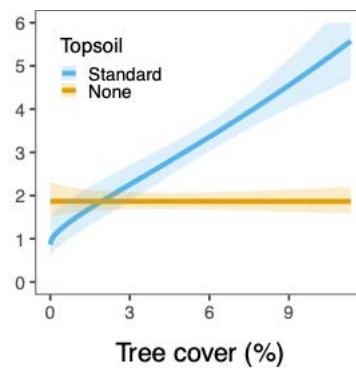
C. Cranberry survival (proportion) as a function of greenhouse applied inoculation of field soil



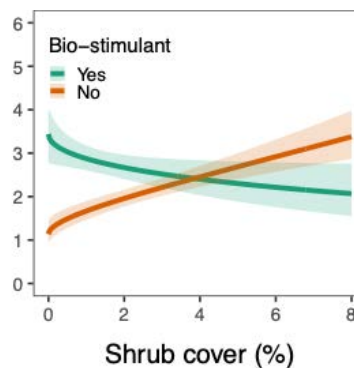
D. Cranberry cover (%) as a function of hitchhiked species



E. Cranberry cover (%) as a function of understory tree cover (%) and topsoil treatment



F. Cranberry cover (%) as a function of understory shrub cover (%) and presence/absence of bio-stimulant



G. Cranberry cover (%) as a function of grass cover (%) and presence/absence of bio-stimulant

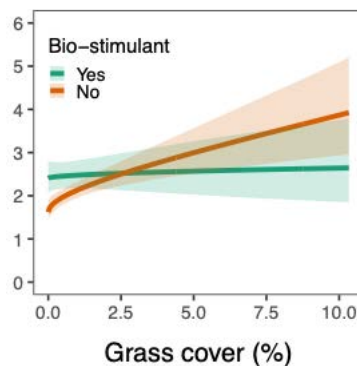
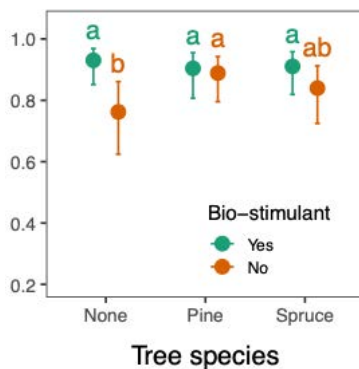
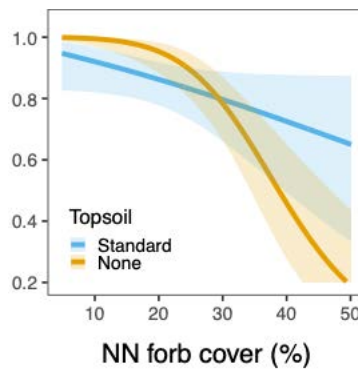


Figure 4: Significant effects of treatments and associated vegetation on the **survival and cover of bog cranberry** at the end of the experiment (2025). Error bars and ribbons represent the 95% confidence intervals. Letters indicate significant difference between means ($\alpha < 0.05$).

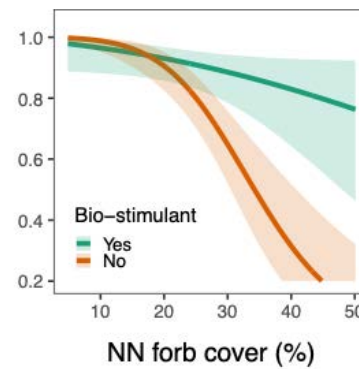
A. Labrador tea survival (proportion) as a function of hitchhiked species and presence/absence of bio-stimulant



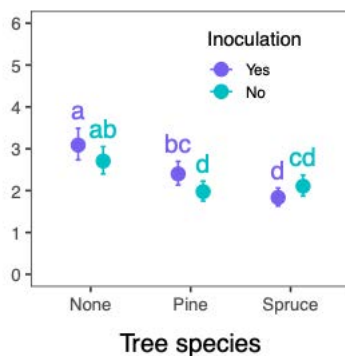
B. Labrador tea survival (proportion) as a function of non-native forb cover and topsoil treatment



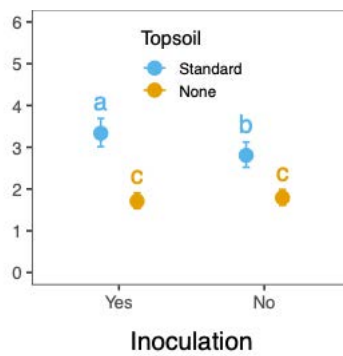
C. Labrador tea survival (proportion) as a function of non-native forb cover and presence/absence of bio-stimulant



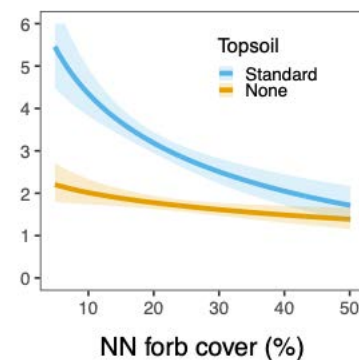
D. Labrador tea cover (%) as a function of hitchhiked species and greenhouse inoculation



E. Labrador tea cover (%) as a function of greenhouse inoculation and topsoil treatment



F. Labrador tea cover (%) as a function of non-native forb cover and topsoil treatment



G. Labrador tea cover (%) as a function of overstory tree stem counts and topsoil treatment

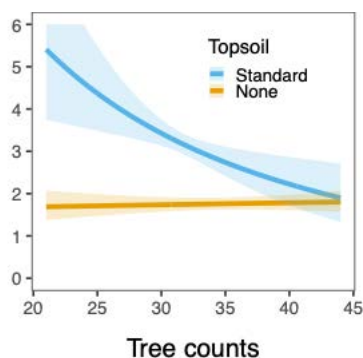


Figure 5: Significant effects of treatments and associated vegetation on the **survival and cover of Labrador tea** at the end of the experiment (2025). Error bars and ribbons represent the 95% confidence intervals. Letters indicate significant difference between means ($\alpha < 0.05$).



Figure 6: Images from the final year of assessment (August 2025) in the standard topsoil treatment illustrating ericaceous shrubs grown singly and with hitchhiked conifer species.

Jack pine - cranberry



Jack pine - blueberry



Jack pine – Labrador tea



White spruce - cranberry



White spruce - blueberry



White spruce – Labrador tea



White spruce - single



Jack pine - single



Figure 7: Images from the final year of assessment (August 2025) in the standard topsoil treatment illustrating conifer species grown singly and with hitchhiked ericaceous shrubs.

Table 1: Formulae used to run the generalized linear mixed-effects models of the effect of topsoil treatment, inoculation treatment, bio-stimulant treatment, tree/shrub species, and the interactions between them on the survival and growth of white spruce, Jack pine, and hitchhiked native shrubs (common blueberry, bog cranberry, and Labrador tea) after three growing seasons. Models were built following a stepwise procedure that added significant vegetation predictors ($p < 0.05$) to the core fixed effects; squared (^{2}): only two-way interactions included due to model convergence issues. The distribution of the response variable was selected based on AIC and Q-Q plots showing the distribution of residuals. Block, plot, line, subline (where the inoculation treatments were applied), and cluster (groups of three plants within each subline) were initially included as random effects in all models. However, most of these effects were near zero, which compromised model convergence. Therefore, they were removed, and only the retained random effects are shown in the table.

Species	Response	Core fixed effects	Random effects	Distribution	Link
Spruce	Survival	(Topsoil + Bio-stimulant + Inoculation + Shrub) ^{2}	None	Binomial	Logit
	Height	Topsoil x Bio-stimulant x Inoculation x Shrub	(1 Line/Cluster)	Tweedie	Log
Pine	Survival	(Topsoil + Bio-stimulant + Inoculation + Shrub) ^{2}	(1 Cluster)	Binomial	Logit
	Height	Topsoil x Bio-stimulant x Inoculation x Shrub	(1 Line/Cluster)	Gaussian	Identity
Blueberry	Survival	Topsoil x Bio-stimulant x Inoculation x Tree	(1 Cluster)	Binomial	Logit
	Cover	Topsoil x Bio-stimulant x Inoculation x Tree	(1 Line/Cluster)	Tweedie	Log
Cranberry	Survival	Topsoil x Bio-stimulant x Inoculation x Tree	(1 Line/Cluster)	Binomial	Logit
	Cover	Topsoil x Bio-stimulant x Inoculation x Tree	(1 Line/Cluster)	Tweedie	Log
Labrador tea	Survival	Topsoil x Bio-stimulant x Inoculation x Tree	(1 Line/Cluster)	Binomial	Logit
	Cover	Topsoil x Bio-stimulant x Inoculation x Tree	(1 Line/Cluster)	Gamma	Log

Table 2: Type II Anova tables for the generalized linear (mixed) models of the effect of topsoil treatment, inoculation treatment, bio-stimulant treatment, hitchhiked shrub species, and the interactions between them on the survival and height of white spruce after four growing seasons (2022 thru 2025). Significant ($p < 0.05$) fixed effects are shown in bold and are the ones plotted in the figures.

Response	Factor	χ^2	df	p-value
Spruce survival	Soil	7.67	1	0.006
	Fert	3.94	1	0.047
	Inoc	0.95	1	0.329
	Shrub	4.87	3	0.182
	sqrt(Tree.c)	6.42	1	0.011
	Soil:Fert	10.14	1	0.001
	Soil:Inoc	2.36	1	0.125
	Soil:Shrub	1.55	3	0.671
	Fert:Inoc	0.48	1	0.490
	Fert:Shrub	1.42	3	0.701
	Inoc:Shrub	5.60	3	0.133
	Soil:sqrt(Tree.c)	11.64	1	<0.001
Spruce height	Soil	75.14	1	<0.001
	Fert	33.84	1	<0.001
	Inoc	18.53	1	<0.001
	Shrub	17.92	3	<0.001
	sqrt(Shrubs)	3.78	1	0.052
	sqrt(Forb)	2.43	1	0.119
	sqrt(Tree.c)	3.25	1	0.071
	Soil:Fert	18.56	1	<0.001
	Soil:Inoc	0.33	1	0.563
	Fert:Inoc	0.10	1	0.747
	Soil:Shrub	3.40	3	0.334
	Fert:Shrub	6.38	3	0.094
	Inoc:Shrub	3.17	3	0.366
	Soil:sqrt(Shrubs)	60.82	1	<0.001
	Soil:sqrt(Forb)	16.35	1	<0.001
	Soil:sqrt(Tree.c)	28.11	1	<0.001
	Soil:Fert:Inoc	0.15	1	0.697
	Soil:Fert:Shrub	3.05	3	0.383
	Soil:Inoc:Shrub	1.77	3	0.622
	Fert:Inoc:Shrub	2.08	3	0.556
	Soil:Fert:Inoc:Shrub	2.36	3	0.501

Table 3: Type II Anova tables for the generalized linear mixed models of the effect of topsoil treatment, inoculation treatment, bio-stimulant treatment, hitchhiked shrub species, and the interactions between them on the survival and height of Jack pine after four growing seasons (2022 thru 2025). Significant ($p < 0.05$) fixed effects are shown in bold and are the ones plotted in the figures.

Response	Factor	χ^2	df	p-value
Pine survival	Soil	1.22	1	0.270
	Fert	0.46	1	0.498
	Inoc	6.32	1	0.012
	Shrub	17.47	3	<0.001
	sqrt(Forb_NN)	0.93	1	0.335
	Soil:Fert	0.22	1	0.638
	Soil:Inoc	1.86	1	0.173
	Soil:Shrub	3.46	3	0.326
	Fert:Inoc	3.55	1	0.059
	Fert:Shrub	4.76	3	0.190
	Inoc:Shrub	9.33	3	0.025
	Fert:sqrt(Forb_NN)	8.43	1	0.004
Pine height	Soil	26.96	1	<0.001
	Fert	3.79	1	0.052
	Inoc	1.47	1	0.225
	Shrub	13.43	3	0.004
	sqrt(Shrubs)	20.48	1	<0.001
	sqrt(Forb)	2.21	1	0.137
	Soil:Fert	11.94	1	<0.001
	Soil:Inoc	0.23	1	0.628
	Fert:Inoc	0.02	1	0.878
	Soil:Shrub	6.86	3	0.077
	Fert:Shrub	2.39	3	0.495
	Inoc:Shrub	3.11	3	0.374
	Soil:sqrt(Shrubs)	4.29	1	0.038
	Soil:sqrt(Forb)	5.28	1	0.022
	Soil:Fert:Inoc	0.09	1	0.766
	Soil:Fert:Shrub	7.95	3	0.047
	Soil:Inoc:Shrub	0.90	3	0.825
	Fert:Inoc:Shrub	1.03	3	0.795
	Soil:Fert:Inoc:Shrub	1.89	3	0.595

Table 4: Type II Anova tables for the generalized linear mixed models of the effect of topsoil treatment, inoculation treatment, bio-stimulant treatment, hitchhiked shrub species, and the interactions between them on the survival and height of common blueberry after four growing seasons (2022 thru 2025). Significant ($p < 0.05$) fixed effects are shown in bold and are the ones plotted in the figures.

Response	Factor	χ^2	df	p-value
Blueberry survival	Soil	0.31	1	0.579
	Fert	5.53	1	0.019
	Inoc	0.01	1	0.914
	Tree	16.73	2	<0.001
	sqrt(Trees)	4.64	1	0.031
	sqrt(Forb_NN)	25.42	1	<0.001
	Soil:Fert	7.47	1	0.006
	Soil:Inoc	0.74	1	0.390
	Fert:Inoc	<0.01	1	0.967
	Soil:Tree	7.21	2	0.027
	Fert:Tree	0.46	2	0.794
	Inoc:Tree	0.50	2	0.780
	Soil:sqrt(Trees)	34.73	1	<0.001
	Soil:Fert:Inoc	0.09	1	0.760
	Soil:Fert:Tree	5.74	2	0.057
	Soil:Inoc:Tree	0.70	2	0.706
	Fert:Inoc:Tree	5.95	2	0.051
	Soil:Fert:Inoc:Tree	1.82	2	0.402
Blueberry cover	Soil	18.05	1	<0.001
	Fert	0.49	1	0.484
	Inoc	0.44	1	0.508
	Tree	79.61	2	<0.001
	sqrt(Trees)	1.75	1	0.186
	sqrt(Noxious)	5.07	1	0.024
	sqrt(Shrubs)	1.23	1	0.268
	sqrt(Grass)	0.71	1	0.400
	Soil:Fert	0.16	1	0.691
	Soil:Inoc	1.07	1	0.300
	Fert:Inoc	0.56	1	0.453
	Soil:Tree	7.88	2	0.019
	Fert:Tree	0.46	2	0.794
	Inoc:Tree	1.08	2	0.584
	Soil:sqrt(Trees)	57.72	1	<0.001
	Fert:sqrt(Noxious)	11.01	1	<0.001
	Fert:sqrt(Shrubs)	22.38	1	<0.001
	Fert:sqrt(Grass)	11.00	1	<0.001
	Soil:Fert:Inoc	1.10	1	0.294
	Soil:Fert:Tree	0.63	2	0.731
	Soil:Inoc:Tree	5.22	2	0.074
	Fert:Inoc:Tree	0.66	2	0.718
	Soil:Fert:Inoc:Tree	1.54	2	0.462

Table 5: Type II Anova tables for the generalized linear mixed models of the effect of topsoil treatment, inoculation treatment, bio-stimulant treatment, hitchhiked shrub species, and the interactions between them on the survival and height of bog cranberry after four growing seasons (2022 thru 2025). Significant ($p < 0.05$) fixed effects are shown in bold and are the ones plotted in the figures.

Response	Factor	χ^2	df	p-value
Cranberry survival	Soil	0.21	1	0.650
	Fert	10.59	1	0.001
	Inoc	13.02	1	<0.001
	Tree	13.06	2	0.001
	sqrt(Shrubs)	6.92	1	0.009
	Soil:Fert	0.71	1	0.400
	Soil:Inoc	1.17	1	0.279
	Fert:Inoc	<0.01	1	0.942
	Soil:Tree	0.11	2	0.948
	Fert:Tree	1.90	2	0.387
	Inoc:Tree	1.43	2	0.489
	Soil:Fert:Inoc	3.89	1	0.049
	Soil:Fert:Tree	1.66	2	0.436
	Soil:Inoc:Tree	4.23	2	0.121
	Fert:Inoc:Tree	0.30	2	0.863
	Soil:Fert:Inoc:Tree	0.16	2	0.925
Cranberry cover	Soil	41.34	1	<0.001
	Fert	27.28	1	<0.001
	Inoc	0.93	1	0.334
	Tree	205.96	2	<0.001
	sqrt(Trees)	1.93	1	0.165
	sqrt(Shrubs)	13.34	1	<0.001
	sqrt(Grass)	12.01	1	<0.001
	Soil:Fert	0.16	1	0.686
	Soil:Inoc	4.82	1	0.028
	Fert:Inoc	0.86	1	0.353
	Soil:Tree	2.27	2	0.322
	Fert:Tree	1.90	2	0.386
	Inoc:Tree	1.74	2	0.419
	Soil:sqrt(Trees)	40.34	1	<0.001
	Fert:sqrt(Shrubs)	37.61	1	<0.001
	Fert:sqrt(Grass)	8.30	1	0.004
	Soil:Fert:Inoc	1.17	1	0.279
	Soil:Fert:Tree	0.76	2	0.682
	Soil:Inoc:Tree	1.90	2	0.387
	Fert:Inoc:Tree	0.34	2	0.843
	Soil:Fert:Inoc:Tree	0.17	2	0.920

Table 6: Type II Anova tables for the generalized linear mixed models of the effect of topsoil treatment, inoculation treatment, bio-stimulant treatment, hitchhiked shrub species, and the interactions between them on the survival and height of Labrador tea after four growing seasons (2022 thru 2025). Significant ($p < 0.05$) fixed effects are shown in bold and are the ones plotted in the figures.

Response	Factor	χ^2	df	p-value
Labrador tea survival	Soil	0.34	1	0.560
	Fert	2.24	1	0.135
	Inoc	0.33	1	0.568
	Tree	0.67	2	0.714
	sqrt(Forb_NN)	7.08	1	0.008
	sqrt(Noxious)	4.75	1	0.029
	Soil:Fert	0.98	1	0.322
	Soil:Inoc	2.53	1	0.112
	Fert:Inoc	0.18	1	0.673
	Soil:Tree	5.77	2	0.056
	Fert:Tree	6.13	2	0.047
	Inoc:Tree	0.52	2	0.769
	Fert:sqrt(Forb_NN)	11.54	1	<0.001
	Soil:sqrt(Forb_NN)	13.44	1	<0.001
	Soil:Fert:Inoc	0.08	1	0.779
	Soil:Fert:Tree	0.31	2	0.855
	Soil:Inoc:Tree	1.01	2	0.604
	Fert:Inoc:Tree	0.30	2	0.862
	Soil:Fert:Inoc:Tree	3.95	2	0.139
Labrador tea cover	Soil	87.14	1	<0.001
	Fert	3.44	1	0.064
	Inoc	1.82	1	0.177
	Tree	47.81	2	<0.001
	sqrt(Trees)	28.00	1	<0.001
	sqrt(Forb_NN)	31.98	1	<0.001
	sqrt(Tree.c)	0.56	1	0.454
	Soil:Fert	3.30	1	0.069
	Soil:Inoc	5.48	1	0.019
	Fert:Inoc	0.46	1	0.495
	Soil:Tree	5.96	2	0.051
	Fert:Tree	3.95	2	0.139
	Inoc:Tree	8.95	2	0.011
	Soil:sqrt(Trees)	89.55	1	<0.001
	Soil:sqrt(Forb_NN)	6.46	1	0.011
	Soil:sqrt(Tree.c)	8.04	1	0.005
	Soil:Fert:Inoc	1.08	1	0.298
	Soil:Fert:Tree	0.42	2	0.809
	Soil:Inoc:Tree	2.51	2	0.285
	Fert:Inoc:Tree	3.50	2	0.174
	Soil:Fert:Inoc:Tree	1.73	2	0.422

LESSONS LEARNED

Lessons learned – nursery production considerations for white spruce, Jack pine, bog cranberry, common blueberry and Labrador tea:

- Utilization of soil collected from a field site where these species were growing (Jack pine stand with ericaceous shrub understory) did not yield consistently positive benefits across the species tested. *Thus, greenhouse inoculation with field soil is not recommended at this time though further investigation may be warranted for Labrador tea.*
- Opportunities to hitchhike conifers and ericaceous shrubs:
 - o Both conifers tested appeared to grow and survive as well with hitchhiked ericaceous species as they did alone.
 - o All ericaceous species survived as well and often at higher rates when hitchhiked with conifers; however, all shrubs grew slower compared with single planted seedlings. Nevertheless, while smaller, the hitchhiked shrubs were healthy in appearance (Figure 6).
 - o These findings suggest hitchhiker stock of the species-mixtures tested could be applied with a reasonable expectation that both species will survive post-planting. Importantly, the coniferous species will maintain growth rates similar to singly grown conifers, offering consistent potential for overstory tree development, regardless of the stock type chosen. *The choice of hitchhiking versus planting singly-grown seedlings will come down to the logistics and objectives of revegetation as well as the availability of seedlings and capacity of greenhouse growers to produce these stock types.*

Lessons learned – revegetating industrially-disturbed sites with nursery stock of white spruce, Jack pine, bog cranberry, common blueberry and labrador tea:

- *Overall, this trial suggests that applying topsoil will generally improve growth, though not necessarily the survival (due to competing vegetation) of planted seedlings.* These soil treatments will likely change the type of future forest that develops, either one with higher-tree productivity and growth or a forest that is low-productivity. Both situations (forest types) exist on the landscape, again, the choice of which one to pursue will have to be driven by the reclamation and revegetation goals of a particular site.
- Considerations for coniferous species:
 - o Both white spruce and Jack pine benefited (in terms of growth) in the standard topsoil treatment, provided competition was relatively low. For treatment plots where competing vegetation cover increased, the advantage of the standard topsoil treatment was lost, and growth rates were similar to the no-topsoil treatment. *It is notable that there was no relationship between competing cover and conifer growth in the no-topsoil treatment, suggesting that competing vegetation was not an important factor in this treatment.*
 - o The use of bio-stimulant, applied to seedlings at the time of planting, had a substantial influence (positive) on growth for both conifer species in the standard topsoil treatment; this effect was subtle, however, for the no-topsoil treatment. These findings suggest that this treatment was acting more to stimulate growth rather than by providing a substantive quantity of nutrients; in other words, if there is limited nutrition in the soil available to support conifer growth, a bio-stimulant alone will not be sufficient in overcoming this limitation. *Ultimately, this treatment warrants further investigation to understand if the observations of this trial, located within a single industrial site, are replicable to other sites.*

- Considerations for ericaceous shrub species:
 - o All ericaceous species were able to survive similarly or better in the no-topsoil treatment compared with standard topsoil. *For Labrador tea and common blueberry, competing vegetation tended to negatively influence survival in both soil types though to a greater extent in the standard topsoil treatment.*
 - o Common blueberry growth responded to a complex interaction between soil treatment and vegetation competition; therefore, it is difficult to conclude whether there was a real growth benefit associated with one treatment over the other. *Bog cranberry and Labrador tea grew larger in the standard topsoil treatment, though for Labrador tea the magnitude of this benefit was contingent on vegetation competition levels.*
 - o The use of bio-stimulants is not recommended for bog cranberry or common blueberry given the largely negative (or neutral) responses; however, this treatment may warrant further study for Labrador tea under standard topsoil placement soil conditions.

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Reports & Other Publications

Chartrand-Pleau C., Degenhardt D., Schoonmaker A. (2025) Planting native herbaceous species during land reclamation: 3-year growth response to soil type and competing vegetation. *Forests*; 16: 1442. <https://doi.org/10.3390/f16091442>

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Revegetation



Surmont Boreal Forest Reclamation

COSIA Project Number: LJ0226

Mine and In Situ

Research Provider: NAIT Centre for Boreal Research

Industry Champion: ConocoPhillips

Status: Year 11 of 20

PROJECT SUMMARY

This program of research encompasses study topics of: (1) interim reclamation (also known as temporary reclamation); as well as (2) final reclamation. Even though there is a distinction between interim and final reclamation, 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 redistributed. 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 use of chemical herbicides for noxious weed management; and increase biodiversity. Temporary reforestation of soil stockpiles is an alternative practice gaining adoption that better fits with long-term final reclamation goals in forested settings, particularly the re-establishment of self-sustaining, functional boreal forest systems.

This temporary (or interim) reclamation project is situated on an eight-hectare topsoil and subsoil stockpile that is anticipated to be in place for several decades. 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 non-active 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. At the time this study was initiated, this practice was not 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 soil 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 dynamic patterns found after fires or forest harvesting. Industrial disturbances require soil to be moved during construction and again during reclamation prior to final revegetation. This anthropomorphic soil redistribution 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 favour 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 to answer 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) while also monitoring 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 surface adjustments 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

1. 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?
2. 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?
3. 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).

The objective of this project was to compare localized cluster planting of aspen with conventional planting at uniform spacing. In this project, two key questions will be answered: 1: How many plants are required for a “cluster” to positively impact survival and growth of aspen container stock? 2: Does clustering of aspen influence site-scale stand development?

Study 2: Vegetation Management Solutions for Final Reclamation

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 intentionally broadcasting seed. 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?

Table 1: Formulae used to run the generalized linear mixed-effects models. All models were fitted with GLMM (generalized linear mixed effects model) in R (R core team, 2024), using the package glmmTMB. The fixed and random effects, distribution and link function selected for individual GLMMs are noted in the table.

Response	Fixed effects	Random effects	Distribution	Link
Cluster-scale aspen				
Survival	Soil type + Cluster treatment	Block / Plot / Cluster (or Line)	Binomial	logit
Max height		Block / Plot	Gamma	sqrt
Max DBH		Block / Plot	Gamma	log
Mean height		Block / Plot	Gamma	log
Mean DBH		Block / Plot	Gamma	log
Plot-scale (stand)				
Aspen basal area	Soil type + Cluster treatment	Block	Gamma	log
Stand basal area		Block	Gamma	log
Aspen stem count		Block	Generalized poisson	log
Stand stem count		Block	Generalized poisson	log
Shrub stem count		Block	Generalized poisson	log
Grass cover		Block / Plot	Ordbeta	logit
Native forb cover		Block / Plot	Ordbeta	logit
Non-native forb cover		Block / Plot	Ordbeta	logit
Woody cover		Block / Plot	Ordbeta	logit
Total cover		Block / Plot	Gamma	sqrt
Stand heights	Soil type X Species + Cluster treatment X Species	Block / Plot	Gamma	sqrt

PROGRESS AND ACHIEVEMENTS

For this report, the 2025 monitoring results from Project 3 are presented. This trial was 10 years old at the time of assessment.

Key methodological points relevant to the interpretation of this project:

- The overall density target for the project area was approximately 6,250 stems ha⁻¹ (including aspen at 2,500 stems ha⁻¹) where each of green alder (*Alnus viridis*), pussy willow (*Salix discolor*), paper birch (*Betula papyrifera*) and balsam poplar (*Populus balsamifera*) were planted at 500 stems ha⁻¹, white spruce (*Picea glauca*) at 750 stems ha⁻¹ and jack pine (*Pinus banksiana*) at 1,000 stems ha⁻¹. Tree seedlings were planted in June 2016.
- This project compared the following cluster plantings for aspen to achieve an overall density of approximately 2,500 stems ha⁻¹. No clusters where aspen seedling spacing was 2.0 m (= C1), Clusters of four aspen seedlings at 3.7 m between clusters (= C4), Clusters of 10 aspen seedlings at 5.8 m between clusters (= C10), Clusters of 20 aspen seedlings at 8.2 m between clusters (= C20). Spacing between aspen seedlings within each cluster was approximately 0.25 m. To maintain the same effective density of aspen, the replicate plot sizes necessarily varied to accommodate the same number of aspen clusters per plot (nine clusters) ([Figure 1](#)). The no-clustering treatment had seedlings arranged in six lines, equally spaced, with six aspen seedlings planted in each line and marked with a pigtail.
- 2025 measurements focused on two scales of investigation:
 - o Cluster-scale assessment: where the height and DBH (diameter at breast height, 1.3 m) was recorded for all planted clustered aspen seedlings in the experimental plots. The control plot seedlings (C1) were individually measured in replicate lines within plots.
 - o Plot-scale measurements: which focused on collecting overstory and understory data within a 3.99 m radius circular plot centered within each replicate treatment plot. In each plot, the height and DBH of all tree species were recorded, and tall and medium shrubs were tallied (five heights per shrub species were also measured). Five 0.5 m x 0.5 m quadrats were randomly tossed and vegetative cover by species was recorded.

While the focus of this project was in evaluating clustered planting arrangements of aspen seedlings, findings related to development of these responses across the two soil types — subsoil and topsoil — are also presented, as these soils have had a substantive influence on the development of vegetation in this project. The discussion focused on the two questions relevant to this project, outlined below.

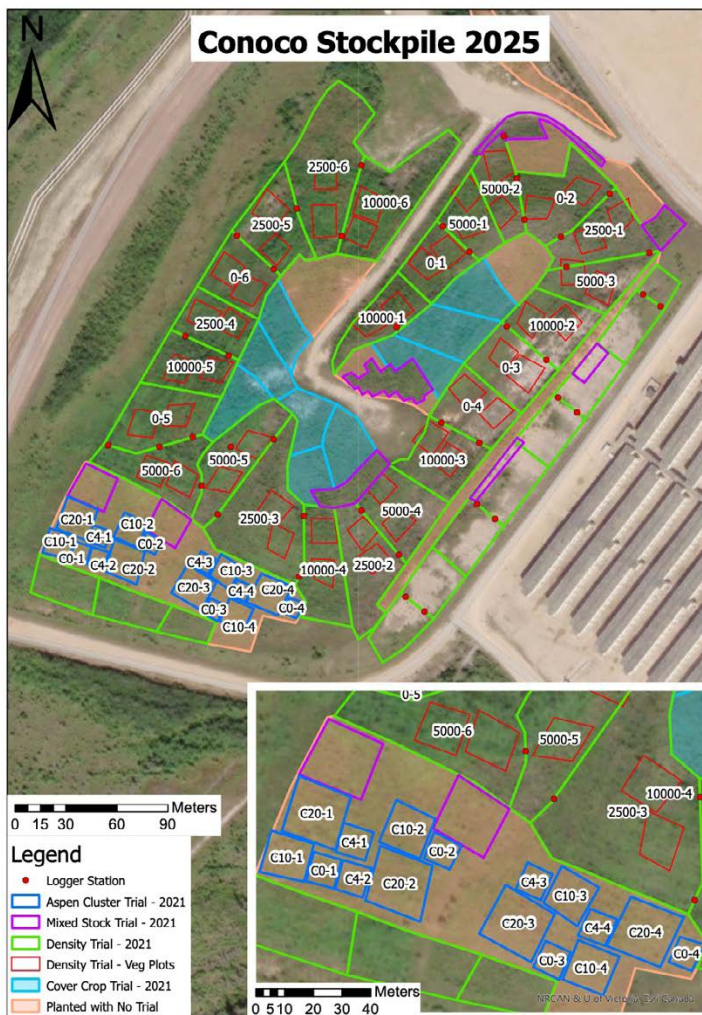


Figure 1: Overview of treatment plot layout across the three projects within the soil stockpile site. The inset (lower right) shows the location of replicate blocks (blue) for Project 3 (Aspen cluster trial). The numbering within each replicate block refers to the clustering of aspen in groups of 0 (no clustering), 4, 10 or 20 aspen plants and the second number the replicate within each cluster type.

Question 1: How many plants are required for a “cluster” to positively impact survival and growth of aspen container stock?

After 10 growing seasons, the largest cluster size (C20) was associated with the lowest survival rates, while non-clustered aspen (C1) maintained the highest survival, with C4 and C10 at intermediate levels ([Figure 2i](#)). Conversely, the maximum height and DBH, reflecting the means of the largest individuals from each cluster or line, followed the opposite pattern, with the greatest heights attained for larger versus smaller cluster treatments and non-clustered aspen ([Figure 2a, e](#)).

Given these contrasting findings, there are two answers to Question 1. To maximize individual-level survival of planted aspen, non-clustered plantings or small clusters of four plants appear to be associated with the greatest benefit. However, to maximize tree growth, clustering aspen in groups of 10 or 20 individuals appears to have the greatest benefit, at least at the scale of the individual tree.

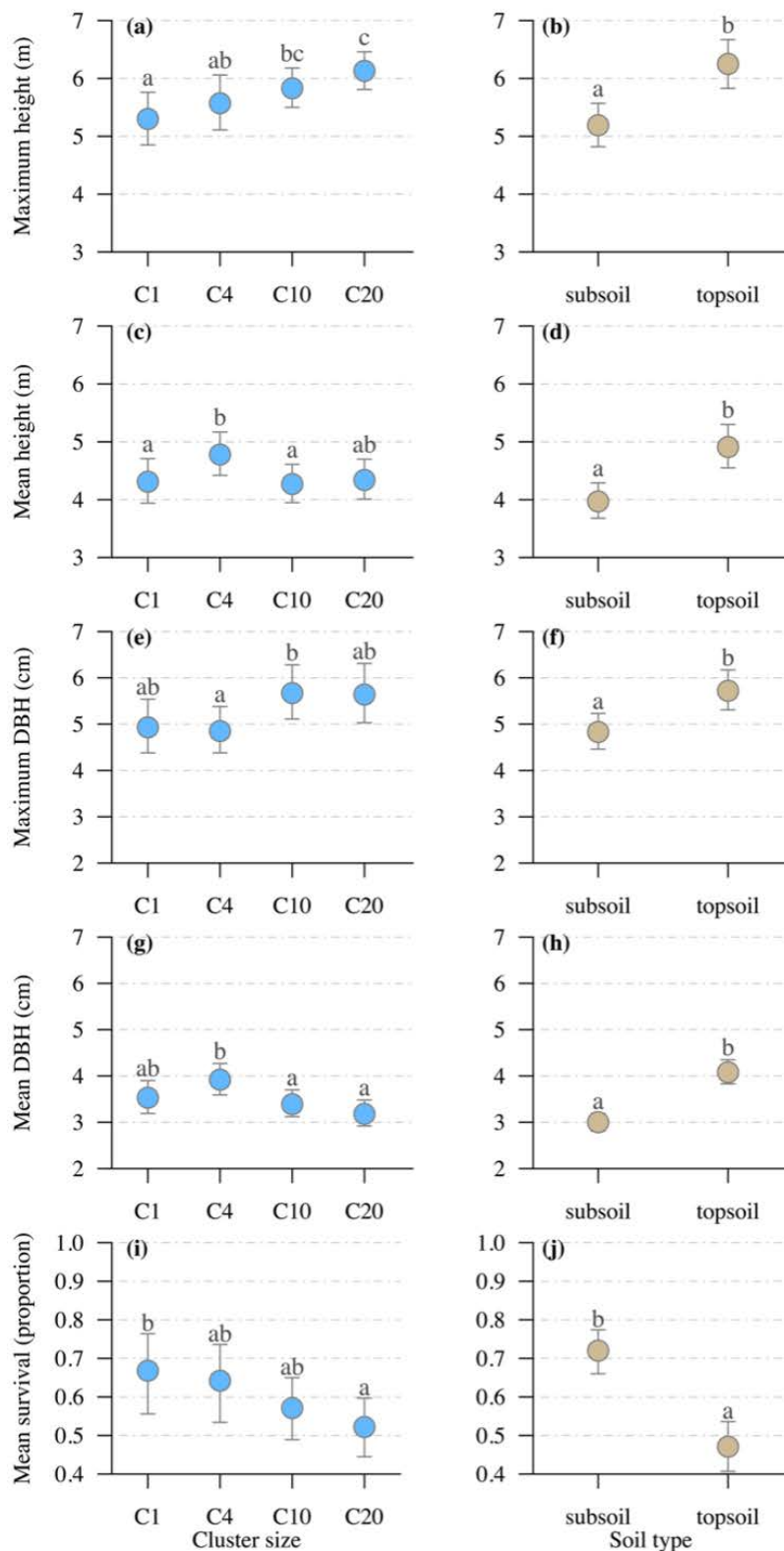


Figure 2: Cluster-scale treatment effects on aspen maximum and mean height and diameter at breast height (DBH, 1.3 m) and cumulative survival after 10 growing seasons. Maximum height and DBH values were determined by averaging across the largest plant from each cluster/line in replicate plots. Cluster size refers to the number of aspen seedlings planted in a grouped arrangement and soil type refers to whether the plot was located on the subsoil or topsoil stockpile. Error bars represent the 95% confidence intervals and differing letters indicate a significant difference between means ($\alpha < 0.05$, $n = 4$ or eight plot replicates).

Question 2: Does clustering of aspen influence site-scale stand development?

At the stand scale, there is some evidence to support the assertion that clusters of aspen may influence some, though not all, site-scale responses:

- The basal area of aspen and all trees (stand) together, as well as total aspen stem counts (density), was highest in the C20 treatment compared with smaller clusters and non-clustered plots ([Figure 3a, c](#)). However, at the stand scale, total tree density was similar amongst all cluster treatments ([Figure 3g](#)), suggesting the increase in stand basal area was at least partly driven by increased basal area of aspen in the C20 treatment. While not statistically different (data not shown), it was also observed that the C20 treatment was associated with larger diameter poplars (*P. balsamifera*) at 2.3 cm on average, compared with the other treatments which averaged 1.4 cm to 1.9 cm. While this may not appear to be meaningful, when this basal area is scaled up to the stand-level, even small increases in diameter can have measurable effects on stand-level basal area; especially given that these plots averaged approximately 20 poplar per circular plot (= 4,000 stems ha⁻¹ of poplar).
- The largest aspen cluster (C20) treatment was also associated with the lowest stem counts of tall and medium shrubs ([Figure 3i](#)), while non-clustered and small clusters (C4) maintained substantially higher shrub counts — approximately 20 per plot or 4,000 stems ha⁻¹.
- Individual tree heights were similar among cluster treatments, with differences in height more strongly associated with soil type ([Figure 4b](#)) and tree species ([Figure 4c](#)).
- There was no evidence that the clustering treatments had a measurable effect on grass, native forb, non-native forb or woody understory vegetation cover though all were influenced by soil type (Table 2).

Table 2: Anova tables for the generalized linear (mixed) models of the effect of soil type and clustering treatment on cluster-level (aspen seedlings planted into various sizes of clustering) and plot-level responses. Note that plot-level height responses included species as a fixed-effect factor with two-way interactions. Testing of the interaction between soil type and clustering treatment could not be done due to the structure of the experimental plots (two block replicates per soil type).

Data scale	Response	Factor	Chi-square value	Degrees of Freedom	P-value
Cluster-scale	Survival	Soil type	31.1540	1	< 0.0001
		Cluster treatment	6.0520	3	0.1091
	Max DBH	Soil type	9.3973	1	0.0022
		Cluster treatment	7.0408	3	0.0706
	Max Height	Soil type	14.2850	1	0.0002
		Cluster treatment	15.8770	3	0.0012
	Mean DBH	Soil type	45.4570	1	< 0.0001
		Cluster treatment	11.3770	3	0.0099
	Mean Height	Soil type	15.0466	1	0.0001
		Cluster treatment	6.8802	3	0.0758

Data scale	Response	Factor	Chi-square value	Degrees of Freedom	P-value
Plot-scale	Aspen basal area	Soil type	1.5841	1	0.2082
		Cluster treatment	23.1018	3	0.0000
	Stand basal area	Soil type	0.0849	1	0.7708
		Cluster treatment	8.3855	3	0.0387
	Aspen stem count	Soil type	19.5390	1	< 0.0001
		Cluster treatment	26.0250	3	< 0.0001
	Stand stem count	Soil type	39.3604	1	< 0.0001
		Cluster treatment	1.1997	3	0.7531
	Stand tree heights	Soil type	15.4789	1	0.0001
		Cluster treatment	3.1413	3	0.3703
		Species	200.5075	4	< 0.0001
		Soil type X Species	4.9213	4	0.2955
		Cluster treatment X Species	8.8697	12	0.7140
	Shrub stem count	Soil type	4.3379	1	0.0373
		Cluster treatment	7.7514	3	0.0514
	Grass cover	Soil type	0.4246	1	0.5146
		Cluster treatment	4.4626	3	0.2156
	Native forb cover	Soil type	1.3094	1	0.2525
		Cluster treatment	2.6996	3	0.4403
	Non-native forb cover	Soil type	5.0431	1	0.0247
		Cluster treatment	0.9731	3	0.8078
	Woody cover	Soil type	18.3827	1	< 0.0001
		Cluster treatment	4.4306	3	0.2186
	Total cover	Soil type	1.5000	1	0.2207
		Cluster treatment	1.1616	3	0.7622

The influence of soil type in this project

In most respects, soil type — whether the trial plots were established into stockpiled topsoil or subsoil — has had a stronger influence on tree growth and understory plant development compared with the clustering of aspen, even 10 years post-planting, when these tree clusters might be expected to start having a larger site-scale influence. Key observations to note:

- Aspen growing in topsoil grew, on average, one metre more in height than those trees planted into subsoil ([Figure 2b, d](#)); conversely, survival was substantially lower in topsoil at < 0.5 compared with > 0.7 in subsoil ([Figure 2j](#)).
- At the site-scale, this trade-off between survival and growth resulted in similar aspen basal area amongst topsoil and subsoil ([Figure 3b](#)). This effect was also observed at the stand level in terms of higher tree counts in subsoil ([Figure 3h](#)) associated with similar levels of basal area ([Figure 3d](#)), despite smaller trees ([Figure 4b](#), height and diameter are highly correlated).

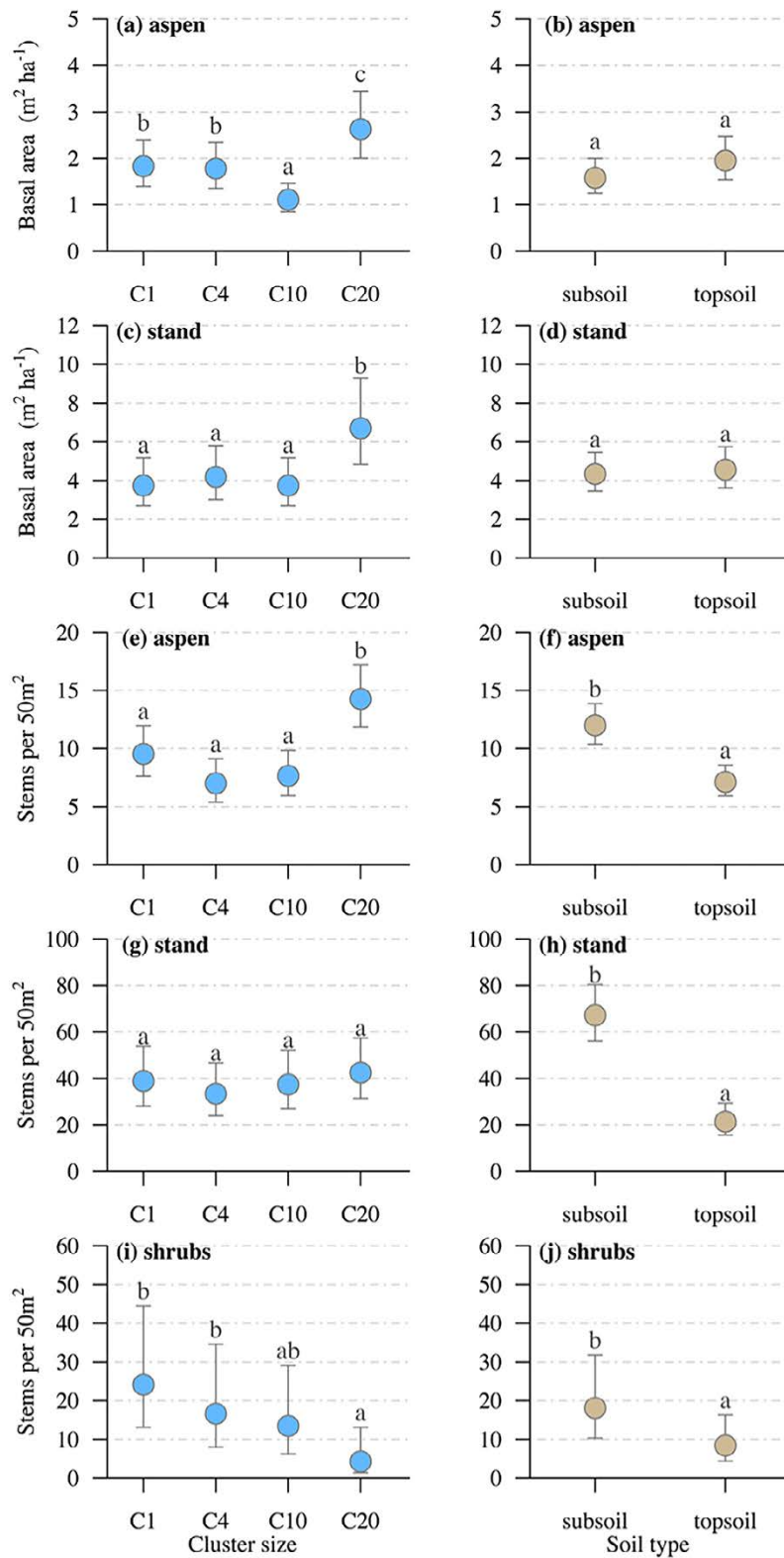


Figure 3: Plot-scale treatment effects on aspen and stand-level (all trees) basal area, stem counts and shrub stem counts after 10 growing seasons. Cluster size refers to the number of aspen seedlings planted in a grouped arrangement and soil type refers to whether the plot was located on the subsoil or topsoil stockpile. To scale plot stem count estimates to stems ha⁻¹ multiply by 200. Error bars represent the 95% confidence intervals and differing letters indicate a significant difference between means ($\alpha < 0.05$, $n = 4$ or eight plot replicates).

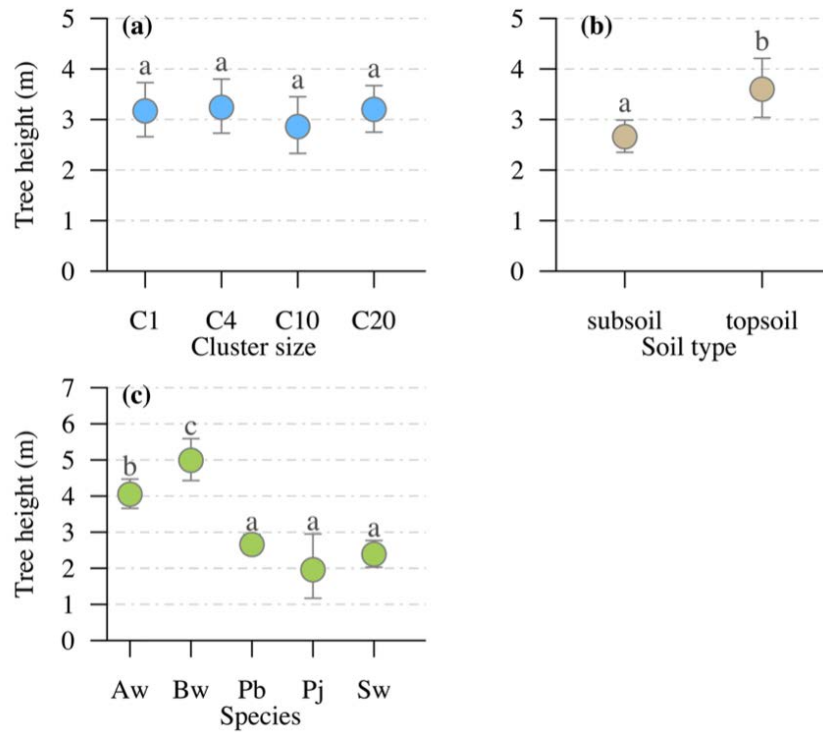


Figure 4: Plot-scale treatment effects on tree height after 10 growing seasons. Cluster size refers to the number of aspen seedlings planted in a grouped arrangement and soil type refers to whether the plot was located on the subsoil or topsoil stockpile. Species: Aw (*Populus tremuloides*), Bw (*Betula papyrifera*), Pb (*Populus balsamifera*), Pj (*Pinus banksiana*) and Sw (*Picea glauca*). Note that due to substantial natural regeneration of Pb, the mean height for this species was shorter than expected as much of this secondary regeneration was less than two metres tall at the time of assessment. Error bars represent the 95% confidence intervals and differing letters indicate a significant difference between means ($\alpha < 0.05$, $n = 4$, eight or 16 plot replicates).

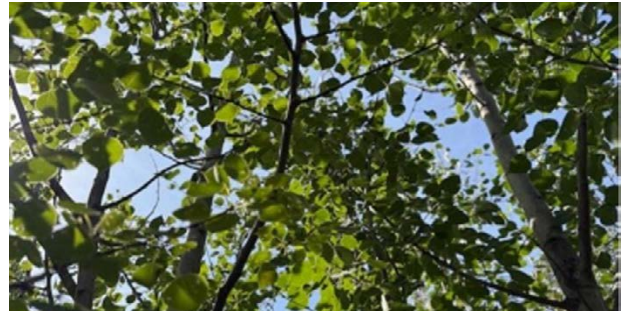
C20-Topsoil



C20-Subsoil



C10-Topsoil



C10-Subsoil



Figure 5: Images from the 2025 growing season illustrating cluster sizes of aspen across topsoil and subsoil (August 2025). Pictures were taken at the center of each plot looking into a cluster of aspen and towards the canopy.

C4-Topsoil



C4-Subsoil



C1-Topsoil



C1-Subsoil



Figure 5 Continued: Images from the 2025 growing season illustrating cluster sizes of aspen across topsoil and subsoil (August 2025). Pictures were taken at the center of each plot looking into a cluster of aspen and towards the canopy.

LESSONS LEARNED

Emerging lessons, 10 years after project initiation:

- Clusters of 20 planted aspen seedlings, spaced approximately 0.25 m apart, appear to increase the maximum height of aspen from 5.3 m to 6.1 m on average. This may be advantageous for aspen, particularly where competition from other broadleaf tree species could limit the capacity for this species to initially establish on these types of sites. However, this treatment appears to come at the cost of increased tree-level mortality, which is likely to be associated by within-cluster competition among individual aspen seedlings.
- At the site scale, despite increased aspen mortality associated with larger aspen clusters, both aspen-specific and tree-stand basal area were maximized (50% higher) for this treatment, relative to smaller cluster treatments and the non-clustered control. Again, the trade-off here appears to be associated with a reduction in tall and medium shrub densities from 4,800 stems ha⁻¹ in the non-clustered control to only 800 stems ha⁻¹ for the C20 clustering treatment.
- Similar to what we have observed previously in project 1 (COSIA, 2023), the effect of soil type has exerted a strong influence on both the growth and stem densities of trees and shrubs. The potential for natural tree regeneration was substantially greater in subsoil at 13,400 stems ha⁻¹ compared with 4,200 stems ha⁻¹ in topsoil, given the initial density of trees established (total) was 5,250 stems ha⁻¹.

Study limitations:

- This was a small-scale pilot study, aimed at exploring this concept. Next steps could involve testing the most potentially viable treatment (clusters of 20 seedlings versus non-clustered seedlings) at a larger scale to ensure repeatability of the findings in this trial.
- Soil quality has played a substantive role; however, given the limitations in the experimental design, it is not possible to test the potential interaction between soil type and clustering. This effect could be further explored in a subsequent trial as interactions might be expected, particularly as natural tree regeneration appeared to play an important role by enhancing the densities of trees in subsoil though not in topsoil.

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PRESENTATIONS AND PUBLICATIONS

No public presentations or publications in 2024.

RESEARCH TEAM AND COLLABORATORS

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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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Jessica Carpio-Lau	NAIT Centre for Boreal Research	Student Research Assistant		

COSIA Vegetation Research Committee (Oil Sands Vegetation Cooperative)

COSIA Project Number: LE0014

Mine and In Situ

Research Provider: Wild Rose Consulting Inc.

Industry Champion: Canadian Natural

Industry Collaborators: Cenovus, ConocoPhillips, Imperial, Suncor, Syncrude

Status: Ongoing

PROJECT SUMMARY

Sixteen years ago, the COSIA Vegetation Research Committee (CVRC), previously known as the Oil Sands Vegetation Cooperative (OSVC), was established to enable collaborative harvesting and banking of native boreal forest seed for use in revegetation and research. In 2014, the CVRC became a project led by Canada's Oil Sands Innovation Alliance (COSIA) Land Environmental Priority Area (EPA).

The CVRC's strategic objectives are twofold:

- To ensure a consistent, genetically diverse supply of quality seeds and propagules of native boreal species, and
- To provide expertise and knowledge to produce and successfully deploy quality seedlings on reclaimed oil sands sites.

The scope of work for this project includes providing resources to assist in effective seed harvest, such as monitoring annual seed harvests, managing records for CVRC seed inventories in the provincial seed bank (Alberta Tree Improvement and Seed Centre, ATISC), and providing technical expertise in the identification, collection, storage, and deployment of native seed. To ensure effective and efficient use of harvested seedlots, the committee provides technical guidance regarding research needs, coordinates research projects, and prepares support documents such as literature reviews and data summaries.

PROGRESS AND ACHIEVEMENTS

Progress was made on evaluating the supply chain of three species:

Low-bush cranberry

Nursery production of this species is unreliable, and studies are ongoing to optimize germination and emergence. Although a germination study (Baah-Acheamfour and Sobze, 2022) realized up to 90% germination, this result was not achieved in a subsequent nursery trial. Therefore, a comprehensive emergence experiment was designed to compare temperatures (fluctuating versus constant) during both the stratification and germination phases. Stratifications began in 2025, and emergence will be monitored starting in June 2026.

Green alder

Historic seedlots of this species have had low viability, and several variables in the supply chain were evaluated. Differences in yield, seedlot purity and germination/viability were compared among populations, multiple harvest dates and extraction methods. In 2024, green alder seed was harvested from three stands at three different times and delivered to two extraction facilities.

Secondarily, establishment success of green alder has been highly variable, and seedlings are being produced for a 2027 outplanting trial.

Labrador tea

As with green alder, historic seedlot quality is poor. Differences in yield, seedlot purity, and germination/viability will be compared among populations and multiple harvest dates. Seed was harvested from three populations on three dates in September 2025. Comparisons of seedlot quality will be conducted in early 2026.

Additionally, establishment success of Labrador tea has been poor and seedling quality will be assessed prior to initiating an outplanting trial.

LESSONS LEARNED

The findings from the green alder seed harvest and seed quality assessment were reported in 2025 and included the following:

- Ideal harvest date varied with population, catkin development can be used to assess maturity
- Little difference was observed between extractors with a slight advantage to tumbling and screening over use of an Oregon Seed Blower

LITERATURE CITED

Baah-Acheamfour M. and J. M. Sobze. 2022. Exposing *Viburnum edule* seeds to a sequence of temperatures affects the germination characteristics. *Seed Science and Technology* 50(2): 235-239.

PRESENTATIONS AND PUBLICATIONS

Reports & Other Publications

Wild Rose Consulting, Inc. 2025. COSIA Vegetation Research Committee Newsletter May 10(1).

Wild Rose Consulting, Inc. 2025. COSIA Vegetation Research Committee Newsletter November 10(2).

RESEARCH TEAM AND COLLABORATORS

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Principal Investigator: Ann Smreciu

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
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Research Collaborators: Mark Baah-Acheamfour, NAIT Centre for Boreal Research

Improving Establishment Success and Early Growth of Trembling Aspen - Field Trial

COSIA Project Number: LJ0255

In Situ

Research Provider: Canadian Forest Service, Natural Resources Canada

Industry Champion: Imperial

Status: Year 8, ongoing

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 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.

To evaluate the effects of fungal inoculation on aspen seedling survival under field conditions, a trial was established in 2018 at the D-East Borrow Site (located at Universal Transverse Mercator zone 12V, easting 538816, northing 6058237, slope 0°) on the Cold Lake Lease. The site was logged in 2008, and topsoil was stripped and stockpiled in 2011, with underlying gravel removed and used for construction on the mine lease in 2013. Topsoil was reapplied and reclamation was completed in 2015. A total of 360 aspen seedlings were planted in three blocks of 120 seedlings. Within each block, 20 replicates of six treatments (seedlings inoculated with five different fungi plus the uninoculated control) were planted.

PROGRESS AND ACHIEVEMENTS

The seedlings have been measured annually since 2019, with the most recent remeasurement occurring in September 2025. Mortality has occurred over the eight growing seasons, and as of the 2025 assessment, 211 of the 360 planted seedlings had survived (Figure 1).

There is a high degree of variability within the trial which has affected the results. Overall survival in the control treatment was 53%. Survival in the inoculated treatments was 50% for seedlings inoculated with *Cryptosporiopsis ericae* (Ce3122), 55% for *Oidiodendron pilicola* (Op3120), 58% for *Lachnum pygmaeum* (Lp3127), 65% for *Cenococcum geophilum* (Cg3129), and 70% for *Rhizoscyphus ericae* (Re3128). Thus, survival in the control treatment was higher than *Cryptosporiopsis ericae*, but lower than for all other inoculated treatments.

When Chi-square analysis of survival was calculated, there was no significant difference in survival based on the treatment that was applied.

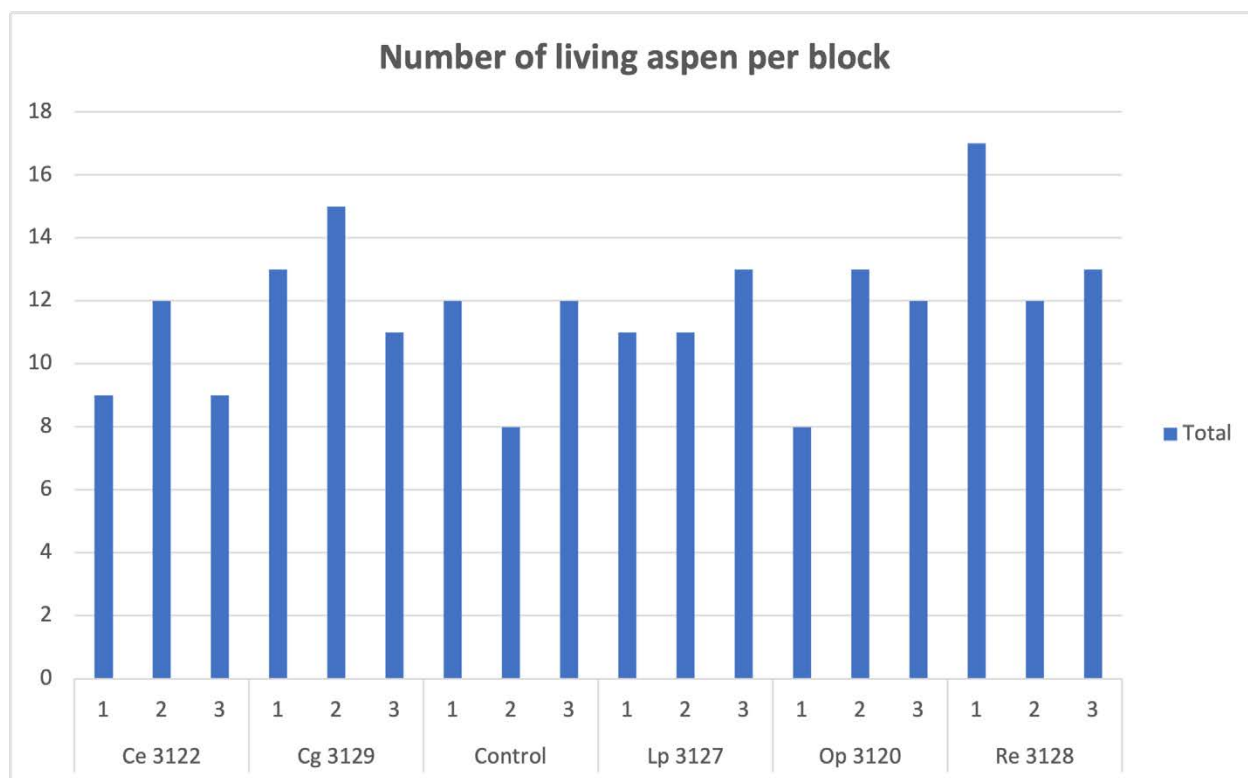


Figure 1: Survival of aspen planted at the D-East Borrow Site. Twenty replicates of each treatment were planted in each block (numbered 1, 2, and 3). Fungi were: *Cryptosporiopsis ericae* (Ce3122), *Oidiodendron pilicola* (Op3120), *Lachnum pygmaeum* (Lp3127), *Cenococcum geophilum* (Cg3129), and *Rhizoscyphus ericae* (Re3128).

All vegetation on the D-East Borrow Site has grown over the course of the trial. At the time of establishment, vegetation was low and the blocks could easily be seen. By 2025 the density and height of the vegetation on the site had increased substantially.

When the heights of the aspen were compared with ANOVA, there were no significant differences between treatments. The control seedlings were generally shorter than the aspen that were inoculated with different fungi, although the height differences were not significantly different. Some of the planted aspen have grown over two metres tall but there are other replicates that have grown at a much slower rate because they are suppressed by other vegetation on site. Researchers have a photographic record of the site changing over time and it was clearly evident at the 2025 remeasure that overall, the vegetation on the D-East Borrow Site is developing very well (Figures 2 and 3).

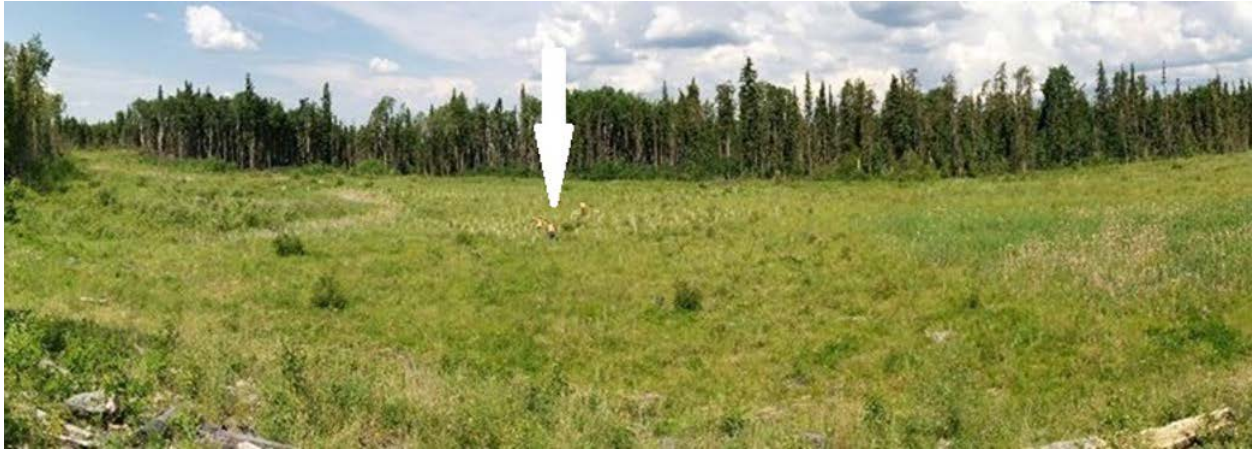


Figure 2: A photo taken during establishment of the trial in 2018 at D-East Borrow Site. The crew is located within block 3 (arrow).



Figure 3: Photo taken in 2025 from the same location as the photo in Figure 2. Arrow points to crew member and shows that the vegetation is approximately head-high.

LESSONS LEARNED

After eight years of establishment, the results currently indicate that inoculation with five-different root associated ectomycorrhizal fungi has promoted growth of planted aspen; however, due to the high level of variability among the planted aspen there is no statistically significant difference between treatments. Researchers will continue to monitor the aspen growing on site and it is possible that statistically significant results will emerge in the future.

Some of the planted aspen are suppressed by the surrounding vegetation, while others are not. It is expected that growth will continue to diverge between the suppressed and released aspen.

Observations from the annual visits to the research site indicate that the vegetation has grown and the site is recovering well.

PRESENTATIONS AND PUBLICATIONS

No presentations or publications in 2025.

RESEARCH TEAM AND COLLABORATORS

Institution: Canadian Forest Service, Natural Resources Canada

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)
Bradley Tomm	Canadian Forest Service	Research Technician		

Prioritizing Zones for Buried Pipeline Revegetation in Caribou Habitat

COSIA Project Number: LE0093

In Situ

Research Provider: Alberta Biodiversity Monitoring Institute

Industry Champion: Canadian Natural

Industry Collaborators: Cenovus, ConocoPhillips, Imperial, Suncor, Syncrude

Status: Year 1 of 1

PROJECT SUMMARY

Many woodland caribou (*Rangifer tarandus caribou*) populations in Alberta have experienced population decline. To support caribou habitat recovery, the Government of Alberta is collaborating with stakeholders to develop sub-regional plans that focus on mitigating future disturbances, restoring degraded habitat, and promoting integrated landscape management. Within the Cold Lake sub-region, which overlaps the Cold Lake caribou range and the Christina sub-range of the East Side Athabasca River (ESAR) herd, land use plans include the regulatory requirement to revegetate active, below-ground pipelines. Given the urgency of caribou recovery efforts, it is critical to prioritize revegetation in a way that maximizes benefits for caribou as quickly as possible while also ensuring cost-effective implementation.

A spatially explicit prioritization framework was developed to support decision-making and regulatory compliance, focussing revegetation efforts in areas where they will have the greatest ecological impact while considering economic feasibility and logistical constraints. To meet sub-regional pipeline regulatory revegetation targets, a structured prioritization framework is essential to ensure revegetation efforts are directed to where they will be most effective. This project prioritized landscape units (townships) for revegetation based on four key criteria:

1. Cost-effectiveness – Areas where revegetation efforts are expected to yield the greatest gains in undisturbed habitat relative to costs.
2. Resource Valuation Layer (RVL) – Consideration of future industrial development potential to avoid re-disturbance of revegetated sites.
3. Caribou Space Use – Incorporation of global positioning system (GPS) telemetry data to prioritize areas most frequently used by caribou, improving short-term benefits for caribou.
4. Seismic Line Restoration – Consideration of restoration efforts conducted by government-led and industry-led projects to build upon existing investments and increase landscape intactness.

To maximize the relevance and endorsement of this project's outcomes, the technical work was initiated by a COSIA Environmental Priority Area Led Study (EPALS) and guided by a multi-stakeholder advisory committee comprising Oil Sands Alliance member companies, the Government of Alberta, the Alberta Energy Regulator, and the research community.

PROGRESS AND ACHIEVEMENTS

This project delivered a spatially explicit, science-based prioritization framework to support pipeline revegetation planning within the Cold Lake sub-region, encompassing the Cold Lake caribou range and the Christina sub-range of the ESAR herd. Building on established COSIA seismic line restoration methodologies and recent peer-reviewed advances (Dickie et al. 2023), the work extends prioritization concepts to below-ground pipelines, addressing a key requirement of the Cold Lake Sub-Regional Plan (Government of Alberta 2022).

A major achievement of this project was the development of an integrated prioritization framework that quantifies the expected gain in undisturbed caribou habitat relative to revegetation cost, while incorporating additional ecological and land-use considerations. This framework combines estimates of habitat gain following pipeline revegetation with indices of cost, future alteration potential (Resource Valuation Layer), completed linear feature restoration, and caribou space use (Figure 1). These components were normalized and combined to calculate a weighted gain-per-cost metric, allowing townships to be grouped into five priority zones ranging from highest to lowest revegetation priority.

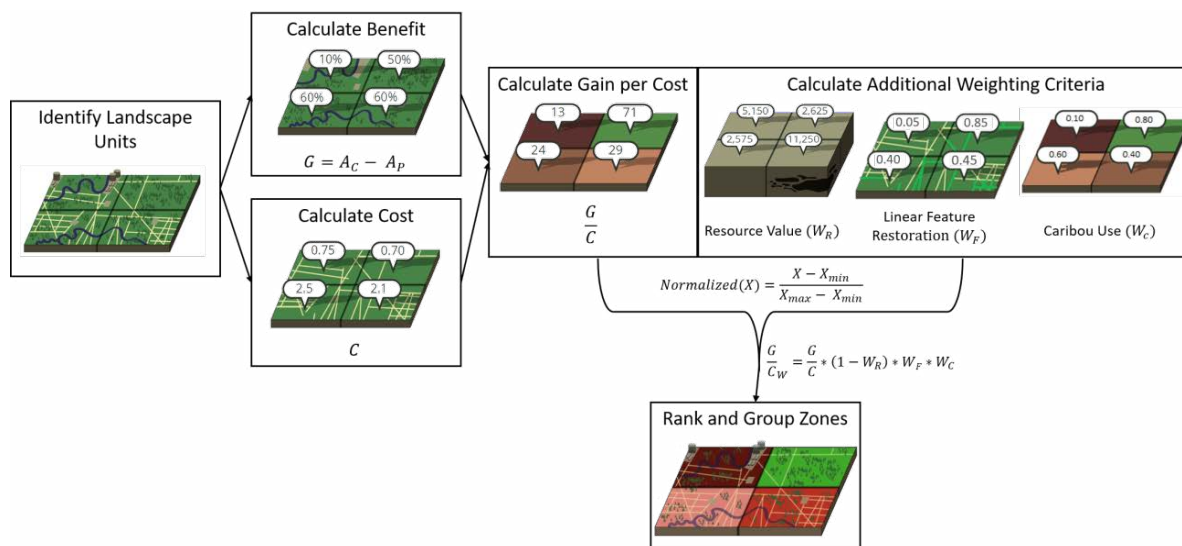


Figure 1: Schematic of the prioritization process in which the benefits of revegetating pipelines relative to the cost of revegetation is combined with additional weighting criteria to group townships into priority zones. The benefit of revegetation, here defined as the gain in undisturbed caribou habitat, G (calculated by subtracting the proportion of each township disturbed by humans post-revegetation, A_P , from the current proportion of each township disturbed by humans, A_C), is divided by the cost of revegetation, C (indexed by density of pipelines), normalized between 0 and 1, and multiplied by the inverse of the potential for future alteration, $1 - W_R$ (indexed by normalized resource value), linear feature restoration effort, W_F (indexed by normalized area treated divided by seismic line area) and current caribou space use, W_C (indexed by normalized caribou utilization distributions), to calculate the weighted gain per cost, G/C_w , and grouped into five priority zones. High priority zones (green) have a higher gain in undisturbed habitat, lower cost of revegetation, lower future alteration potential, higher completed linear feature restoration effort, and higher caribou use. Low priority zones (dark red) have a lower gain in undisturbed habitat, higher cost of revegetation, higher future alteration potential, lower completed linear feature restoration effort, and lower caribou use. Modified from Dickie et al. (2023).

The analysis was conducted at the township scale to support operational regulatory compliance planning while maintaining ecological relevance. Separate prioritizations were completed for areas inside and outside oil sands project areas, reflecting differences in regulatory requirements, operational constraints, and vegetation management practices. This distinction ensures that results are directly applicable to industry planning and regulatory reporting under the Cold Lake Sub-Regional Plan (Government of Alberta 2022).

The project also integrated multiple, up-to-date spatial datasets, including provincial human footprint mapping (ABMI 2023), wildfire history (Government of Alberta 2023), caribou GPS telemetry data (2009-2024), seismic line restoration records from government- and industry-led programs, and a resource valuation layer (CAPP 2016). Incorporating these datasets allowed the prioritization to reflect both current landscape condition and anticipated long-term outcomes, while explicitly avoiding areas with high potential for future re-disturbance.

The resulting priority zones show township-level rankings for pipeline revegetation under alternative disturbance scenarios, including analyses with and without wildfire incorporated into the gain-in-undisturbed-habitat calculations (Figure 2). These outputs provide a clear, map-based decision-support tool that identifies where pipeline revegetation is expected to deliver the greatest near-term and long-term benefits for caribou habitat recovery. By presenting results for multiple scenarios, the project enables users to understand how assumptions about wildfire influence prioritization and to adapt planning accordingly.

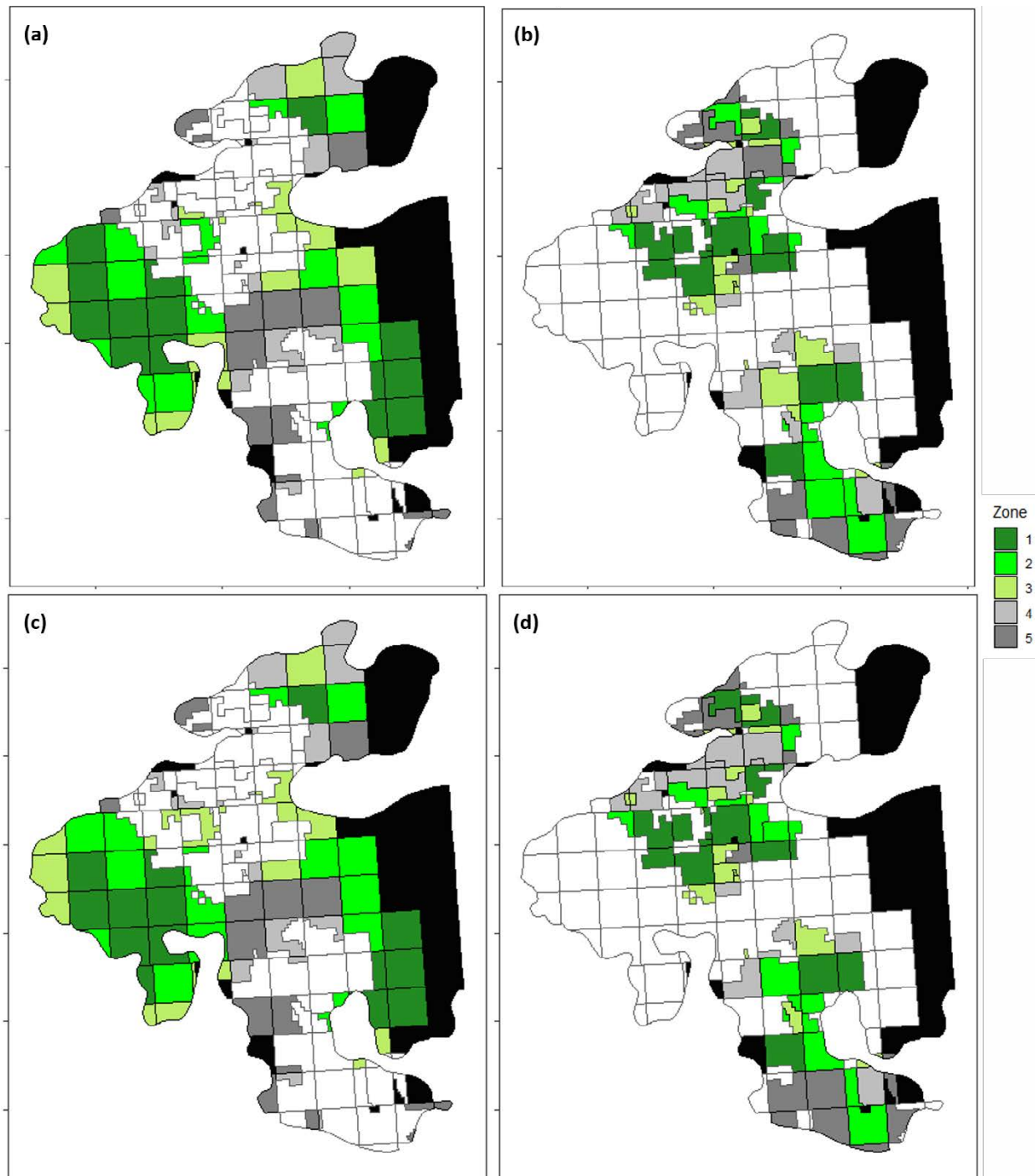


Figure 2: Revegetation priority zones incorporating gain in undisturbed habitat following pipeline revegetation relative to cost, potential future resource value, linear feature restoration effort completed, and caribou use, assessed under different fire disturbance scenarios: Townships (a) outside and (b) inside oil sands project areas with fire excluded from gain in undisturbed calculations, and townships (c) outside and (d) inside oil sands project areas with fire included in gain in undisturbed calculations. Townships are ranked into priority zones for pipeline revegetation, with Zone 1 (dark green) being the highest priority and Zone 5 (dark gray) being the lowest. Solid black townships represent areas with no pipelines and were excluded from the analysis.

Collectively, these outcomes provide Oil Sands Alliance members, regulators, and partners with a transparent and defensible basis for sequencing pipeline revegetation efforts. The framework is readily adaptable as new data become available and can be expanded for application in other caribou ranges subject to similar revegetation requirements.

LESSONS LEARNED

This project demonstrates that a structured, transparent prioritization framework can be effectively applied at a regional scale to support strategic pipeline revegetation planning within caribou habitat in the Cold Lake sub-region. By integrating ecological benefit, cost, caribou space use, future development potential, and existing seismic line restoration efforts, the approach provides a defensible method for sequencing revegetation efforts across a large and operationally complex landscape and for supporting regulatory compliance.

The prioritization framework explicitly recognizes the distinct regulatory and operational contexts that apply inside and outside oil sands project areas and differentiates prioritization accordingly. This ensures results remain relevant to jurisdiction specific requirements while maintaining consistency in overall decision making.

The resulting prioritization framework is both adaptable and repeatable. The methodology developed through this project can be readily updated as new spatial datasets become available and can be scaled or replicated in other caribou ranges or sub-regions where similar revegetation requirements apply. This work may be refined and expanded for application in other caribou ranges in Alberta. This flexibility supports consistent application across jurisdictions while allowing for region-specific considerations.

The framework provides a decision-support tool to guide strategic revegetation efforts both inside and outside oil sands project areas. It offers the flexibility to incorporate additional value-add data as new information becomes available, such as natural vegetation regeneration, multi use corridor evaluation, future energy and forestry disturbance, and habitat protection areas. This adaptable approach ensures that revegetation planning remains aligned with evolving regulatory and conservation objectives, as well as operational constraints, while contributing to long-term caribou habitat recovery.

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PRESENTATIONS AND PUBLICATIONS

No available public presentations or publications in 2025.

RESEARCH TEAM AND COLLABORATORS

Institution: Alberta Biodiversity Monitoring Institute

Principal Investigator: Dr. Melanie Dickie

Name	Institution or Company	Degree or Job Title	Degree Start Date (Students Only)	Degree Completion Date (Students Only)
Natasha Crosland	Alberta Biodiversity Monitoring Institute	Applied Science Coordinator		
Melanie Dickie	Alberta Biodiversity Monitoring Institute	Caribou Ecology Manager		

Wildlife Research and Monitoring



Canadian Toad (*Anaxyrus hemiophrys*) Mitigation, Monitoring, and Habitat Suitability Index Modeling

COSIA Project Number: LJ0325 and LJ0326

Mine

Research Provider: LGL Limited environmental research associates (LGL Limited)

Industry Champion: Canadian Natural

Industry Collaborators: Suncor

Status: Ongoing

PROJECT SUMMARY

The Canadian Toad (*Anaxyrus hemiophrys*) is known to occur in the Athabasca Oil Sands Region (AOSR), including in ponds and wetlands on Canadian Natural's Horizon and Albion Oil Sands, as well as Suncor's Base Plant and Fort Hills mine operations. Canadian Toads have been documented by staff from Canadian Natural, Suncor, and LGL Limited, as well as during work associated with the Early Successional Wildlife Dynamics Program ([COSIA Project LJ0013](#)). Their current status in Alberta is "May be at Risk," though robust data are lacking. Despite the confirmed presence of this species on these leases, there remains considerable uncertainty regarding; (1) annual variation in wetland occupancy; (2) the occurrence and characterization of suitable overwintering habitat; and (3) whether Canadian Toads can be safely relocated from areas likely to be impacted by mine development into suitable receptor ponds.

To address the above uncertainties, and to reduce the impact on Canadian Toads during mine expansion, a Canadian Toad monitoring and mitigation plan was developed in 2017 and conducted annually between 2018 and 2025. The primary objective of this work is to relocate toads from wetlands within the mine footprint to mitigate the effects of habitat loss on toads. In pursuit of this objective, the following tasks were identified:

Task 1: Determine wetland occupancy of breeding Canadian Toads and other amphibians.

Task 2: Test Canadian Toads for chytridiomycosis (*Bd* infection) and ranavirus at collection and receiving sites prior to relocation.

Task 3: Translocate toads and/or egg masses with subsequent monitoring to determine success of relocations.

Task 4: Identify, characterize, and monitor suitable overwintering habitat.

Task 5: Apply, validate and, if needed, refine the updated Canadian Toad habitat suitability index model for each lease.

Task 6: Develop a radio telemetry study to track Canadian Toad movement and locate overwintering sites.

Between 2017 and 2022 the main study area consisted of Horizon and Horizon South with some opportunistic Automatic Recording Unit (ARU) monitoring at Albion. In 2023 the Albion Sands lease was fully incorporated into this project; all research methods employed at Horizon, including mitigation translocations, were expanded to include Albion. In 2023, Suncor (Suncor Base Plant and Fort Hills Operations) joined the Canadian Toad Monitoring Joint Industry Project.

Tasks 1 to 3 have been an ongoing effort since the project's inception in 2018. Task 1 requires conducting nocturnal calling surveys, performed in person or via ARUs, and daytime visual encounter surveys (Task 1 also involved the development of a Canadian Toad environmental DNA assay in 2019 under COSIA project LJ0327).

To determine wetland occupancy, acoustic data are collected from ARUs and analyzed using pattern-recognition software to detect species-specific vocalizations. Hits identified by the software are validated by a trained biologist who then targets those sites with recent calling activity for follow-up visual encounter surveys. This improves survey efficiency by focusing on sites with confirmed calling activity. During the follow-up field surveys Canadian Toads are captured, measured, weighed, and photographed. Dermal swabs may also be collected at this time pursuant to Task 2: testing for ranavirus and *Batrachochytrium dendrobatidis* (*Bd*), the causative fungal pathogen of chytridiomycosis. However, while *Bd* is readily transmissible and can persist in the environment between hosts (Carey et al. 2006), testing toads prior to translocation is not essential for our purposes, as individuals are not moved further than their annual unaided natural movement distances, and not outside of mineral lease boundaries, thus avoiding introduction of *Bd* and ranavirus into uninfected ponds or watersheds. Therefore, mitigation translocations (Task 3) can then be carried out, while ensuring toads are moved only between wetlands in which *Bd* and ranavirus infection statuses are likely similar. Translocations alleviate the immediate threat of habitat loss due to encroaching mine activities but further study is needed to determine their long-term efficacy (Randall et al., 2018). Receiving sites will remain a monitoring focus to evaluate translocation outcomes. Success is measured in the near-term as initial translocation survivorship, then over subsequent years as annual recruitment, with the ultimate goal of establishing or augmenting self-sustaining populations.

In 2019, the Canadian Toad habitat suitability index (HSI) model was updated to address regulatory requirements associated with Canadian Natural's *Environmental Protection and Enhancement Act* (EPEA) approvals (Horizon Lease: 149968-01-00; Albion Sands Lease: 20809-02-00 [Muskeg River Mine] and 00153125-01-00 [Jackpine Mine]) and to inform recent initiatives regarding Canadian Toad relocations on Canadian Natural's Horizon Oil Sands (Hawkes and Papini 2020a, b). In 2024, the Canadian Toad HSI model was updated and applied to Suncor's Base Plant (EPEA 94-03-00) and Fort Hills Operations (EPEA 151469-01-00).

HSI models use a rubric to score environmental and biophysical traits on their suitability as habitat for a taxon of interest. Mapping the model output produces a prediction of the occurrence of suitable habitat on the landscape. The updated HSI model considered habitat attributes used in previous models (i.e., 1999, 2005, and 2007) but placed increased weight on overwintering habitat, while reducing the relative importance of breeding habitat. The update emphasizes the relationship between suitable overwintering habitat (friable soils up to 1.25 m in depth in the a and b ecosites), breeding habitat (certain shallow water ponds and wetland habitats), and, importantly, the

distance between them. To sustain populations year-round, wintering and breeding habitats must co-occur within the range of Canadian Toad seasonal movements. As a frost-intolerant amphibian species near the northern end of their range, Canadian Toads in the Athabasca Oil Sands Region have adapted life-history traits to help them endure the harsh winters. They spend much of the year underground in upland areas, beneath the frostline but above the water table, to insulate themselves from freezing temperatures (Hamilton et al., 1998; Russell et al., 2000). Thus, their overwintering habitats must possess specific thermal and hydrological properties while being accessible to a low-vagility species with a limited capacity for digging.

Habitat models require several internal and external validation measures to confirm model assumptions are reasonably met (Muir et al., 2011). Assumptions are inherent in the design of every model; validation procedures are used to ensure the assumptions being made accurately reflect reality. Internal validation involves reviewing model outputs, sensitivity testing, and calibrating variable weightings and model equations (see Van Horne and Wiens 1991). External validation is concerned with comparing model predictions to data collected in the field, i.e., ground-truthing. Ideally, model developers will have access to a test variable that is indicative of habitat quality. For example, species abundance/density or a measure of population success such as body condition or annual recruitment. In the absence of a convenient test variable, or for species that are difficult to survey, an alternate method may be used whereby habitat quality is independently assessed by expert opinion (Brooks 1997).

For Canadian Natural, external model validation began in earnest in 2022. Polygons were sampled using a generalized random-tessellation stratified (GRTS) design, a spatially-balanced sampling method that can accommodate variable inclusion probabilities (Stevens and Olsen 2004). At each site LGL biologists conducted qualitative assessments of the habitat features relevant to overwintering Canadian Toads, focusing on soil characteristics. This involved digging pits to appraise soils in terms of their ability to support effective hibernacula. Researchers focused on the texture, consistency, and accessibility of mineral soils — all key components of overwintering habitat. To support toad hibernacula over the winter, soils should be loose, friable, well-drained, and accessible to a depth of 1 m to 1.5 m (Hamilton et al., 1998). Habitat model validation was completed in 2025 at all leases and the results of the update and application of the Canadian Toad HSI model reported in Hawkes and Adama (2025).

Recent declines in Canadian Toad populations in Alberta are believed to be caused in part by a lack of habitats on the landscape with the hydrological and thermal properties required to sustain overwintering toads (Eaton et al., 2008; Browne 2009). For this reason, locating and characterizing winter habitat has become a priority for Canadian Toad ecologists. The updated habitat model described by Hawkes and Adama (2025) will be an important resource for identifying and conserving suitable Canadian Toad habitat throughout the AOSR, including at Canadian Natural and Suncor operations. The updated HSI model will support this program by identifying habitat on Suncor leases that could be involved in mitigation translocations, either as donor sites within the mine footprint or receiving sites away from mine disturbance.

Though progress was made on several other aspects of the toad mitigation program at Canadian Natural, more work remains to assess translocation success, characterize overwintering habitat where it occurs, and pursue new and innovative ways to conserve Canadian Toad habitat in the future. Future research directions will continue to support mitigation of impacts to Canadian Toads and their habitat, utilizing translocations where necessary.

PROGRESS AND ACHIEVEMENTS

In 2025, LGL made progress on three of six main tasks. They (1) assessed wetland occupancy using ARU arrays and in-person surveys (Task 1), (2) relocated 25,920 Canadian Toads away from the impact of mine operations on Canadian Natural's leases (Task 3), and (3) completed fieldwork to validate the updated habitat suitability index model (Tasks 4 and 5). In 2025, the radio telemetry component (Task 6) was not addressed because few toads large enough to support the weight of the transmitter were encountered and no new overwintering hibernacula were confirmed.

LGL investigated Canadian Toad presence (Task 1) at Canadian Natural's leases using ARUs and field-based surveys. Ponds and wetlands at Horizon Oil Sands, Horizon South, and Albian Sands were monitored by 22 ARUs that recorded acoustic activity nightly for the duration of the active season (roughly May to September; Figure 1, Figure 2). The ARU data were used along with habitat features, future mine development land use plans, historical amphibian occurrence, and observations from other contractors on site to guide a survey effort of 278 worker-hours. Surveys were conducted nocturnally and during the day to target different stages of Canadian Toad breeding phenology: calling activity generally occurs at night in late May and early June while juveniles and recent metamorphs are more likely to be encountered during daylight hours in July and August (Breckenridge and Tester 1961; Eaton et al., 2005). Total detections decreased compared to 2024 at Horizon and Horizon South but increased at Albian Sands with the discovery of several newly active wetlands. Canadian Toads were also present at the designated receiving sites at both leases.

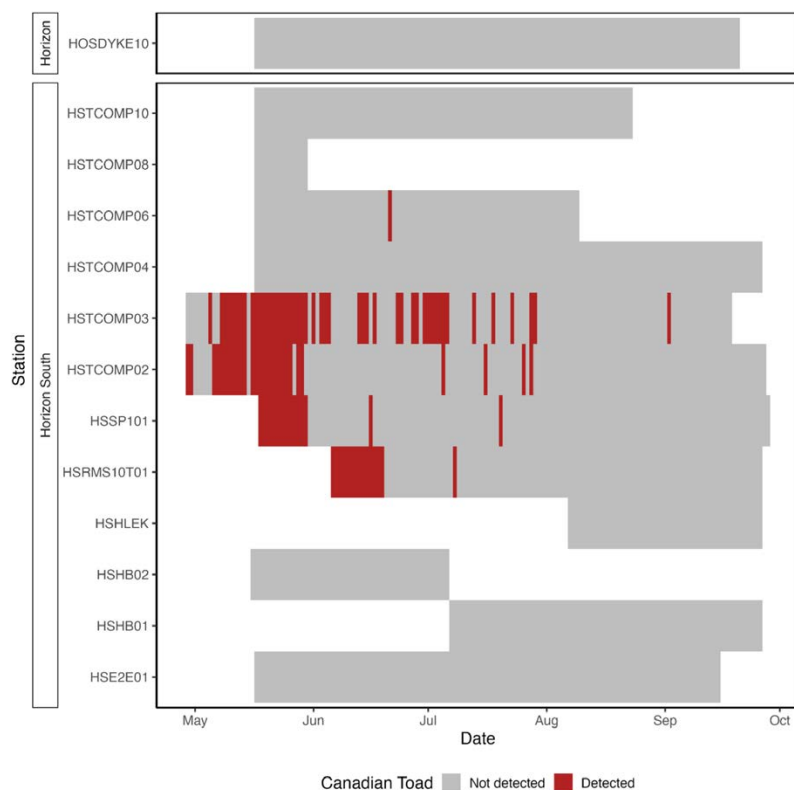


Figure 1: Timeseries of detections by ARUs stationed on Canadian Natural Horizon and Horizon South in 2025. Data for HSHLEK May – July missing due to ARU data corruption.

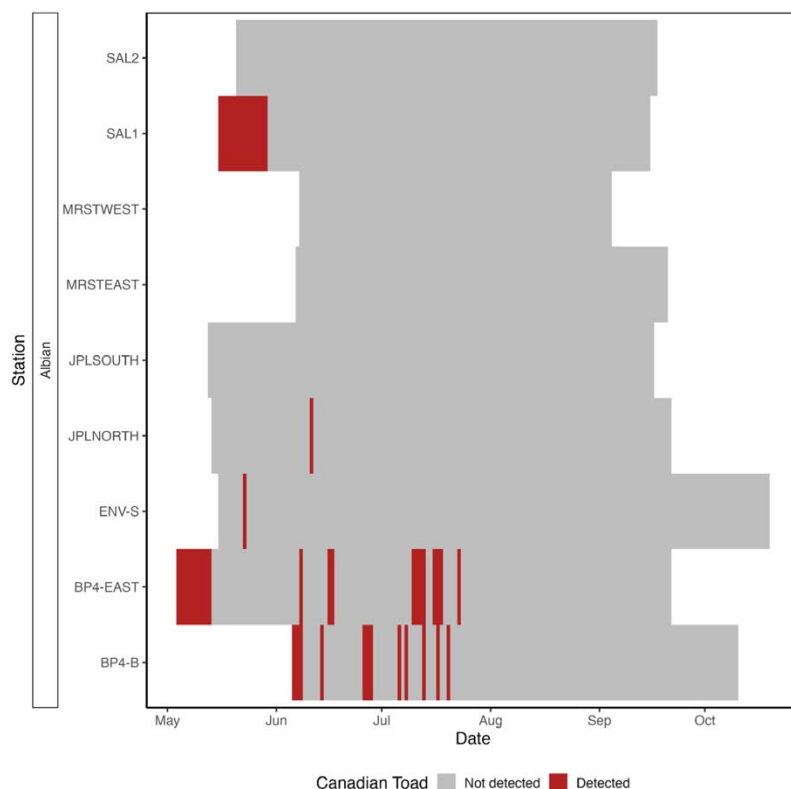


Figure 2: Timeseries of detections by ARUs stationed on Canadian Natural Albian South in 2025.

No tests for chytridiomycosis and ranavirus (Task 2) were conducted due to changes to the requirements for testing within the Alberta Environment Parks and Wildlife Permit License #24-289 that allowed translocation without testing as long as translocation occurred only over distances they could potentially travel unaided annually, and not outside of mineral lease boundaries. Furthermore, no toads of any life stages were observed with signs of infection that would warrant confirmation through testing.

Task 3 was addressed at Horizon South and Albian Sands. In August, 1,779 toads were captured at Horizon South and relocated to the receiving site at Toad Complex and included one egg string, 769 larvae, 1,004 metamorphs, and five adults. At Albian Sands, 24,141 Canadian Toads were translocated to Mrs. T's Lake and Jackpine Lake and included three egg strings, 10,840 larvae, 13,286 metamorphs, eight juveniles, and four adults (Table 1).

Table 1: Total number of Canadian Toad (all life stages) translocated at Canadian Natural's Horizon and Albian leases.

Lease	Relocation Area	Eggs	Larvae	Metamorph	Juvenile	Adult	Total
Horizon South	Toad Complex	1	769	1,004	0	5	1,779
Albian	Jackpine Lake	3	4,423	5,769	8	3	10,206
Albian	Mrs. T's Lake	0	6,417	7,517	0	1	13,935

Tasks 4 and 5 address the importance of developing the body of knowledge surrounding Canadian Toad seasonal habitats for use in applied ecological studies such as this. LGL documented new habitat at both Horizon and Albion (Task 4), including occupied breeding wetlands and potentially suitable overwintering habitat. The Albion Sands lease continued to receive a greater survey effort than it had prior to 2024 as part of its incorporation into this Canadian Toad mitigation project, which resulted in the discovery of several new sites of interest.

Field validation of the updated Canadian Toad habitat suitability model was completed for Canadian Natural leases between 2022 and 2024 (100 overwintering validation plots across Horizon and Albion) and for Suncor leases in 2025 (123 plots across Base Plant and Fort Hills). Validation involves assessing overwinter habitat features at a subset of mapped polygons and comparing field ratings to model predictions. This process tests whether the spatial datasets used to run the model reflect conditions on the ground and whether model variables (e.g., soil texture, organic forest floor horizons [litter, fermentation, and humus; LFH] depth, rooting, compaction, moisture) are relevant components of overwinter habitat suitability. Overall, model predictions showed moderate to good correspondence with field appraisals, and the model generally ranked plots from least to most suitable in a manner consistent with field observations. However, the validation also identified a systematic tendency for the model to overpredict overwinter suitability — most notably for polygons mapped as Moderate — particularly where field conditions reflected compaction, saturated/fine-textured soils, dense rooting zones, or thick LFH layers that reduce soil penetrability and likely limit access to frost-free depths. Habitat in polygons with minimal mechanical disturbance was generally better predicted than habitat in reclaimed or otherwise industrially altered areas, where rapid and fine-scale changes to substrates are not always captured by available spatial layers. As such, the model appears to effectively identify where suitable overwinter habitat is likely to occur, but outputs should be interpreted in the context of recent and historical mine activity and the presence of anthropogenic or opportunistic habitats that may not align with mapped natural features.

In 2025, the updated HSI was applied across multiple oil sands leases and continued to indicate substantially lower habitat suitability than earlier EIA-era mapping, reflecting improved differentiation of overwinter habitat and reduced overprediction of high-suitability habitat. For Horizon Oil Sands, the 2025 updated HSI identified 7,406 ha (38.6%) of suitable habitat, including 402 ha (2.1%) rated High, with most suitable habitat classified as Low (4,564 ha; 23.8%) and Moderate (2,440 ha; 12.7%). For Horizon South, the 2025 updated HSI identified 9,423 ha (43.7%) of suitable habitat, including 483 ha (2.2%) rated High, with most suitable habitat classified as Low (5,434 ha; 25.2%) and Moderate (3,506 ha; 16.3%). For Albion Sands, the 2025 updated HSI identified 4,089 ha (47.5%) of suitable habitat, including 285 ha (3.1%) rated High, with most suitable habitat classified as Low (2,915 ha; 33.9%) and Moderate (889 ha; 10.3%). For Suncor's Base Plant, the 2025 updated HSI identified 6,797 ha (28.3%) of suitable habitat, including 177 ha (0.7%) rated High, with most suitable habitat classified as Low. For Fort Hills, the 2025 updated HSI identified 3,910 ha (21.5%) of suitable habitat, including 379 ha (2.1%) rated High, again dominated by Low-suitability habitat (Figure 3; Table 2). These results do not imply an absence of Canadian Toad habitat on the leases; rather, they reflect the model's structure, which places strong constraints on suitability based on the combined occurrence of suitable breeding habitat, suitable overwintering substrates, and the distance between these limiting habitat components, while accounting for disturbance. As with prior applications, the HSI outputs should be treated as biologically informed hypotheses derived from literature and expert interpretation, and considered relative to the still-limited empirical understanding of Canadian Toad overwintering habitat use in the Athabasca Oil Sands Region. The 2025 validation results provide strong support that the updated model is directionally robust and ecologically more realistic than earlier models, while also reinforcing the need for continued empirical work (e.g., telemetry and targeted overwinter confirmation) to better link predicted high-suitability classes to functional overwinter survival across dynamic, actively managed industrial landscapes.

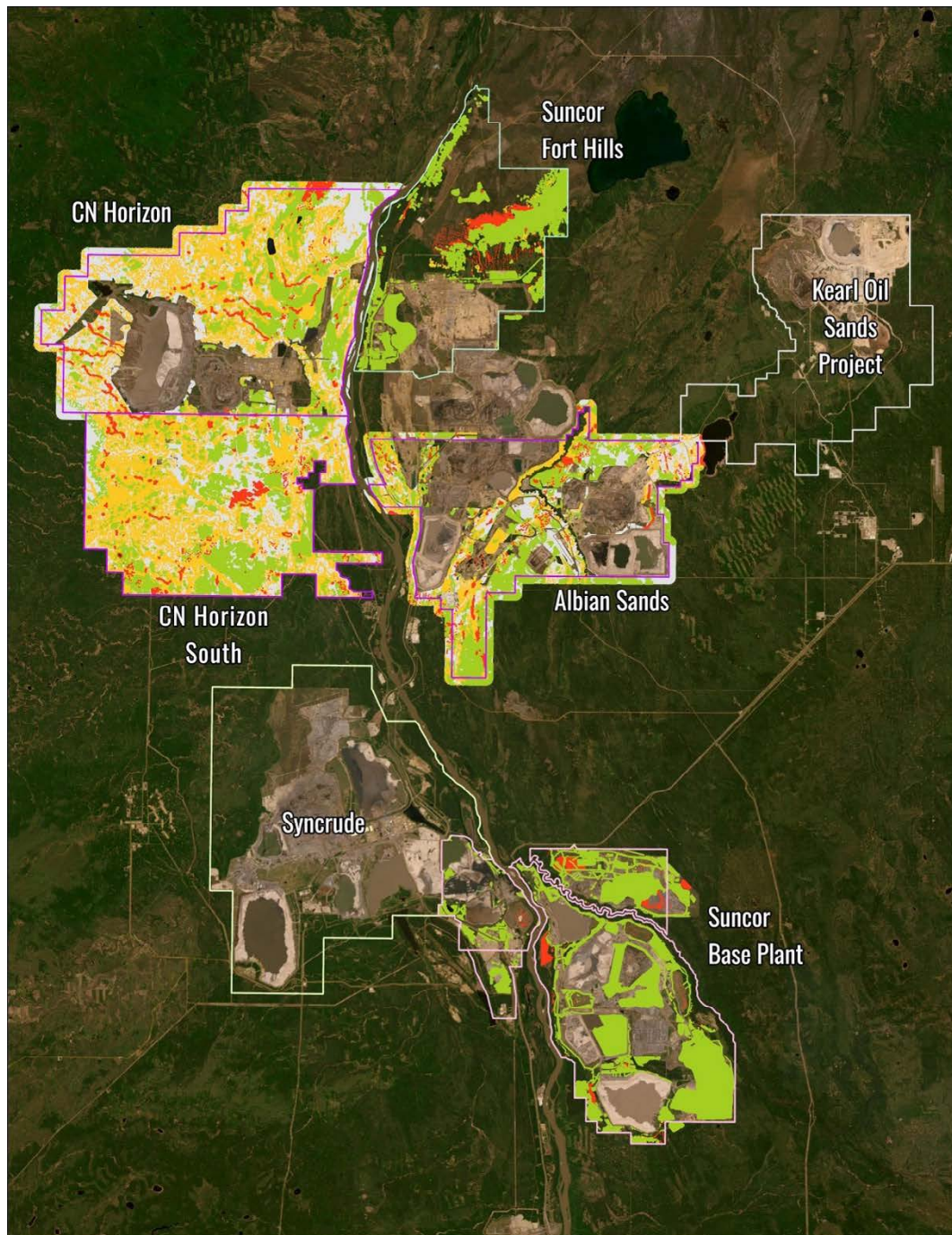


Figure 3: Distribution of high, moderate, low, and nil suitability Canadian Toad habitat on Canadian Natural's Horizon Oil Sands, Horizon South, Albian Sands, and Suncor's base plant and Fort Hills Operations. Mapping output based on the application of the HSI model updated in 2025. Colour ramp: red = high suitability; orange = moderate; green = low.

Table 2: Total area (hectares) predicted to provide high, moderate, low, and nil suitability habitat value for Canadian Toad on Canadian Natural's Horizon Oil Sands, Horizon South, and Albain Sands and Suncor's base plant and Fort Hills operations. The distribution of high through nil habitat suitability is shown in Figure 3

Lease	HSI Rating				Total (ha)
	High	Moderate	Low	Nil	
Horizon Oil Sands	440.30	2,434.90	4,538.10	11,600.90	19,014.20
Horizon South	482.61	3,506.35	5,434.34	12,127.46	21,550.77
Albain Sands	213.00	891.50	2,987.00	4,517.00	8,608.50
Suncor Base	177.14	400.37	6,219.51	17,178.72	23,975.74
Fort Hills	379.01	364.99	3,166.01	14,277.99	18,188.00
Total Area (ha)	1,692.06	7,598.11	22,344.96	59,702.07	91,337.21

Based on the available literature and the results of field validation completed between 2022 and 2025, it is reasonable to assume that loose or very friable (e.g., sandy to loamy-sand) soils extending to depths of approximately 1.0 m to 1.2 m provide highly suitable overwintering habitat for Canadian Toads, as these substrates facilitate burrowing to frost-free depths. Field validation of the updated HSI confirms that overwinter habitat suitability is strongly associated with soil texture, soil moisture, LFH thickness, rooting density, and degree of compaction. However, uncertainty remains regarding the extent to which alternative overwintering features — such as old squirrel middens, small mammal burrows, or American beaver (*Castor canadensis*) lodges — may function as viable overwintering habitat, particularly within disturbed or reclaimed landscapes. In addition, the suitability of different wetland types for breeding has not been comprehensively validated, and the current model relies on generalized aspects of Canadian Toad ecology and the characterization of known or suspected breeding habitats rather than direct confirmation of successful reproduction or recruitment.

Results from the 2025 validation indicate that, while the updated HSI provides a more ecologically realistic depiction of overwinter habitat than earlier EIA-era models, it tends to overpredict moderate suitability in areas affected by compaction, saturated or fine-textured soils, dense rooting, or recent industrial disturbance not fully captured by spatial datasets. Future field work — including targeted soil sampling, continued ground-truthing of spatial inputs, and systematic confirmation of breeding habitat use — will further refine and validate the model and improve its application to mitigation planning associated with mine expansion. Continued validation sampling at Suncor Base Plant and Fort Hills Operations is proposed to address remaining uncertainties and to strengthen confidence in the Canadian Toad HSI. As with all habitat suitability index models, iterative refinement and subsequent validation will be required as additional empirical information on Canadian Toad ecology becomes available.

LESSONS LEARNED

Monitoring, habitat modelling, and translocation mitigation programs conducted at Horizon, Horizon South, and Albian Sands continue to provide valuable, transferable lessons for amphibian mitigation on active industrial landscapes.

1. Early-season detection of breeding activity is fundamental to effective mitigation. Across all leases, delayed identification of breeding sites consistently resulted in a higher proportion of larvae and metamorphs requiring salvage. Earlier-season monitoring improved the ability to identify breeding activity and reduced testing requirements allowed for translocation before larval development was advanced, supporting more efficient mitigation.
2. Canadian Toads may exhibit low breeding-site fidelity and short-term habitat plasticity in industrial environments. Interannual shifts in breeding locations were observed across all leases, with some historically active sites becoming inactive while newly disturbed or recently created habitats were rapidly colonized. Productive breeding repeatedly occurred in ephemeral, mineral-soil wetlands associated with mine activities. These findings demonstrate that mitigation programs must remain adaptive and responsive to changing site conditions rather than relying exclusively on historically known breeding locations.
3. Reliance on older, coarse-resolution habitat models can substantially overestimate available habitat and misinform mitigation planning. Comparisons between EIA-era HSIs and the updated model showed that earlier approaches consistently overpredicted suitable habitat across multiple leases. The updated HSI, which integrates finer-scale datasets and places increased emphasis on overwintering habitat, produced more conservative and ecologically defensible outputs. This reinforces the importance of periodically updating habitat models as spatial datasets and ecological understanding improve.
4. Overwintering habitat represents a critical limiting factor that must be explicitly considered in both mitigation and reclamation planning. Field validation confirmed that coarse-textured, friable soils with limited compaction, rooting, and LFH development were most consistently associated with higher overwinter suitability, while fine-textured, compacted, organic, or saturated soils were associated with low suitability. Incorporating soil and subsurface attributes improved model performance relative to earlier approaches that inferred overwinter suitability indirectly and provides clearer guidance for evaluating translocation suitability and reclamation potential.
5. Spatial habitat models alone do not fully capture the dynamic nature of habitat availability on active leases. Field observations consistently documented Canadian Toad use of opportunistic or incidentally created habitats — such as sandy roadcuts, berms, excavations, and disturbed wetlands — that are not well represented in mapped datasets. As a result, habitat models are most effective when applied as decision-support tools interpreted alongside site-specific knowledge of disturbance patterns, ground conditions, and ongoing industrial activities.
6. Combining habitat suitability mapping with habitat capability mapping (HCM) improves mitigation and reclamation planning. Differences between HSI and HCM outputs identified areas that are currently unsuitable but biophysically capable of supporting Canadian Toad habitat in the long term. This distinction supports more transparent and defensible decision-making by identifying locations where reclamation or soil reconstruction efforts may plausibly improve future habitat conditions, while also identifying areas where inherent site limitations constrain recovery.

7. Consolidation of translocated individuals into a limited number of receiving sites can be operationally effective but requires structured follow-up monitoring. At Horizon South, repeated detections and increased calling activity at Toad Complex indicate continued use of the receiving site. At Albian Sands, Jackpine Lake and Mrs. T's Lake functioned as receiving sites; however, limited evidence of breeding or post-release persistence was documented in 2025. These outcomes highlight that designation of receiving sites alone does not confirm mitigation effectiveness and that ongoing surveillance is necessary to evaluate outcomes.
8. High reproductive output at core breeding complexes can overwhelm salvage capacity despite consistent application of mitigation protocols. For example, at Albian Sands, exceptionally high larval densities resulted in a substantial increase in translocation numbers relative to the previous year, and salvage benchmarks were not consistently achievable across all ponds. These results demonstrate that catch-per-unit-effort-based stopping criteria may be difficult to meet in complex, interconnected, high-density breeding systems and that annual environmental variability can significantly influence mitigation outcomes.
9. Mitigation outcomes are best interpreted at the landscape scale rather than at individual pond or site scales. Although some ponds met salvage thresholds, the proximity and connectivity of multiple breeding and overwintering features mean that Canadian Toad presence is likely to persist in the broader area. Translocation mitigation reduces immediate risk from habitat loss but does not eliminate local occupancy where suitable habitat remains nearby.
10. Current datasets support cautious interpretation of translocation success. While increased calling activity and repeated detections near receiving sites are consistent with continued habitat use, limitations in follow-up monitoring, the predominance of early life stages in translocation cohorts, and the absence of direct evidence of overwinter survival constrain definitive conclusions. These findings reinforce the importance of pairing mitigation actions with appropriately designed monitoring programs to evaluate outcomes while meeting mitigation objectives.

Collectively, these lessons demonstrate that effective Canadian Toad mitigation on industrial landscapes depends on early-season detection, adaptive monitoring and salvage strategies, updated habitat models that reflect limiting life-history requirements, and realistic expectations regarding salvage completeness and translocation outcomes.

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PRESENTATIONS AND PUBLICATIONS

Conference Presentations/Posters

Canadian Toad Habitat Suitability Index Model Update and Validation. 2025 COSIA Land EPA Symposium, Calgary Alberta, 3 December 2025. Oral presentation.

Reports & Other Publications

Hawkes, V. C. and D. B. Adama 2025. Canadian Toad (*Anaxyrus hemiophrys*) habitat suitability index model update and application for Suncor Base Plant and Fort Hills operations. LGL report EA4362. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for Suncor Energy Inc., Fort McMurray, AB. 47 pp + Appendix.

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Early Successional Wildlife Dynamics Program

COSIA Project Number: LJ0013

Mine

Tour Facilitator: LGL Limited environmental research associates

Industry Champion: Canadian Natural Resources Limited

Industry Collaborators: Canadian Natural Upgrading Limited, Suncor Energy Oil Sands Limited Partnership (Suncor and Fort Hill Operations), Imperial, ConocoPhillips

Status: Supplemental Year 3

PROJECT SUMMARY

The Early Successional Wildlife Dynamics (ESWD) program is a long-term, multi-taxa wildlife monitoring program designed to assess the efficacy of upland reclamation to provide habitat for wildlife in the mineable and in situ portions of the Athabasca Oil Sands Region (AOSR). Sampling for the ESWD program occurs on seven different types of sites: (1) reclaimed (REC); (2) reclaimed habitat adjacent to compensation lake (COMP); (3) mature forest (MF); (4) cleared habitats (CLR); (5) logged (LOG); (6) burned (BRN) habitats; and (7) fragmented mature forest (FMF). The FMF sites are only located at the Surmont lease at this point, and are mature forests that have 3D, low-impact seismic grids present within them. Although the primary contrast of interest is between REC and MF sites, sampling from COMP, LOG, BRN, FMF and CLR habitats provide an indication of whether wildlife usage patterns on reclaimed landforms are consistent with those associated with sites recovering from stand replacing fire, logging, or site clearing. Since the ESWD program began, much has been learned about wildlife use of the different habitat types, however, more remains to be learned about year-round use by species other than mammalian wildlife.

The ESWD program, initiated in 2012, evaluates wildlife use and function of reclaimed upland habitats through the collection of baseline data to characterize the occurrence and distribution of wildlife across the various site types, and analysis of habitat productivity and function to inform reclamation practices. While initially implemented on surface mines within the Athabasca Oil Sands Region, the program has since expanded to include in situ operations. A summary of work is provided in Hawkes et al. (2021), with additional papers published in the peer-reviewed literature (Hawkes and Gerwing, 2019; Hawkes et al., 2021; Hawkes et al., 2024).

Collection of baseline data is still ongoing on certain leases to complete the five years of data collection associated with the ESWD program, including several sites on Canadian Natural's Albion Sands, sites at ConocoPhillips Surmont Project, and several locations at Suncor's Fort Hills Operations, and Imperial's Kearl Oil Sands. Despite gaps in the dataset due to availability of some site types (BRN, CLR, LOG), with five or more years of data collected in many of the current sites there is a well-developed baseline for both REC and MF sites. The objectives of the program are now shifting toward assisting operators in developing wildlife habitats during reclamation while meeting environmental approval requirements and supporting the establishment of performance criteria in *Environmental Protection and Enhancement Act (EPEA)* approvals for wildlife habitat, ecosystem function, sustainability, and biodiversity. Future analyses will use

both newly collected data and existing ESWD data dating back to 2012. This report briefly summarizes the status and updates to early data collection and presents the results from ESWD activities conducted during the 2025 program year.

PROGRESS AND ACHIEVEMENTS

Baseline Data Collection

Baseline data collected for the ESWD program provide insight into wildlife occurrence and distribution across the six habitat types described in various publications (Hawkes and Gerwing 2019; Hawkes et al., 2021; 2024). A seventh site type – fragmented mature forest – occurs on ConocoPhillips Surmont project and is characterized as mature forest bisected by seismic cutlines. While data coverage has expanded over time, some data gaps remain due to (1) limited sample sizes for certain habitat and (2) ongoing program changes, including the addition of new sites. Ongoing baseline sampling will continue to address the following data gaps and program updates:

1. **Sample size limitations:** Sample sizes remain limited for some habitat types. For example, Logged (LOG), burned (BRN), cleared (CLR), and compensation lake (COMP) sites continue to be difficult to locate in areas where sampling is feasible. But importantly, older REC sites (those greater than 38 years post-reclamation) are required to fill data gaps and efforts to access those sites are ongoing.
2. **Program updates and site additions:** Recently added sites, including the expansion into in situ oil sands operations at the ConocoPhillips Surmont lease in 2023, do not yet have a complete five-year dataset. Program expansion to additional in situ sites and new reclamation areas in the mineable portion of the AOSR is anticipated in future years, particularly to support questions relating to possible differences in reclaimed habitat development on sites targeting different ecosystems.

Data collection at these sites will continue until sufficient coverage is achieved. Baseline sampling for the 2025 program included:

- **Amphibian Surveys:** Incidental observations and visual encounter surveys at opportunistic, natural, and created wetlands, and compensation lakes
- **ARUs:** Deployment of acoustic and ultrasonic autonomous recording units in early spring to mid-fall to monitor amphibians, songbirds and bats
- **Songbirds:** Spring/summer songbird point counts
- **Raptors:** Incidental observations
- **Small mammal trapping:** Fall small mammal live trapping and mark-recapture surveys, along with a pilot program using baited camera traps
- **Vegetation and habitat assessments:** 10 m x 10 m plots (usually three to five per site) established to assess the species and cover of all vascular plants in each type of site
- **Motion-activated Cameras (general and winter active):** Deployment and maintenance of motion-activated cameras to monitor the occurrence and distribution of medium and large-sized mammals and other wildlife
- **Arthropod sampling:** Terrestrial arthropod sampling using pitfall traps (for beetles and spiders) in the spring and malaise traps in the spring/summer for aerial insects
- **Incidental observations:** All wildlife species recorded on site were documented

Summaries of baseline results from previous years are provided in past COSIA progress reports and are not included in this report (but see Hawkes and Gerwing 2019; Hawkes et al., 2021; 2024). An update to the small mammal trapping program in 2025, which included a pilot camera trapping program to photograph small mammals, is described below.

Small Mammal Camera Trapping

In September 2025, LGL Limited, in cooperation with staff from the Alberta Biodiversity Monitoring Institute (ABMI), conducted a pilot program to test a method for documenting small mammals using baited camera traps (Figure 1). The camera traps are based on a study conducted by a graduate student at the University of Alberta that used this method to document small mammal abundance without the need for capture and handling. The pilot program was conducted at the ConocoPhillips Surmont lease in conjunction with the regularly occurring capture and release small mammal monitoring.

Two grids of camera traps were deployed immediately adjacent to existing small mammal grids, including one at a REC site and one at a MF site. Using the same bait (black-oil sunflower seeds), proximity to existing sites, along with simultaneous live trapping, will allow for comparisons between the two methods and determine whether a transition to this less invasive method is feasible while still maintaining the existing dataset. While current methods allow individuals to be “marked” with ear tags, the limited number of recaptures does not support accurate population density measurements. Camera traps may provide a more complete picture of small mammal species presence, as traps are never closed and cameras continually monitor the baited tube between checks. Camera traps may also reduce the need for constant trap checks as there is no risk of mortality associated with capture, which may reduce the number of field personnel and overall time spent in the field. In addition, shrew mortality, a common problem with traps that close due to the high metabolic needs of shrews and their dietary requirements, should be eliminated. Results from the analysis of the camera data will be used to assess the optimal number of traps to deploy at each site and more work is required to relate the small mammal trap data collected by live-trapping and camera trapping.

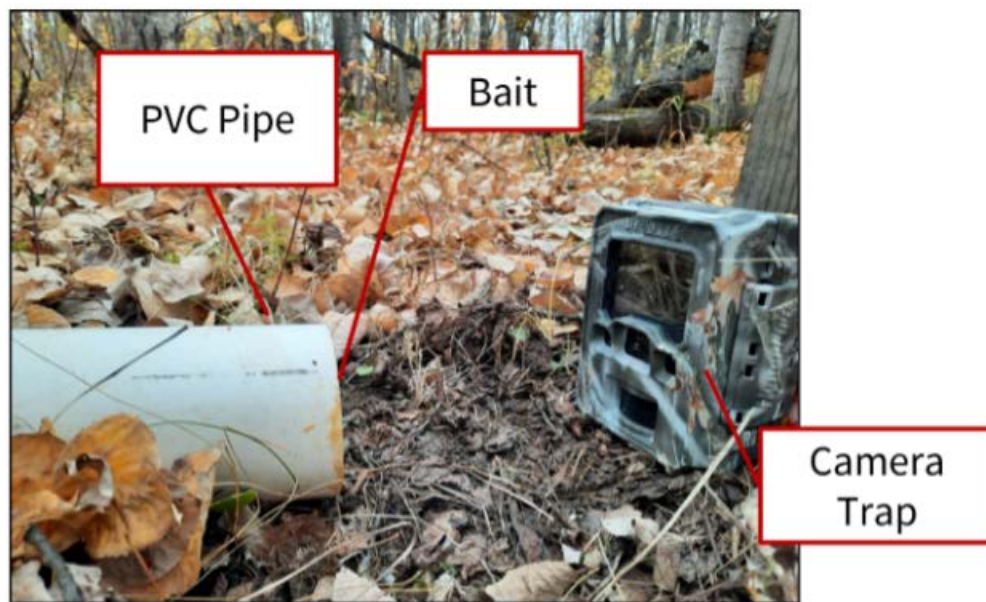


Figure 1: Setup for a small mammal camera trap.

At this time, camera trap photographs have been uploaded and tagged (see Figure 2 for example photos). However, no analysis has yet been conducted. Future analysis will compare the photographs to current data by creating a dataset using simulated trap checks so that only the first animal caught on each camera after two specified times of day is retained. These specified times will correspond to, and therefore mimic, the trap checks on a traditional mammal trap that closes when triggered. The entire camera dataset will be used to measure other summary statistics such as species richness and relative abundance.



Figure 2: Example photographs of small mammals detected at the Surmont lease during the September 2025 camera trap pilot program. Clockwise from top left: Meadow Vole (*Microtus pennsylvanicus*), Southern Red-backed Vole (*Myodes gapperi*), North American Deer Mouse (*Peromyscus maniculatus*), and Northern Flying Squirrel (*Glaucomys sabrinus*).

In addition to the animals pictured above, observations included several shrews (*Sorex spp.*), Snowshoe Hare (*Lepus americanus*), American Marten (*Martes americana*), and American Red Squirrel (*Tamiasciurus hudsonicus*).

New and future analyses

New aspects of the ESWD program are being conducted on all sites, including those that are undergoing baseline data collection. Three components of the program have been initiated, including:

- Food sources for birds, bats, small mammals and amphibians
- Food sources for carnivores and raptors
- Winter bird use of reclaimed lands

These new components are at different stages of implementation. Results available to date are presented below for the food source component, focused on birds, bats, small mammals, and amphibians. The proposed study on food sources for carnivores and raptors remains in the preliminary planning stage. A more comprehensive summary is provided for winter bird use of reclaimed lands, as surveys for this component are now complete.

Food Sources for Birds, Bats, Small Mammals and Amphibians

Arthropods (e.g., insects and spiders) play a critical role in terrestrial and freshwater ecosystems and are a food source for many species including birds, bats, small mammals, amphibians, reptiles, and fish. To evaluate how reclaimed sites in the oil sands region are contributing to functional wildlife habitat, project researchers are conducting terrestrial arthropod sampling focused on both ground-dwelling and aerial insectivores. Sampling of ground-dwelling arthropods (primarily beetles and spiders) using pitfall traps is being conducted as baseline. Sampling of flying insects using Malaise traps was initiated in 2023, with preliminary results available.

From 2023 to 2025, Malaise traps have been deployed across an increasing number of ESWD plots for assessing diversity and biomass of aerial insects (Table 2), with a low of 13 plots in 2023 to a high of 50 plots in 2025.

Table 2: Number of plots sampled for aerial insects in each year from 2023 to 2025 for the Early Successional Wildlife Dynamics (ESWD program).

Lease	2023	2024	2025
Albian Sands	–	7	7
Horizon Oil Sands	–	7	7
Horizon South	–	3	5
Fort Hills Operations	3	3	3
Suncor Base Plant	–	11	11
Kearl Oil Sands	3	4	5
CPC Surmont	7	10	12
Total plots sampled annually	13	45	50

Detailed analyses are forthcoming. To date, a total of 16 insect Orders were identified from Malaise trap samples. Diptera (i.e., Flies) and Hymenoptera (e.g., Bees, Wasps, and Ants) dominated samples with 127,275 and 15,217 individuals, respectively. Sixty families of Diptera and 42 families of Hymenoptera have been identified with the most abundant taxa being Cecidomyiidae (Gall and Forest Midges; 16,764 individuals), Chironomidae (Non-biting Midges; 15,470 individuals), and Simuliidae (Black Flies; 14,486 individuals). The greatest number of families (i.e., Family Richness) were collected in 2024 (92 families), followed by 2025 (90 families), and 2023 (79 families), though the number of individuals collected varied greatly by year (Figure 3). Future analyses may explore compositional differences and relationships with birds and/or bats.

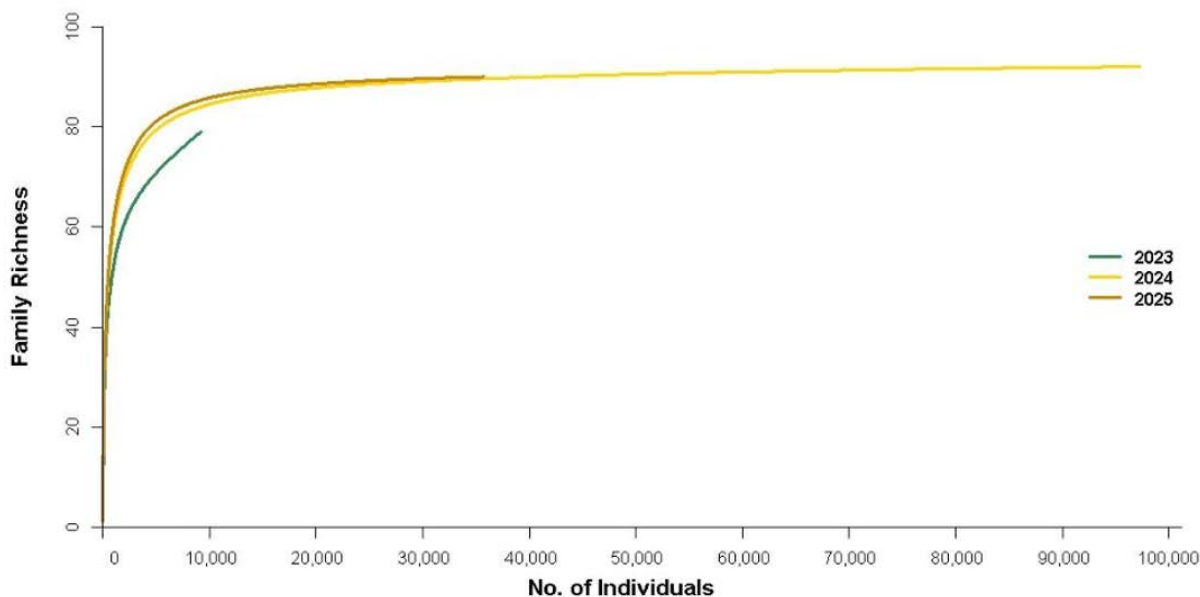


Figure 3: Number of Diptera and Hymenoptera families (i.e., Family richness) for aerial insects in each year by the number of individuals sampled.

Food Sources for Carnivores and Raptors

As a primary food source for various mammalian carnivores and avian predators, small mammals play an important role in influencing predator use of reclaimed habitats and their successful return to reclaimed landscapes. Within the ESWD program, a proposed study is being developed to examine small mammal occurrence and distribution in relation to habitat features that can be influenced by reclamation practices, with the objective of identifying conditions that support healthy small mammal populations. Habitat features under consideration include coarse woody debris, snag placement, litter cover, site topography, and proximity to adjacent habitats such as mature forest and wetlands. The proposed approach includes a desktop-based analysis to model relationships between these habitat features and small mammal occurrence.

During the 2025 program year, this component remained in the preliminary planning and study design phase, with existing prey and predator abundance and distribution data not yet analyzed. Further refinement of study design and analyses is anticipated in future program years.

Winter Bird Use of Reclaimed Lands

Winter birds are used as an indicator to assess the ability of reclaimed habitats to support wildlife year-round. A winter bird monitoring program focused on documenting the occurrence and distribution of winter-resident birds and birds migrating from arctic breeding sites. The program was implemented in January 2024 and continued through 2025.

Winter bird surveys were conducted between February 2024 and March 2025 to document bird presence and activity (Table 3). Surveys were completed during late winter (February–March) in 2024 and during both early winter (November–January) and late winter (February–March) of the 2024-25 season. In total, 57 plots were surveyed

across all leases, including the following habitat types: REC (n = 26), MF (n = 15), FMF (n = 3), COMP (n = 6), LOG (n = 1), CLR (n = 3), and BRN (n = 3). Across all plots, 148 surveys were completed, comprising 45 late winter 2024 surveys, 56 early winter 2024-25 surveys, and 47 late winter 2025 surveys.

Table 3: Winter bird sampling sites per lease with ESWD habitat types and number of surveys.

Lease/Treatment	No. of Plots	Total No. of Surveys (across all plots)		
		Late Winter 2024	Early Winter 2024/2025	Late Winter 2025
Albian Sands	8	7	8	7
CLR	2	2	2	2
COMP	1	1	1	1
LOG	1	1	1	1
MF	1	1	1	1
REC	3	2	3	2
Horizon Oil Sands	15	12	15	10
BRN	1	1	1	1
COMP	3	1	3	1
MF	7	7	7	6
REC	4	3	4	2
Fort Hills Operations	4	3	4	3
BRN	2	1	2	2
CLR	1	1	1	1
COMP	1	1	1	0
Suncor Base Plant	12	11	11	10
MF	2	2	2	2
REC	10	9	9	8
CPC Surmont	12	12	12	12
MF	2	2	2	2
REC	7	7	7	7
FMF	3	3	3	3
Kearl Oil Sands	6	0	6	5
COMP	1	0	1	1
MF	3	0	3	2
REC	2	0	2	2

Bird detections are summarized by treatment type for individual species and groups of birds, including gallinaceous birds (grouse species), in Table 4. A total of 954 bird detections were recorded during surveys. Detections included visual and auditory observations, as well as indirect signs of bird use such as tracks, scat, and signs of foraging. Common Redpoll accounted for approximately 39.7% of all detections (n = 379). Other frequently detected species and groups included Common Raven (18.1%), Black-capped Chickadee (6.1%), Grouse species (9.0%), Canada Jay (4.1%), Black-billed Magpie (3.0%), and Snow Bunting (3.0%).

Table 4: Total number of bird detections by species and habitat types across all winter bird surveys in 2024 and 2025. Includes visual and auditory detections as well as signs such as tracks, scat, or signs of foraging. Habitat types are: Burned Forest (BRN); Cleared (CLR); Compensation Lake (COMP); Fragmented Mature Forest (FF); Logged (LOG); Mature Forest (MF); and Reclaimed (REC).

Species	Plot Type							Total
	BRN	CLR	COMP	FF	LOG	MF	REC	
American Crow							1	1
American Three-toed Woodpecker						1		1
Bald Eagle							1	1
Black-billed Magpie	1	3	2			1	22	29
Black-backed Woodpecker						1		1
Black-capped Chickadee	2	3	5	2	4	21	21	58
Blue Jay			1				1	2
Boreal Chickadee		1	1	3		8	4	17
Bohemian Waxwing						3	1	4
Canada Jay		2	2	4	1	25	5	39
Common Raven	5	8	24	3	2	33	98	173
Common Redpoll	7	28	92	4		45	203	379
Downy Woodpecker						3	1	4
Grouse (unknown species)		8	4	2	2	5	35	56
Harry Woodpecker						4	1	5
Hoary Redpoll							1	1
Northern Goshawk						1		1
Northern Saw-whet Owl			2					2
Passerine species			1				2	3
Pine Grosbeak		3	1	1		4	7	16
Pileated Woodpecker			2	3		8		13
Red Crossbill						3	1	4
Redpoll			26			7	18	51
Ruffed Grouse							5	5
Sharp-tailed Grouse	3	11	1				3	18
Snow Bunting						2	27	29
Spruce Grouse					1		5	6
Woodpecker species			2	1		7	2	12
White-winged Crossbill	2					5		7
Willow Ptarmigan							1	1
Unknown bird species		4	3	1		3	4	15
Total	20	71	169	24	10	190	470	954

Note: Detection numbers represent conservative totals, as counts were standardized prior to analysis by converting ranges and non-discrete values to single values for consistency across surveys.

LESSONS LEARNED

- The results of wildlife occurrence and distribution on reclaimed landforms have been the subject of recent publications (Hawkes and Gerwing, 2019; Hawkes et al., 2021, and Hawkes et al., 2024). In each instance, the authors report that regardless of the developmental trajectory of reclaimed habitats, or even the targeted ecosite, progression towards increased wildlife community similarity between landforms reclaimed to an upland ecosite and mature forest typical of the surrounding boreal forest is apparent in the data (Hawkes and Gerwing, 2019).
- The ESWD program is advancing our understanding of wildlife use of reclaimed landforms, helping operators meet *EPEA* requirements as they pertain to mitigating impacts to wildlife and wildlife habitat.
- Achieving adequate sample sizes to establish a baseline of the ecological diversity and heterogeneity across the different habitat types included in the ESWD program is essential for a robust analysis of reclamation effectiveness in the AOSR. Of relevance to the ESWD program is the ability to sample older reclaimed sites (i.e., those greater than 38 years post-reclamation), which has been identified as a data gap associated with the current program.
- Winter bird data are being collected using a moving transect within a one-hectare area at each ESWD site. The precise methods are evolving as project researchers are learning to deal with the noise created when moving in a snow-covered environment. Observers are now spending more time standing still and listening for birds, then moving quickly to another stopping point.
- Data collected for the ESWD program support assessments of food sources for birds, bats, small mammals and amphibians, carnivores and raptors.
- The use of camera traps to sample small mammals is promising and provides a relatively non-invasive and non-lethal approach to sampling small mammals. Additional analytical work is required to determine whether the data collected via small mammal live-trapping is comparable to data collected by camera traps.

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Caribou Detection in Boreal Forest Environments

COSIA Project Number: LE0075

In Situ

Research Provider: University of Saskatchewan

Industry Champion: Suncor

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

Status: Year 4 of 5

PROJECT SUMMARY

This project integrates innovation and interdisciplinary research to address persistent challenges in wildlife conservation across the boreal forests of Alberta, Saskatchewan, Manitoba, and the Northwest Territories. Organized around a set of defined Research Milestones, the program is designed to advance practical and scalable approaches for monitoring wildlife populations and habitat change across large, remote landscapes. The work responds directly to long-standing data limitations that constrain the ability to understand, anticipate, and manage ecological change across the Boreal Plains and Boreal Shield.

The program brings together a multi-sector partnership that includes Indigenous organizations, provincial and federal governments, non-governmental organizations, industrial partners in both the public and private sectors, and academic researchers from three universities. This structure supports co-developed research priorities, shared governance through an active Program Advisory Committee, and sustained knowledge exchange across jurisdictions and sectors.

The overarching intent of the program is to deliver tools, data, and analytical capacity that support conservation and management of the boreal ecosystem while safeguarding key socioecological values. Outcomes are both partner-specific and shared, including the continued evolution of the Program Advisory Committee toward a standing knowledge-sharing consortium, referred to as the Boreal Network. This network is intended to facilitate synthesis, comparison, and application of findings related to the causes and consequences of environmental change in the western boreal forest.

The goals of the project and partnership are to:

1. Advance an innovative and interdisciplinary program that addresses critical knowledge gaps limiting understanding of the causes of change in the western boreal forest; and
2. Increase social, institutional, and academic capacity to mitigate the consequences of those changes and reduce the risk of accelerating unintended impacts on species, food systems, and regional economies.

Funding from COSIA (Oil Sands Alliance), used as matched funding for a Natural Science and Engineering Research Council (NSERC) Alliance grant (**ALLRP-567154-21**, “*Innovation and interdisciplinary research to understand the causes and mitigate consequences of environmental change in the Boreal Plains*”), was directed at advancing the first two of seven Research Milestones, including:

Research Milestone 1: New Approaches to Wildlife Detection (M1) addresses the fundamental challenge of obtaining cost-effective, spatially extensive data on wildlife populations at the scale of boreal ecozones. While local-scale information on relative abundance can be derived from traditional ecological knowledge and conventional scientific approaches, equivalencies often break down when extrapolated across regions due to differences in survey methods, coverage, and detectability. M1 focuses on developing a standardized aerial imaging approach capable of generating consistent data across jurisdictions and landscapes.

Under M1, a multispectral, high-resolution, and scalable TK-7 imaging payload, mounted on a fixed-wing aircraft, has been deployed operationally to collect colour and thermal imagery across large areas. The system acquires imagery in contiguous strips using co-boresighted sensors, producing datasets suitable for visual interpretation, annotation, and computer-assisted analysis. Imaging resolution scales with altitude flown. At an altitude of approximately 450 m, the TK-7 imaging payload achieves approximately 3 cm colour and approximately 15 cm thermal ground resolution while imaging a swath about 180 m wide. Whereas, at an altitude of approximately 760 m resolution scales to approximately 5 cm (colour) and approximately 25 cm (thermal) while covering a much broader swath of roughly 640 m in a single pass.

While originally developed for fire detection, the TK-7 platform has proven capable of supporting wildlife-related applications, particularly for generating standardized imagery required for downstream analytical development. Work under M1 has demonstrated that the primary limitation on automated wildlife counting is not image acquisition, but the availability of sufficiently large and diverse training datasets for model development.

Research Milestone 2: Modelling Species Abundances (M2) builds directly on M1 by applying standardized imagery and complementary ground-based data to address data-intensive questions related to species densities and food-web dynamics.

Study blocks extend from western Manitoba through Prince Albert National Park in Saskatchewan, east-central Alberta, the Alberta foothills, and into the southern Northwest Territories. Within these regions, project partners are supporting collaring programs and contemporary abundance surveys for species including moose, boreal caribou, wolves, black bears, and bison.

Rather than relying on single-species estimates, M2 is structured to evaluate relative multi-species densities using a combination of aerial imagery, camera trapping, telemetry, and partner-provided survey data. As datasets accumulate, this framework is intended to support hypothesis testing related to coexistence, exclusion, and apparent competition across varying boreal environments. By the later stages of the program, the assembled dataset is expected to represent one of the most comprehensive resources available for evaluating higher-trophic-level dynamics in boreal systems, while remaining grounded in standardized and transparent data collection methods.

PROGRESS AND ACHIEVEMENTS

During 2025, the program made substantial progress toward its stated M1 objectives of evaluating high-resolution aerial imagery as a scalable monitoring tool and advancing the analytical framework required for automated wildlife detection. Including the completion of aerial surveys using the TK-7 multispectral imaging system across multiple study areas. These surveys generated consistent colour and thermal imagery suitable for visual interpretation, annotation, and computer-vision development. Survey protocols, flight altitudes, and processing workflows were standardized to ensure comparability across regions and species.

A key achievement during this reporting period was the advancement of the analytical foundation required for automated analysis of aerial imagery. This included the integration of datasets into a unified processing and annotation pipeline, with correction for matching thermal and colour imagery. Although the sensors were co-boresighted, a detectable phase shift between colour and thermal image tiles needed to be corrected, and this has since been resolved.

In parallel, targeted surveys were initiated in systems designed explicitly to amplify training data (see Lessons Learned). These included plains bison surveys in Prince Albert National Park flown at multiple altitudes to evaluate detection performance under near-known density conditions. These surveys provide controlled reference data for evaluating annotation accuracy, model sensitivity, and the effects of flight altitude and habitat context on detectability.

Directly relevant to program objectives, MSc student Pranav Chandramouli, finalized a thesis and reported new methods for semantic segmentation in aerial imagery under few-sample conditions, demonstrating that composite data augmentation strategies can improve model performance when training datasets are limited. One of the chief issues encountered was how to advance the identification and counting of wildlife using computer vision methods, such as convolutional neural networks, when targets are rare on the landscape. This work addresses the central analytical constraint identified in the program and provides a validated methodological basis for continued development of wildlife detection models.

Operational results from visual interpretation of imagery further demonstrated the capability of the platform to detect certain — if unexpected — wildlife-related features consistently across large areas. As documented in McLoughlin et al. (2025), aerial imagery enabled rapid identification of beaver dams and lodges at landscape scales, providing quantitative spatial data on wetland systems and hydrological modification. While these detections were not the primary objective of the program, they represent a documented and reproducible outcome of the imaging system during 2025.

Overall, progress during this reporting period demonstrates that the aerial imaging platform and associated workflows are operationally mature for data acquisition and habitat-scale interpretation, while analytical development for automated wildlife detection has advanced through coordinated surveys, standardized datasets, and peer-reviewed methodological contributions.

LESSONS LEARNED

Results from this reporting period highlight several lessons of direct relevance to industry. Most importantly, the transition from wildlife detection to reliable wildlife counting is constrained primarily by the availability of appropriate training datasets rather than by sensor performance. High-resolution colour and thermal imagery can be collected consistently and at scale, but automated counting of low-density and mobile species such as caribou requires large numbers of annotated examples spanning multiple habitats, seasons, and viewing conditions. This reinforces that automated wildlife counting must be approached as a cumulative, multi-year capability rather than an outcome of a single project.

In contrast, wildlife-related features that are stationary and structurally distinct emerged as immediately detectable using aerial imagery. Beaver dams and lodges were identified rapidly and consistently because they persist in fixed locations and produce clear hydrological and structural signatures. As documented in McLoughlin et al. (2025), aerial detections substantially expanded spatial coverage relative to ground surveys, even though neither method achieved complete detection on its own. For industry, this distinction clarifies why certain ecological indicators can be operationalized quickly while others require longer-term analytical investment.

The lack of overlap between individual aerial and ground detections of beaver structures further illustrates the complementary nature of monitoring approaches. Ground surveys provide local confirmation and contextual detail but are limited by access and spatial extent. Aerial imagery provides broad coverage and repeatability but limited information on activity status. Integrating these approaches improves efficiency and transparency by reducing reliance on exhaustive ground coverage while retaining ecological interpretation where access is feasible.

Another key lesson is the value of reference systems with higher or better-known animal densities for method validation. Surveys of plains bison and feral horses, conducted in conjunction with existing management counts, provide essential benchmarks for evaluating detection accuracy, annotation error, and model performance. These systems reduce uncertainty before automated methods are applied to rare or sensitive species, lowering technical and reputational risk for industry applications.

Taken together, these lessons indicate that high-resolution aerial imagery can be deployed immediately for habitat monitoring and for tracking landscape-scale ecological features, while automated wildlife counting should proceed through a staged and transparent development pathway. For industry, this approach supports near-term monitoring needs while ensuring that future analytical tools are validated, defensible, and aligned with regulatory and management expectations.

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Reports & Other Publications

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Environmental Research and Monitoring



Boreal Ecosystem Recovery and Assessment — Phase 2

COSIA Project Number: LJ0220

In Situ

Research Provider: University of Calgary

Industry Champion: ConocoPhillips

Industry Collaborators: Cenovus, Canadian Natural, Imperial, Alberta-Pacific Forest Industries Ltd.

Status: Year 5 of 5

PROJECT SUMMARY

The Boreal Ecosystem Recovery and Assessment (BERA) program (www.bera-project.org) is a multi-sectoral partnership of academic researchers and partners from industry, government, and non-government organizations.

The central goal of BERA is to understand ecosystem responses to industrial disturbance, and to develop strategies for restoring disturbed landscapes. BERA's research supports four strategic management goals associated with industrial disturbance:

1. Promoting a return to forest cover
2. Restoring natural carbon dynamics
3. Maintaining wildlife habitat
4. Enhancing woodland caribou habitat

Practitioners involved in boreal restoration are interested in helping maximize effectiveness and efficiency of restoration activities. BERA conducts research on every phase of restoration — planning, implementation, and monitoring — to provide practitioners with the key knowledge, tools, and techniques they need to enhance understanding and improve outcomes of restoration activities.

PROGRESS AND ACHIEVEMENTS

Seismic lines are narrow corridors cleared through forests and other vegetated landscapes to facilitate seismic surveys for subsurface geological exploration. These clearings allow for the placement of seismic sensors (geophones) and charges as well as provide access routes for equipment. Over time, seismic line construction methods have evolved, leading to two primary classifications: (i) legacy seismic lines and (ii) low-impact seismic (LIS) lines. Legacy seismic lines, constructed predominantly from the late 1940s until the late 1990s, are typically 5 m to 10 m wide. Built using heavy machinery like bulldozers, these lines are straight and wide, resulting in significant disturbance to the soil and vegetation. Low-impact seismic (LIS) lines emerged in the mid-1990s as a method to minimize environmental impact.

These lines are narrower, ranging from approximately 1.75 m to 3 m in width, and employ mulchers to remove aboveground vegetation while preserving root structures. The BERA program's 2025 contributions to understanding and mitigating these effects are summarized below.

Songbirds in upland boreal forests respond to the width of linear features

Tharindu Kalukapuge, Department of Biological Sciences, University of Alberta

While the footprint of linear features is extensive, its effects on biodiversity are not yet well-understood. Some species at risk have lower abundance/use along or near linear features, presumably because of edge avoidance (e.g., Canada warbler; *Cardellina canadensis*), or are affected by increased mortality (e.g., woodland caribou; *Rangifer tarandus caribou*) due to higher use and faster movement of predators along and near seismic lines. However, the assumption from studies on focal species that linear features have negative impacts on all aspects of biodiversity is tenuous. The number of species that react in a positive versus negative way and the identity of those species is important to understand from a land use and reclamation perspective.

Songbirds respond differently to the width of linear features in mixedwood and deciduous forests. Many bird species associated with older forests have been observed to decline as lines get wider. For species capable of living in early seral conditions, wider linear features create habitat. The traditional grouping of linear features into vegetated (soft) versus non-vegetated (hard), currently used in regulatory decision making and land use planning, is too coarse to properly track responses by birds to energy sector development and recovery. Results from bird studies suggest linear feature width is an important consideration in restoration prioritization.

Small Mammal Use of Linear Features

Alessandro Franceschini, Department of Biological Sciences, University of Alberta

This study provides the first region-wide evidence that linear feature width, not just presence, directly reduces small mammal use in Alberta's oil sands forests. Forest-associated small mammals showed marked declines in use as feature width increased, with no compensatory increases by open-habitat species. These results give industry partners clear guidance on where to focus restoration and the rationale for minimizing linear feature width where feasible to reduce effects on small mammals.

Baited remote wildlife cameras were deployed at 354 paired sites on seismic lines, pipelines, powerlines, and adjacent forest in the Lower Athabasca region. Sites spanned 3 m to 100 m corridor widths across oil sands leases and nearby Crown land, allowing us to link corridor width to small-mammal use. Across 3 m to 100 m wide seismic, pipeline, and powerline rights-of-way, we found that wider corridors consistently reduce small mammal activity, especially for forest-associated species like red-backed voles and red squirrels. However, expected gains in open-habitat species were not observed. This decline in use by forest-associated species begins at widths typical of legacy seismic lines (5 m to 10 m) and becomes greatest on wide pipelines and powerlines (15 m to 100 m). Conversely, legacy lines that have recovered to narrow, vegetated strips, as well as modern, narrow, low-impact seismic lines, are used more frequently and are less strongly avoided by small mammals.

For operators, these results identify linear feature width as a practical management lever. Keeping new corridors as narrow and vegetated as operationally feasible may reduce impacts, although the trade-off between one wide feature versus two narrower features was not evaluated. Targeting existing pipelines and powerlines for strategic tree and shrub re-establishment or partial narrowing, may deliver the greatest biodiversity benefit per restoration dollar.

Managers are encouraged to prioritize restoration of wide corridors and seismic lines to support small mammals at the landscape scale.

As this is one of the first region-wide tests of width effects across multiple soft linear feature types, this work provides concrete, data-driven guidance that can be incorporated into planning, routing, and reclamation approaches to support biodiversity goals. However, because the study focuses on small mammals in a single region and time window, responses of other wildlife groups, seasons, and future vegetation conditions remain uncertain.

LiDAR-based Seedling Growth Monitoring Along Seismic Lines

Yusif Sitobu Abdullai, Department of Geography, University of Calgary

Characterization of post-disturbance vegetation growth along legacy seismic lines and other linear disturbances is important for forest management. However, peer-reviewed work aimed at mapping vegetation growth on industrial disturbances with airborne LiDAR (light detection and ranging) data is limited. This study demonstrates how multi-temporal LiDAR data used to map conifer seedling growth along seismic lines is influenced by the choice of remote-sensing unit of analysis (pixels or point clouds) and ecosite type (upland or lowland).

BERA researchers compared point cloud- and raster-based approaches to estimate seedling growth in upland and wetland ecosite types in a seven square kilometre study area over a five-year monitoring period. A sample of 194 field-measured seedlings were used to assess the accuracy of various processing techniques. Results showed that point-cloud models produced more accurate estimates of seedling growth than raster models. The point-cloud 60th percentile metric model performed better (RMSE = 25.70 cm, MAE = 15.05 cm) than alternative approaches. Surprisingly, seedling growth in upland sites were more accurately predicted (RMSE = 20.55 cm, MAE = 11.27 cm, MEDAE = 7.03 cm) than seedling growth in lowland sites. Researchers attribute this pattern to the unbalanced effect of data-processing strategies designed to limit the effect of overhanging vegetation on narrow linear features. Processing techniques aimed at solving vegetation-overhang issues in upland sites tended to degrade the quality on growth estimates in lowland sites. As a result, BERA researchers suggest that site-specific processing strategies will likely be required.

Seedling-growth monitoring through multi-temporal remote sensing brings a dynamic component to recovery assessment on industrial disturbances that complements static metrics such as seedling height, density, and coverage. Continued development of LiDAR-processing strategies that permit the reliable measurement of seedling growth over large areas would further benefit this assessment.

Inverted soil mounding increases tree growth but does not expedite initial ecosystem recovery on seismic lines in forested fens

Colleen M. Sutheimer, Department of Renewable Resources, University of Alberta

Federal policy requires that at least 65% of habitat within woodland caribou (*Rangifer tarandus caribou*) ranges be undisturbed to support caribou recovery. In Alberta, reaching that target will require restoring tens of thousands of kilometres of seismic lines through active or passive approaches. As such, adaptive and evidence-based restoration is needed to guide recovery. Research has assessed dominant tree and peatland surface responses to seismic line restoration separately but rarely in combination, contributing to uncertainty about which restoration practices are most beneficial. Structural responses in forested fens were analyzed to identify whether active (inverted soil mounding and tree planting) versus passive (natural regeneration) restoration more effectively promoted ecosystem

recovery on seismic lines, compared with adjacent undisturbed reference fens. Tree density, tree height, low- and tall-woody shrub density, microtopography, and ground cover (forbs, graminoids, bryophytes, and open water and soil) were sampled on seismic lines and adjacent reference fens within three forested fens (one poor, two rich). Active restoration (n = 21; six to eight years post-treatment) and passive restoration (n = 20; 10 to 24 years post-disturbance) were compared with adjacent undisturbed reference fens (n = 41).

Active restoration using inverted soil mounding and tree planting was not found to expedite initial ecological recovery of forested fens relative to passive restoration. However, tree height and density did increase on actively restored seismic lines, particularly in rich fens, where 27% of passively restored seismic lines had no tree regeneration at all. Losses in microtopography and bryophyte cover, and increases in open water and exposed soil, persisted on actively treated seismic lines, whereas passively restored seismic lines had peatland surfaces more like adjacent reference fens. In cases where active restoration does not expedite recovery of multiple ecosystem components, it must minimize resetting existing regeneration. Otherwise, it will impede recovery relative to passive restoration. This work focused on forested peatlands, but more work is needed to compare active and passive restoration for other boreal forest ecosites and assess new active restoration practices.

Mean annual tree ring growth increases with seismic line width and wildfire

Kate E. Stigter, Department of Renewable Resources, University of Alberta

Networks of narrow forest clearings used for exploration of underground oil and gas deposits have fragmented forested boreal peatlands in Western Canada. Seismic lines compact peatland surfaces, delaying tree regeneration.

Wildfire is a dominant driver of vegetation succession and interacts with seismic lines. In forested boreal peatlands, wildfire can promote regeneration, but it can also compound the effects of seismic lines.

While tree density and height responses on seismic lines have been well studied, the radial growth of individual trees – measured as annual changes in stem radius by counting growth rings – has not. This study addressed this knowledge gap by examining 139 cross-sections of regenerating black spruce (*Picea mariana*) and tamarack (*Larix laricina*) from 55 seismic lines in forested peatlands to summarize radial growth. The sample included both unburned seismic lines and seismic lines that burned within 25 years of tree clearing. The study then identified how seismic line width and recent wildfire influenced mean annual ring width of the more common black spruce (mm yr⁻¹).

Mean annual ring width from 2013 to 2017 in black spruce increased by 12% (95% CI 0, 24; p = 0.043) for each one-metre increase in seismic line width and, separately (additive), increased by 42% (95% CI 3, 96; p = 0.031) on lines that had recently burned. Greater radial growth on wider lines after wildfire suggests that growth is most limited by light availability and possibly competition. Seismic lines that are in forested peatlands that are not shaded have substantial capacity to regenerate passively without active restoration following wildfire. Radial growth provides a sensitive and useful metric for assessing regeneration dynamics on seismic lines. Although this study focused on seismic line width and wildfire, effects of soil and hydrological conditions could also be assessed with this approach.

The BERA Framework: a flexible strategy for assessing seismic line recovery over large areas

Gereon Seeberg, Department of Geography, Ludwig-Maximilians-Universität Munich / University of Calgary

The goal of this study is to develop a flexible, remote-sensing-based framework for assessing the recovery status of seismic lines across large areas of boreal forest using objective and repeatable criteria. The resulting framework

supports the production of linear feature inventories and enables consistent planning and monitoring of restoration efforts at landscape scales.

Linear feature restoration is a critical component of woodland caribou (*Rangifer tarandus caribou*) habitat recovery in Western Canada. To support this need, the BERA Framework provides a structured workflow that includes planning, data acquisition, data processing, assessment, and review. The assessment itself involves identifying and delineating seismic lines, subdividing them into short segments, and scoring each segment based on attributes measured relative to either a local or global reference condition. Line attributes are scored on a standardized 0–1 scale and combined into an overall recovery score. Thresholds can be applied within decision-tree logic to classify segments by recovery status, and results are subsequently scaled from segment-level assessments to entire seismic lines.

The framework is intentionally flexible, allowing different data types, line attributes, and reference conditions to be incorporated depending on the objectives of a given assessment. This flexibility is demonstrated through two applications. First, the framework was adapted to implement the establishment survey component of the Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta. Second, a custom holistic assessment was developed using adjacent forest conditions as a reference to support longer-term recovery evaluation. In both cases, airborne LiDAR and optical remote sensing data from a mixedwood boreal region of Alberta were used to derive tree detection layers and height metrics. Depending on the application, attributes including tree abundance, microtopography, human and animal line use, and animal viewsheds were integrated to produce an overall assessment of seismic line recovery status.

Seismic line re-disturbance alters microtopography and hydrology in a boreal rich fen

Xue Yan Chan, Department of Geography, University of Calgary

Seismic lines are widespread in Alberta's peatlands, yet the consequences of reusing these corridors for new seismic programs remain poorly understood. This study explored how repeated disturbance alters peatland microtopography and hydrology — key controls on tree regeneration and carbon processes. Understanding whether reuse slows or redirects natural recovery is essential for guiding restoration decisions and evaluating trade-offs between minimizing new footprint areas and preventing further degradation of recovering sites.

Drone-based LiDAR and two-centimetre optical imagery were used to quantify ground depression, hummock cover, depth-to-water, and surface water across new (2021), old (1996), and redisturbed (1996 + 2021) seismic lines in a boreal rich fen. Disturbance classes were compared against adjacent undisturbed peatland to interpret trajectories of microtopographic and hydrological change. Across all disturbance histories, seismic lines were more depressed, wetter, and had less microtopographic variability than surrounding peatland. While old lines showed partial recovery of microtopography, new lines followed similar initial recovery pathways. However, redisturbed lines were consistently the most altered. Redisturbance removed the recovered microforms and further increased wetness. These patterns indicate that reuse interrupts recovery and can intensify existing degradation. Repeated disturbance can prolong or intensify hydrological alteration, further limiting tree regeneration and potentially influencing carbon dynamics.

High-resolution Remotely Piloted Aircraft System (RPAS) datasets offer a practical tool to identify where reuse may exacerbate conditions, support pre-treatment planning, and prioritize restoration actions on lines with elevated wetness or flattened microtopography. This study is based on a single fen and three disturbance histories, so its applicability to other peatland types, conditions, and equipment remains uncertain.

Seismic lines increase non-native plant infiltration along roads in the oil sands region

Leonardo Viliani, PhD, Department of Renewable Resources, University of Alberta

In western Canada's boreal forest, seismic lines are a major source of habitat fragmentation. In some cases, these linear clearings intersect or overlap with other disturbances, such as wildfires and roads. A key question is how overlapping disturbances combine to shape ecological processes of conservation concern, particularly the infiltration of non-native plant species into native boreal ecosystems.

This project examined how the spatial co-occurrence of seismic lines and wildfires influences the establishment of non-native plants along roads, thereby altering ecosystem vulnerability to invasion. Differences in the ratio of non-native to native plant cover were tested between burned and unburned mesic upland boreal forests, and on and off seismic lines, at increasing distances from seven different roads. At each site, a pair of 40-m parallel transects was established running perpendicular to the road (one on a seismic line and one 50 m into the adjacent forest). Because the influence of distance was expected to decline non-linearly, distances from the roadside edge were transformed using the natural logarithm.

Seismic lines and roads were found to synergistically increase non-native cover, although distance from the roadside edge acted as an antagonistic limit to further infiltration into the forest. Although the open habitats created by seismic lines facilitate the establishment of non-native plants, native species are well adapted to the boreal forest's intense fire regimes. As a result, post-fire vegetation showed comparable cover of native and non-native species. Interestingly, the results reveal a synergistic composite effect between fire and seismic lines, with increases in non-native plant cover near roads. This effect is countered by an antagonistic effect of the distance from roadside edge, which limits their infiltration further into the forest. As natural and anthropogenic disturbances in the boreal forest increase due to human activities, these findings emphasize the need to consider the importance of wildfires in mitigating the effects of seismic lines on native plant communities. Although the study findings reveal a clear interactive effect of seismic lines and wildfires, it does not account for the additional complexity that may arise when these footprints intersect with other disturbances at different scales.

Early succession across boreal forest transitions depends on successive disturbances

Colleen M. Sutheimer, Department of Renewable Resources, University of Alberta

Transitional forests occur within steep gradients of topography and productivity between upland and peatland forests margins. Transitional boreal forests account for nearly 9% of all wetlands in boreal North America and provide valuable structure and function in boreal landscapes, slowing water flow into adjacent forests during seasonal flooding and providing habitat for wildlife. Although transitional boreal forests do not accumulate substantial amounts of peat, they do support carbon accumulation. Across western North American boreal forests, there is a paucity of data on early succession in transitional boreal forests and, more generally, a gap in knowledge regarding early succession following multiple successive disturbances. This study addressed this gap by examining early succession across boreal forest transitions after seismic line and recent (< 25 years) wildfire disturbances.

Researchers measured densities and characterized the composition of regenerating (< 1.3 m tall or < 1 cm diameter at 1.3 m) and recruiting ($\geq$ 1.3 m tall or $\geq$ 1 cm diameter at 1.3 m) trees and tall woody shrubs on unburned and recently burned seismic lines across boreal forest transitions (upland, transitional, and peatland forests). Generalized linear mixed modeling and multi-model inference approaches were used to characterize regenerating and recruiting trees and tall shrubs. The study also sought to identify the relative effects of disturbance from both individual and successive disturbances.

In mesic upland forests, wildfire promotes regeneration and recruitment, as expected, facilitating early-successional forest recovery. However, the forest recovery in transitional and peatland forests was more complex. Wildfire promoted regeneration on seismic lines in these ecosites but did not consistently increase recruitment, suggesting that they are arrested in succession. The persistence of early successional species (trembling aspen and jack pine) in these transitional and peatland forests, combined with limited recruitment of late-successional species like black spruce, suggests that disturbances are resulting in shifts in tree species composition. While progression through early successional stages was observed 10 to 24 years after seismic lines were cut or burned (regeneration and recruitment), it remains unknown whether these forests will progress into later successional stages (early and mature forest development).

The Influence of subsurface and microtopographic soil properties on seedling regeneration on treated and untreated seismic lines

Sophia Kanthak, Department of Geography, Ludwig-Maximilians-Universität Munich / University of Calgary

The first objective of this project was to identify subsurface factors influencing seedling regeneration on treated and untreated seismic lines. While previous research has demonstrated that mounding can alter soil properties in wetlands, comprehensive research on the peat properties of seismic lines remains limited. To address this gap, this project continued Sean Hillson's earlier work (Assessing the pedological impact of inverted soil mounding techniques on wetland ecosystems in Northeastern Alberta) by adding the carbon to nitrogen (C:N) ratio of the LiDea (LiDAR and Ecosystem Assessment) Pilot 2023 samples to the analysis.

In addition, this project explored a remote sensing approach to measuring microtopography from drone data and incorporated it into the analysis. In the second objective, the effects of vegetation, microtopography and soil properties on seedling abundance and growth were tested to identify the most influential variables on recovery. The data were collected at the LiDea I study site.

The results show that microtopography was the metric most strongly associated with the presence or absence of tree seedlings, but vegetation still shaped seedling counts. However, even though soil mounding facilitates recovery, it also substantially changes soil physical and chemical properties, increasing bulk density and decreasing organic matter content and the C:N ratio. The results suggest that inverted soil mounding can improve forest regeneration by creating an environment with higher distance to the water table and more microtopographic variability, as well as changes in physicochemical properties of soils; however, these properties differ from natural soil conditions. While mounding aims to recreate natural microforms, its influence on vegetation composition and physical and chemical soil properties should be carefully considered when choosing the appropriate treatment method for a site. This research only encompasses a single study site and may not be representative of other regions.

LESSONS LEARNED

1. Linear feature width is a primary and actionable driver of ecological response for birds and small mammals

Results from songbird and small mammal studies demonstrate that corridor width consistently explains variation in habitat use and community composition more effectively than the simple presence or absence of linear features. Forest-associated small mammals showed marked declines in use as feature width increased, with no compensatory increases by open-habitat species, while songbird communities in upland boreal forests responded systematically to corridor width.

These effects begin at widths typical of legacy seismic lines and intensify on wide pipelines and powerlines, indicating that width is a defensible and practical metric for evaluating ecological effects and recovery potential.

2. Passive recovery can be effective. Inverted mounding and planting can increase tree growth and density but does not necessarily accelerate ecosystem recovery

Evidence from forested peatland studies shows that inverted mounding and planting increased tree height and density but did not necessarily expedite recovery of other ecosystem components, including microtopography and bryophyte cover, relative to passive regeneration. In some cases, active treatments reset existing regeneration or surface structure, resulting in recovery trajectories that lagged untreated lines. In other cases, especially in fens, tree responses to mounding are positive. Together, these results indicate that passive recovery can be a viable pathway under certain site conditions and that active restoration treatments should be designed to provide a predictable incremental benefit over passive recovery processes.

3. Recovery trajectories are strongly shaped by disturbance interactions, and re-disturbance can intensify or prolong degradation.

Across peatland and transitional forest studies, recovery outcomes vary depending on the interaction between seismic lines, wildfire, and redisturbance. Redisturbed seismic lines consistently exhibited greater ground depression, increased wetness, and loss of previously recovered microforms, demonstrating that reuse interrupts recovery trajectories and can exacerbate hydrological constraints on regeneration. Wildfire increased radial growth (measured as the width of tree rings) of regenerating black spruce and moderated non-native plant infiltration away from roads, but it also contributed to arrested succession and shifts in species composition in transitional and peatland forests. These results show that recovery outcomes cannot be inferred from individual disturbances alone and must be interpreted in the context of overlapping disturbance histories.

4. Remote sensing enables objective, scalable assessment of recovery status, supporting consistent evaluation at landscape scales.

LiDAR and high-resolution optical analyses, combined with deep-learning-based processing, enable landscape-scale assessment of seismic line regeneration and quantification of key microtopographic, hydrological, and woody vegetation growth conditions. This permits managers and regulators to distinguish areas of minimal, moderate, and high recovery accurately and efficiently over large areas. Results from seedling-detection and growth-monitoring studies show that method performance is strongly controlled by data characteristics. High-resolution RGB (red, green and blue) imagery outperforms coarser multispectral data for detecting small black spruce and tamarack seedlings, whereas point-cloud-based LiDAR approaches outperform raster methods for quantifying woody growth. Where spatial resolution is held constant, additional spectral bands provide modest, context-dependent accuracy gains in seedling-detection applications. LiDAR fusion adds limited benefit for seedling detection but supports growth mapping and structural characterization. The BERA Framework – an emerging approach to seismic-line recovery assessment – demonstrates that these remote-sensing outputs can be integrated into standardized, segment-based scoring and aggregated through decision-tree logic to assess entire seismic lines while retaining spatial detail. Together, these results show that remote sensing provides a defensible foundation for repeatable inventories, monitoring, and comparison of recovery progress aligned with caribou habitat-recovery objectives.

PRESENTATIONS AND PUBLICATIONS

Published Theses

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Byford, N. 2026. High-Resolution Remote Sensing and Deep Learning for Assessing Tree Regeneration on Boreal Disturbances. Master's thesis, University of Calgary.

Chan, X. 2026. RPAS-Based Mapping of Peatland Microtopography and Hydrology: A Case Study of Repeated Seismic Line Disturbance in Northern Alberta. Master's thesis, University of Calgary.

Wiemer, F. F. L. 2025. Mapping Microtopography to Predict Vegetation Recovery on Seismic Lines Using Drone-Based Remote Sensing and Machine Learning. M. Sc. Thesis. Ludwigs-Maximilian Universitaet, Munich, Germany.

Yeomans, T. M. 2025. Troubling the pixel. Master's thesis, University of Calgary, Calgary, Canada.

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Franceschini A., Martinez-Lanfranco, J. A, and E. Bayne. 2025. The influence of linear feature width on small mammal communities in northeastern Alberta. *Canadian Journal of Zoology* 103: 1-14. <https://doi.org/10.1139/cjz-2025-0078>

McDermid, G. J., I. Terenteva, and X. Y. Chan. 2025. Mapping Trails and Tracks in the Boreal Forest Using LiDAR and Convolutional Neural Networks. *Remote Sensing* 17 (9), 1539. <https://www.mdpi.com/2072-4292/17/9/1539>

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Viliani, L. and S. E. Nielsen. 2025. Composite effects of forest harvests and seismic lines influence re-establishment of trees and shrubs in Alberta's mesic upland boreal forest. *Forest Ecology and Management*. Volume 580, 15 March 2025, 122506. <https://doi.org/10.1016/j.foreco.2025.122506>

Conference Presentations/Posters

Bayatvarkeshi, M., Strack, M., Ketcheson, S., Dickie, M., and Serrouya, R. 2025. How do seismic line disturbances affect snow accumulation in boreal forests? CGU, Saskatoon, Saskatchewan, May 25-29.

Bayatvarkeshi, M., Strack, M., and Ketcheson, S. 2025. How do seismic line disturbances affect snow accumulation in boreal forests? Peatland Science Symposium and Can-Peat Annual Meeting. Feb 18-22. Kananaskis, Alberta.

Franceschini, A., Bayne, E. 2025. The influence of linear feature width on small mammal communities in northeastern Alberta. Alberta Society of Professional Biologist Conference, Banff, AB. November 27.

Linke, J., Fong, M., McDermid, G., Strack, M., Bayne, E., Ketcheson, S., Sutheimer, C., Davies, M., Terentieva, I., Dickie, M. and S. Nielsen. 2025. Geospatial Tools for Seismic-line Restoration Planning: Cost Projections and Restoration Targets. 46th Canadian Remote Sensing Society Conference, Lethbridge, AB, Canada, June 17, 2025.

McDermid, G. J., Sutheimer, C. M., Leston, L. Restoration in Focus: Emerging Knowledge, Tools, and Technologies in boreal restoration. Alberta Society of Professional Biologists Conference and Annual General Meetings, Banff, AB. November 26

Kalukapuge, T., C. M. Godwin, K. R. Foster, J. F. Saracco, L. Leston and E. Bayne. Energy sector footprints reorganize bird communities across space and time in the boreal forest of Alberta, Canada. Alberta Society of Professional Biologist Conference, Banff, AB. November 27.

Pour, M. J., M. M. Rahman, J. Simms, Q. Y. Zeng, J. Linke, and G. J. McDermid. Operationalizing seismic line delineation at scale: a comparison of machine learning approaches. 46th Canadian Symposium on Remote Sensing. Lethbridge, Alberta.

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Saini, A., Dharni, B., Leston, L., Bayne, E. 2025. Factors influencing the probability of linear feature damage by off-highway vehicle activity in northeastern Alberta. Alberta Society of Professional Biologist Conference, Banff, AB. November 27.

Shellian, C. A., Terentieva, I., Fong, K., Linke, J., McDermid, G. J. 2025. Evaluating drivers of tree restoration success on restored seismic lines using geospatial and field data. Alberta Society of Professional Biologists 2025 Conference, Banff, AB. November 27

Sutheimer, C. M., Nielsen, S. E. 2025. From prioritization to practice: Restoring fragmented boreal forests within woodland caribou habitat. Alberta Society of Professional Biologists Conference and Annual General Meetings, Banff, AB. November 25

Sutheimer, C. M., Nielsen, S. E. 2025. Do active restoration treatments promote initial ecosystem recovery on seismic lines in boreal forested fens? Alberta Society of Professional Biologists Conference and Annual General Meetings, Banff, AB. November 25

Sutheimer, C. M., Nielsen, S.E. 2025. Restoring forested peatlands: Is active restoration expediting the recovery of boreal woodland caribou habitat? Faculty of Agricultural, Life, and Environmental Sciences Graduate Research Conference, Edmonton, AB. April 1

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Terenteva, I., N. Byford, and G. J. McDermid. Geospatial tools for seismic line restoration deep learning-based seedling detection. 46th Canadian Symposium on Remote Sensing. Lethbridge, Alberta.

Viliani, L., Nielsen, S. E. 2025. Composite effects of forest harvests and seismic lines influence reestablishment of trees and shrubs in Alberta's mesic upland boreal forest. Alberta Society of Professional Biologists Conference and Annual General Meetings, Banff, AB. November 25

Viliani, L., Sutheimer, C. M., & Nielsen, S. E. 2025. Identifying restoration priorities for habitat defragmentation: a case study in Alberta's oil sands. International Association of Landscape Ecology - North America Conference and Annual Meeting, Raleigh, NC, USA. April 14.

Quayle, S., Nielsen, S. E. 2025. Linear disturbances & browse subsidy. Alberta Society of Professional Biologists Conference and Annual General Meetings, Banff, AB. November 25

RESEARCH TEAM AND COLLABORATORS

Institution: University of Calgary

Principal Investigator: Dr. Greg McDermid

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Erin Bayne	University of Alberta	Professor		
Maria Strack	University of Waterloo	Professor		
Scott Ketcheson	Athabasca University	Associate Professor		
Julia Linke	University of Calgary	Science Coordinator		
Richard Zeng	University of Calgary	Geospatial Technician		
Maverick Fong	University of Calgary	Geospatial Technician		
Claudia Maurer	University of Calgary	Admin. Coordinator		
Jiaao Guo	University of Calgary/ABMI	Research Coordinator		
Irina Terenteva	University of Calgary	Post-Doctoral Fellow		
Colette Shellian	University of Calgary	PhD Student	2020	2027
Tanya Yeomans	University of Calgary	MSc Student	2021	2025
Xue Yan Chan	University of Calgary	MSc Student	2022	2025
Nicole Byford	University of Calgary	MSc Student	2022	2025
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Jesse Tigner	Swamp Donkey Solutions	Ecologist		
Ellie Goud	St. Mary's University	Assistant Professor		
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Diana Stralberg	Canadian Forest Service	Research Scientist		
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Anna Dabros	Canadian Forest Service	Research Scientist		
Guillermo Castilla	Canadian Forest Service	Research Scientist		
Ralf Ludwig	Ludwigs-Maximilian University	Professor		

2025 COSIA Land Environmental Priority Area Symposium

COSIA Project Number: LE0100

In Situ and Mine

Symposium Facilitator: Enviro Q&A Services

Industry Champion: Imperial

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

Status: Complete

PROJECT SUMMARY

On December 3, 2025, Canada's Oil Sands Innovation Alliance's (COSIA) Land Environmental Priority Area (EPA) held a one-day symposium in Calgary to share key research with 60 participants, including industry members, researchers and regulators.

The goal of the symposium was to showcase in situ and mine environmental and reclamation research projects completed within the last five years in the Land EPA, and to create a forum for technical discussions and interactions among specialists from different sectors. More specifically, the Symposium provided an opportunity to bring interested parties together to review project outcomes, discuss findings and strengthen relationships. Additionally, non-COSIA participants expressed a desire to better understand how Land EPA research projects align with their own processes and how the research presented relates to other public events they have attended, including field tours and presentations in other forums.

PROGRESS AND ACHIEVEMENTS

The symposium consisted of six research presentations spanning mining and in-situ projects, with topics including vegetation, soils, wetlands, and wildlife. An additional presentation provided insights into knowledge exchange tools that COSIA Land EPA is testing or could use to maximize the value of Land EPA research.

Traditional research presentations tend to focus on the what and how, whereas industry and regulators need to understand the why and the practical implications. Accordingly, presentations for this audience should place less emphasis on how the work was completed and more emphasis on why it was done and how the resulting knowledge can be applied. To ensure these perspectives were addressed, an industry representative was assigned as a co-presenter.

In addition to the presentations, experienced industry members, consultants and researchers participated in two panel discussions that addressed the following themes:

- 1) Selecting optimum vegetation treatments and revegetation methods; and
- 2) Applying monitoring data and tools.

During these sessions, panelists discussed questions from the moderator, as well as questions emerging from the audience related to each theme.

LESSONS LEARNED

The 2025 COSIA Land Symposium was a great opportunity to share knowledge gained from research projects on key topics addressed within the Land EPA. It also encouraged reflection on why these research studies are conducted and how the lessons learned from these projects are implemented in the field.

Overall, the one-day symposium helped to create awareness of some of the work being done by the Land EPA to advance environmental and reclamation-related topics in the oil sands, and it generated thoughtful discussions among participants during the presentations and panel discussions.

SYMPOSIUM FACILITATORS AND SPEAKERS

Facilitators: Chris Powter (Enviro Q&A Services)

Planning Team: Robert Albricht (ConocoPhillips), Carolina Berdugo-Clavijo (Imperial), Jack O'Neill (Oil Sands Alliance), and Lindsay Clothier (Oil Sands Alliance).

List of Speakers:

Name	Institution or Company	Presenter	Discussion Panelist
Bin Xu	NAIT Center for Boreal Research	X	
James Agate	Canadian Natural		
Lori Neufeld	Imperial	X	X
Virgil Hawkes	LGL Limited environmental research associates	X	X
Joanne Hogg	Canadian Natural	X	
Eric Girard	Suncor		X
Michael Cody	Cenovus		X
Amanda Schoonmaker	NAIT Centre for Boreal Research	X	X
Samantha Tavener	Owl Moon Environmental Inc.	X	
Robert Albricht	ConocoPhillips	X	X
Brittany Flemming	Montrose Environmental	X	
Carolina Berdugo-Clavijo	Imperial	X	
Jon Hornung	Suncor		X
Carla Wytrykush	Suncor		X
Matthew Pyper	Fuse Consulting	X	

Restoration Lessons and Future Guidance

COSIA Project Number: LE0096

Research Provider: Fuse Consulting

Workshop Leader: Cenovus

Status: Year 1 of 1

PROJECT SUMMARY

COSIA has identified a critical gap in knowledge transfer and technology adoption among practitioners involved in COSIA projects and innovation, including in the practice of habitat restoration.

In November 2025, COSIA hosted a restoration workshop with the objective of advancing caribou habitat restoration in Alberta by bringing together field workers, operators, consultants, managers, policy makers, and researchers to discuss and share knowledge. This workshop was intentionally designed to focus on practitioners with direct, on-the-ground experience in caribou habitat restoration. Attendees learned through the sharing of experiences, successes, and failures in restoration.

Specific workshop objectives included learning from each other, alignment around common goals, and open discussion and brainstorming to inform future improvements.

PROGRESS AND ACHIEVEMENTS

Workshop feedback from participants indicates that the knowledge extension exercise was highly successful.

Participants had the opportunity to engage extensively through small-group sessions. Keynote addresses set the stage, and discussions were periodically summarized throughout the two-day event.

LESSONS LEARNED

Ultimately, the need for well-defined problem statements to guide habitat restoration was emphasized, as perspectives and associated evidence were tested for alignment with the problem. For example, in many cases, reclamation practices satisfy aesthetic outcomes and recreate soil-plant systems, but clear evidence for alignment under restoration requirements for linear features in caribou habitat was limited.

Participants were challenged to devise prescriptions for sites with marginal vegetation recovery and diverse edaphic conditions. These exercises underlined the need for continual evidence-based improvement in caribou habitat restoration, and highlight a substantial need for increased capacity across the restoration community of practice, or “ecosystem,” at all levels of involvement.

Equipment



Restoration Equipment Modernization

COSIA Project Number: LJ0345

In Situ

Research Providers: Fuse, Falcon & Swift

Industry Champion: Cenovus

Status: Final Cumulative Summary

PROJECT SUMMARY

Petroleum exploration and delineation in Western Canada result in a pattern of forest disturbance across time and space that have no historical analogue. These disturbances frequently create novel ecosites in which soil-plant systems are fundamentally altered. Specifically, following these types of disturbances, vegetation regeneration may not occur at a pace, or with structural characteristics, similar to historical patterns. Ecological responses to these novel patterns of disturbance include increased predation rates on, and population decline of, woodland caribou. Determining when active interventions (e.g., habitat restoration treatments) are warranted, and how to apply them, is a fundamental question facing the resource industry in Alberta.

The restoration of legacy exploration disturbances represents a substantial conservation challenge and liability, as hundreds of thousands of kilometres of linear features may require restoration. Existing treatment methods are costly and extremely time-consuming, and current inventory and assessment systems rely on manual/visual assessment mobilized by helicopter.

Over the past 10 years, Cenovus has carried out a program of technical innovation focused on improving habitat restoration treatment technologies, which has included:

- Development of prime mover (heavy equipment) technology capable of working on peatlands (muskeg) in non-frozen conditions
- Testing of drawn site-preparation implements, specifically the Bracke™ three-row moulder
- Testing of beyond visual line of site (BVLOS) remotely piloted aircraft systems (RPAS)
- Testing of machine learning for analysis of remote sensing data

A test and fail-fast philosophy was employed to eliminate ineffective technologies.

Tools that demonstrated effectiveness in addressing site limiting factors were retained and tested further. Promising initial performance of the Bracke™ moulder prompted the innovation of an amphibious Bracke, which emerged as a strong performer by significantly enhancing operational efficiency while maintaining ecological efficacy.

The Bracke™ was found to accelerate mechanical treatment speeds by a factor of 10 while maintaining high microsite persistence and quality.

More recently, Cenovus's objective was to test the first use of a BVLOS RPAS for restoration monitoring. In addition to speed and safety advantages, RPAS assessment systems have the potential to conduct a full census, as opposed to sampling, of ecological responses. Specifically, it is proposed that a census of conifer regeneration is possible.

PROGRESS AND ACHIEVEMENTS

Using the RPAS-based data, Cenovus completed a successful restoration establishment assessment of restoration treatments (established 2013-2015) according to the Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta (2017).

It was demonstrated that reliable restoration establishment surveys can be completed using remote (RPAS) technology and machine learning.

Establishment surveys have yet to be conducted manually in Alberta under any other initiative, so direct comparison to a manual approach isn't possible. However, it is estimated that remote/machine-learning systems will be more accurate by virtue of being a census as opposed to a sample, and much faster, cheaper and safer than manual approaches.

LESSONS LEARNED

Overall, the key lesson from this work to date is the importance of incorporating knowledge extension and technology transfer into technical innovation and commercialization.

In Alberta, government policy decisions to control and administer habitat restoration treatments has limited the number of new suppliers and alternative treatment approaches. For example, Alberta still conducts restoration in a winter-only model, despite significant evidence for improved technologies. This suggests that additional effort in knowledge extension and technology transfer might help to mitigate the current lack of adoption.

LITERATURE CITED

Alberta Environment (2017) Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta. Unpublished.

PRESENTATIONS AND PUBLICATIONS

Reports & Other Publications

EMISSIONS REDUCTION ALBERTA (ERA) 2024. Linear Restoration Equipment Modernization and Deployment. NON-CONFIDENTIAL FINAL OUTCOMES REPORT (FOR) Prepared by: Rachel Tiessen, Sonya Odsen, Matthew Pyper, Jesse Tigner and Jason Barrie. https://www.eralberta.ca/wp-content/uploads/2025/05/Cenovus_ERATrial_NonConfidentialFinalReport_Final.pdf

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