

CLEAN RESOURCES FINAL PUBLIC REPORT TEMPLATE

1. PROJECT INFORMATION:

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AI Project Advisor:	Dallas Johnson

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3. PROJECT PARTNERS

The project was jointly funded by OptiSeis, Alberta Innovates, CRIN, NRC-IRAP, Canadian Natural Resources Ltd., Cenovus Energy, ConocoPhillips, Imperial Oil Resources Ltd., and Suncor Energy with datasets donated by several of the companies.

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A. EXECUTIVE SUMMARY

OptiSeis Solutions Ltd., a subsurface visualization and analytics company, is the Canadian developer of the EcoSeis™ an OptiSeis trademarked product technology. EcoSeis is the Company's proprietary exploration footprint reduction design and analytics technology that allows operators to focus on their subsurface targets while reducing the environmental footprint including GHG and surface impacts. EcoSeis enables companies to accomplish their goal of providing environmentally sustainable and reliable energy for generations to come.

The focus of this project was to advance the EcoSeis methodology and software implementation. EcoSeis is an innovative land footprint reduction technology that allows any company with subsurface operations, including oil and gas operators, to sustainably acquire high resolution seismic images of their resources. The technology is a first of its kind collaboration that successfully brings environmental conservation and GHG accounting practices into the design and execution of data collection in the field. EcoSeis utilizes proprietary algorithms to rank biological, ecological, and geographical surface information to automatically guide the creation of custom survey designs.

Field acquisition of subsurface data is often conducted in remote areas with varying terrain and habitat types. Historically, seismic exploration in forested regions has required the clearing of cutlines for safe access and equipment deployment resulting in numerous interconnected pathways, traditionally creating an extensive network of crossing orthogonal access lines. Decades of ecological research has uncovered the impact this work has on revegetation as well as the challenges it poses to sensitive species and habitats. Innovative land stewardship combined with recording equipment miniaturization was the spark that drove OptiSeis to envision and create EcoSeis, which can reduce the total amount of seismic line clearing by more than 50%.

The EcoSeis methodology, which reduces the total amount of line clearing within a seismic program by up to 50%, results in reduced land footprint and GHG/methane emissions associated with the burning of fossil fuels and emitted from peatlands compacted by machinery. This is accomplished by utilizing irregular and alternative geometries that minimize the amount of line clearing all while maintaining subsurface data quality and reducing costs. Additionally, EcoSeis has the potential to reduce seismic data acquisition costs by 10-25%. This methodology was initially developed during the successful EcoSeis Phase 1 project. The EcoSeis Phase 2 project provided an opportunity to test the technology in conjunction with a conventional seismic program in order to fully quantify the benefits of EcoSeis and complete the technology validation process. A key issue for the adoption of new technologies and processes is proving that the approach provides equal to or greater information while being cost competitive. The challenge is that the process of proving of the technology requires direct comparison to results from the traditional approach, thus significantly increasing the cost during the testing.

Activities performed during the project included a full-scale technical field comparison, which involved environmental studies, seismic acquisition of 2D, 3D, and 4D datasets, and statistical tracking of all field equipment, followed by analysis of the results through seismic data processing, quantitative interpretation, and statistical analysis to determine land footprint and GHG emissions reductions. The purpose of the project was to demonstrate that EcoSeis provides equal to or superior subsurface

information while enabling the environmental footprint including surface disturbance in comparison to standard practice while meeting industry standards for safety thereby advancing towards commercial acceptance of the process. The project results include: 1) a technically proven method to reduce both the land footprint and the emissions associated with seismic acquisition without compromising subsurface data quality, (2) the generation of high-quality datasets for additional environmental studies, and (3) job creation & retention.

The benefits to the oil and gas industry include acquiring cost-effective, high-quality subsurface data needed for business-critical decisions while reducing the environmental impact and ensuring workforce safety standards during field operations. These benefits can accrue to any company with subsurface operations including critical mineral mining, geothermal well placement, and in the nascent carbon capture & storage sector, where it can be utilized for more cost-effective monitoring. By using EcoSeis to acquire seismic with reduced GHG emissions and less land footprint, Canadian O&G operations can become lower carbon from the very beginning of the exploration cycle meeting their GHG emissions reduction goals.

EcoSeis benefits Canada by enabling ethical and sustainable resource development in all sectors that require accurate subsurface imaging. The EcoSeis software and processes provide an opportunity for highly skilled environmental and geo scientists to work collaboratively in collecting and analyzing data for ecological development of resources. Additionally, the data collected during the project will provide opportunities for further research in the fields of geophysics, environmental science, and data analytics.

B. INTRODUCTION

Sector Introduction

The initial focus market for the technology is Oil & Gas Exploration and Production companies in Alberta that have seismic programs in the Oil Sands Region (OSR). Seismic exploration for oil and gas in the Canadian boreal forest requires the clearing of trees along seismic lines to provide safe access for equipment deployment. The resulting footprint can result in cutting 10-25% of the total program area depending on the distribution pattern of the seismic cutlines (Larson, 2020). Seismic line clearing is typically done in an orthogonal pattern generating interconnected pathways, increasing forest fragmentation which negatively affects sensitive species. These benefits accrue to any party requiring subsurface analytics including critical mineral mining, geothermal, and the nascent carbon capture & storage sector.

The initial driver for the technology included proposed changes to seismic regulations for new seismic cutlines in Alberta, including reducing line of sight to less than 100m and decreasing receiver line width to 0.75m after 2024 (draft Cold Lake Sub-Regional Plan). Additionally, there is a push to reclaim existing seismic lines with industry actively testing various reclamation methods. These efforts are costly, so industry is also pursuing methods to minimize the footprint of seismic data acquisition activities, which, as a result, would reduce the reclamation effort that may be required in future for new seismic programs.

Seismic data acquisition activity can also result in soil compaction and a higher water table, leading to elevated methane emissions (Strack et al. 2019, Feng et al. 2020). GHG emissions are also associated with seismic acquisition such as instantaneous fossil fuel emissions that occur during field operations (a single seismic program may use more than 100 litres of diesel per linear km of seismic line). The oil and gas industry has expressed interest in any seismic technology that can reduce both the environmental impact and the cost of acquiring good quality seismic data (COSIA Challenge, 2017). This is of particular importance in areas that would be impacted by the potential changes to seismic regulations as new technologies that meet the requirements would enable access to assets in sensitive areas that would otherwise be stranded. Many cleantech challenges have been initiated by industry to solve these problems, including the 2017 COSIA Land Challenge, the 2020 Imperial Challenge – CleanTech Alliance, and the 2021 COSIA-Foresight-Alberta Innovates Reducing Seismic Exploration Footprint challenge, in which EcoSeis won second place.

The proposed regulatory changes and the need to reduce seismic acquisition land footprint requires a new approach to acquiring seismic data, which has created opportunities for development of new seismic acquisition technologies. Some of the solutions that have been proposed to address these problems include minimizing cutting by flying equipment in with a helicopter, utilizing alternative sampling theorems to reduce the amount of equipment needed, and miniaturizing seismic equipment (energy sources and/or receivers). Individually, these solutions can provide benefits such as reduced line widths and less overall cutting of the boreal forest, but habitat fragmentation due to interconnected seismic lines remains a problem and the total reduction in cutting is often less than 25%.

Knowledge/Technology Gaps

A key issue for the adoption of new technologies and processes is proving that the approach provides equal to or greater information while being cost competitive. The problems associated with alternative approaches include subsurface information being insufficient resulting in perceived risk and/or the approach adding significant execution cost or risk. Additionally, the process of proving a new technology requires direct comparison to results from the traditional approach, thus significantly increasing the cost during the testing.

To solve these problems, the project involved environmental studies to accurately measure the re-growth on seismic lines in various types of habitats where seismic data is acquired, geophysical studies examining the imaging accuracy of various alternative seismic geometries, and the joint acquisition of both conventional seismic datasets utilizing traditional geometries and equipment and new geometries and alternative, miniaturized equipment.

C. PROJECT DESCRIPTION

Knowledge/Technology Description

EcoSeis™ is an innovative technology that allows resource developers (e.g., oil and gas, carbon capture & storage, critical minerals) to sustainably acquire high-resolution seismic images of their resources by utilizing proprietary algorithms that incorporate biological, ecological, and geographical surface information to automate the creation of custom survey designs for optimal subsurface imaging and efficient field operations. The technology brings environmental conservation and GHG accounting into the design and execution of data collection in the field. Originally developed for remote areas with varying terrain and habitat types where historic seismic exploration has required the clearing of cutlines for safe access and equipment deployment, the technology is equally applicable in areas with other sensitive habitats (grasslands, wetlands) or in open areas (farmland, tundra, deserts) where its operational efficiency and improved imaging capabilities provide significant advantages over conventional methods.

EcoSeis enables a significant reduction in land footprint and GHG emissions associated with acquiring subsurface images while maintaining or improving subsurface data quality. EcoSeis' high-resolution imaging and analysis enables safe and efficient field operations which can lead to increased customer revenue from subsurface operations as well as the potential to reduce operating costs. EcoSeis' proprietary algorithms enable placement of seismic sources and receivers on the same line as opposed to separate lines as with traditional seismic, without any reduction in subsurface data quality (Figure 1). It is noted that the reduction in footprint has significant long-term environmental benefits related to reducing methane release from land disturbance as well as impact on wildlife habitats. By reducing the number of cutlines and adjusting deployment methods, EcoSeis can reduce the surface impact and associated emissions by up to 50% in comparison to traditional seismic approaches.

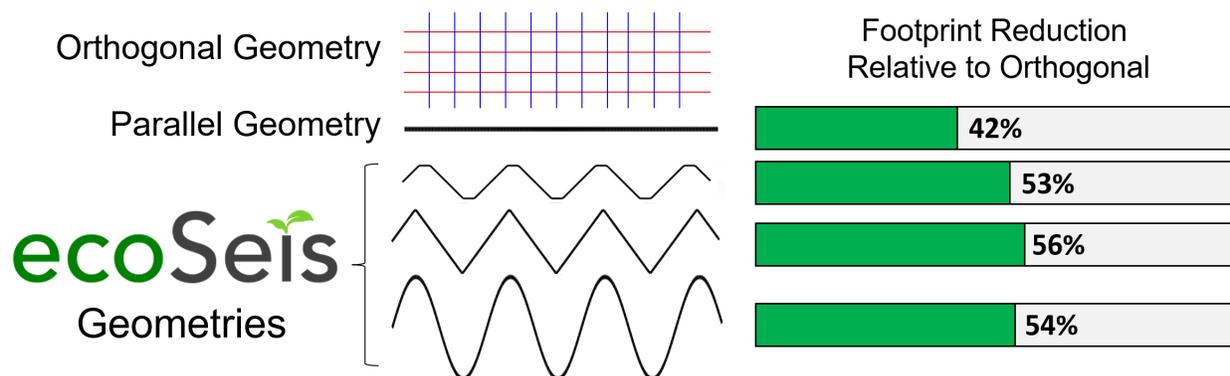


Figure 1: Conventional Orthogonal geometries have grids of source (red) and receiver (blue) lines. Parallel and EcoSeis geometries have sources and receivers on the same lines, but EcoSeis also utilizes unique distributions of the lines and the stations on the lines to achieve better subsurface resolution. Note that actual percentages will depend on the line intervals selected and the equipment type chosen.

Project Objectives & Updates

The key goals of the project were:

- (1) To complete technical validation of the EcoSeis methodology through a field trial that compared an EcoSeis seismic program with a conventional 3D seismic acquisition program. Validation methods included processing, interpretation, and inversion analyses.
- (2) Quantify the reduction in land footprint and GHG emissions achieved with EcoSeis, and
- (3) Implement the solution in OptiSeis' proprietary software.

As a result of the site selected for the field trial, 4D timelapse analysis was also performed, which provided an opportunity to gain valuable insights into sparse 4D repeat surveys. Results from the test may enable more cost-effective timelapse (4D) seismic surveys for Carbon Capture and Storage (CCS) sites, where verifying the conformance and containment of the CO₂ forms a critical part of measurement, monitoring, and verification (MMV) programs.

Performance Metrics

The original project success metrics included a 35% or greater reduction in seismic linear disturbances and 20% or greater reduction in areal disturbances, and a 15% or greater reduction in GHG emissions associated with seismic acquisition. However, the project significantly exceeded this by demonstrating that land footprint and GHG emissions reductions of up to 50% are possible utilizing the EcoSeis technology.

D. METHODOLOGY

The primary objective of the project was to complete a real-world, technical field trial of the technology. This involved acquisition of the two seismic datasets along with seismic processing, interpretation, inversion, environmental, and statistical analyses.

The project was divided into two milestones with the first focused on preliminary studies and field operations, and the second focused on data processing and analytics. Within each milestone, work was divided into four categories: Geophysics, Environment/Field Operations, Data Analytics, and Software. The following narrative describes the work completed for each milestone within these categories along with the results.

Milestone 1: February 2022 – March 2023

The primary objective of Milestone 1 was to acquire both an EcoSeis and a conventional 3D orthogonal seismic dataset in the winter of 2022-23. This involved preliminary geophysical and environmental studies, operational planning, and field operations. Work completed by category included:

Geophysics

Processing, Interpretation, and Inversion Analyses

The goal of this work was to complete a quantitative interpretation analysis (inversion) of both miniaturized source and 3D EcoSeis datasets evaluated through processing and interpretation during the EcoSeis Phase 1 project. All of this work was completed in Calgary, AB at OptiSeis and subcontractors' offices.

Decimation tests utilizing the 2D miniaturized source datasets were conducted and inversion analyses were completed. Additionally, a PhD candidate from the University of Alberta worked with OptiSeis to develop novel dispersed source array algorithms. This helped increase understanding of what would be required to design dispersed source arrays for improved seismic bandwidth. Results from one of the source analyses was published in the January 2023 issue of the EAGE's (European Association of Geoscientists and Engineers) journal, *First Break* (Vol. 41, No. 1: 77-86. The use of miniaturised seismic sources for reduced environmental impact).

All the seismic acquisition geometries from Phase 1 along with an additional ten 3D geometries were successfully processed, interpreted, and run through initial inversion and interpretation analyses. Initial results were published in the international SEG (Society of Exploration Geophysicists) journal, *The Leading Edge* in January 2023 (Vol. 42, No. 1: 61-68. EcoSeis: A novel acquisition method for optimizing seismic resolution while minimizing environmental footprint).

During this work of analyzing the alternative geometries, it was found that some modifications would further improve the environmental benefits and subsurface image quality, which was completed in Milestone 2.

EcoSeis Seismic Acquisition Design

This work began with an evaluation of the four potential site locations put forward by the participating oil companies for hosting the field operations. Sites were evaluated on technical and operational merit. The evaluation included both a conventional seismic acquisition target evaluation as well as an examination of project timing and budgetary constraints. A SAGD site in the Athabasca region of northeastern Alberta was selected. After site selection was complete, a detailed EcoSeis analysis was completed to generate the EcoSeis geometry to be acquired with the planned conventional 3D orthogonal geometry. One of the benefits of the selected site was that it enabled more complete separation of the conventional and EcoSeis operations due to the conventional survey containing buried sources and receivers. However, this also introduced some technical and operational variations that needed to be accounted for in the seismic data processing and in the statistical analyses during Milestone 2.

Environmental Studies

Two environmental studies were planned as part of the project: a seismic line re-growth study and a seismic line cutting test. The office components of this work were completed at OptiSeis and subcontractor offices in Calgary, AB and the field work was completed at host company sites in northern Alberta.

Re-growth Study

A seismic line re-growth study was conducted to compare the re-growth on low-impact seismic cut lines (LIS) vs. natural recovery after a forest fire vs. undisturbed forest. Results from this were incorporated into EcoSeis program implementation with a focus on reducing the impact of seismic cut lines in sensitive habitats and/or areas with slower natural regrowth, thus reducing the amount and cost of reclamation needed for seismic cut lines. All the preparation for and collection of the field data for regrowth study was completed between May 2022 and September 2023. Previously, between 2010 and 2012, a series of low impact seismic (LIS) lines in the area were assessed to document natural vegetation recovery of LIS that were cut 8-10 years prior. During the 2022 growing season these same sites were re-sampled to quantify 18 to 20 years post cutting natural recovery. In addition, an area that was burned during the 2002 House River Fire, adjacent to the study area, was also assessed to quantify natural recover post cutting and post wildfire.

In the original study, percentage cover of shrubs (ericaceous shrubs and tree species), graminoids, lichen and mosses, as well as visual obstruction from vegetation measured along transects were assessed. Findings on visual obstruction from the first study were published in Kansas et al. 2015 (Canadian Wildlife Biology and Management [4]:2:137-149). The current study expanded on this and included stem counts and heights of tree species in subplots along the transect. Field sampling for LIS and fire was grouped by Ecosite. A total of 170 plots were completed. Ninety plots (10 per Ecosite) were completed as re-sampling of the original lines cut only once, and 80 plots (10 per ecosite) were completed in areas affected by the House River Fire. Results from the study were analyzed in Milestone 2.

Line Cutting Test

During Q4 2022 detailed planning for the line cutting test was conducted. However, as a result of the changes in the host company's operational priorities and timelines, the testing for the line cutting test had to be moved to another location. This required additional field approvals which, unfortunately, could not be obtained in time to complete the test prior to the end of the winter season. Therefore, the test was moved to the following seismic season (Q4 2023/Q1 2024).

Field Operations

EcoSeis 3D

As a result of the site selected, changes occurred to the exact testing plan. The 3D/4D field testing was moved from Q1 2023 to Q4 2022 in order to accommodate the host company's field schedule. This resulted in some of the tests originally planned to occur together at one location being moved to other locations in northern Alberta. Additionally, one of the miniaturized sources to be utilized on the 3D test could not be prepared in time for testing due to COVID-19 related manufacturing and shipping delays, so was not included in the project.

Field operations for both the EcoSeis and conventional seismic programs began on October 24, 2022, and were safely and successfully completed on time and on budget on December 15, 2022. As mentioned previously, there were some changes to the program with the majority of the dispersed arrays acquired on separate 2D lines. However, in one portion of the program, the EcoSeis program was acquired with one miniature source as well as the conventional explosive. This enabled some limited dispersed array testing in processing. The conventional seismic program did not require line clearing as both the sources and receivers had cased shot holes. Sources were reloaded and receivers, which were only single component geophones, were connected for recording. The EcoSeis program, however, was cut at a narrower 1.75m wide line width and had explosive sources (both conventional and miniature) drilled in. Recording was conducted with surface three-component geophones. The conventional and EcoSeis programs were recorded jointly so that all of the conventional sources were shot into the EcoSeis receivers and vice versa. This enabled various combinations of geometry decimations in processing.

Dispersed Source & Receiver Arrays

Two 2D dispersed array tests were conducted, one for receivers and one for sources. Eight different sensors (geophone and accelerometer) from four manufacturers were incorporated into a 2D seismic line test acquired in November 2022. Dispersed source array tests were also conducted on another 2D line that was acquired in February/March 2023. Results from these tests were analyzed in Milestone 2.

Software & Analytics

Software

Software development involved further enhancements to the EcoSeis design algorithms to improve program layout and efficiency. This work was ongoing through Milestone 1 and 2. During field operations, statistics such as equipment movement, costs, and fuel use were tracked for all phases of the operations in order to accurately quantify the emissions reduction associated with EcoSeis. Analysis of this data was completed in Milestone 2. All software work occurred at OptiSeis offices in Calgary, Alberta.

Emissions Tracking

During the seismic acquisition field operations, all operational activities for both the conventional and EcoSeis geometries were tracked. This included location tracking of all equipment and personnel as well as tracking of fuel usage by operation type. This data was analyzed in Milestone 2 to determine the potential emissions reductions with the use of the EcoSeis methodology.

Milestone 2: April 2023 – April 2024

The objective of this milestone was to complete processing of all seismic datasets (conventional & EcoSeis) developed and acquired in Milestone 1, complete the Quantitative Interpretation analyses of the processed datasets, complete the statistical analyses of all data tracked during the field operations, and finish updating the software. Work completed by category included:

Geophysics

All geophysical work was completed by OptiSeis and subcontractors in Calgary, Alberta.

Processing, Interpretation, and Inversion Analyses

Alternative seismic acquisition geometries identified during Milestone 1 were processed, interpreted and inverted resulting in a total of 29 3D seismic geometries undergoing evaluation: nine orthogonal/modified orthogonal, four grid, and sixteen linear/parallel/EcoSeis. The purpose of this testing was to identify alternative linear geometries that could significantly reduce the surface land footprint while still providing accurate subsurface images. Given the success achieved with several EcoSeis geometries, end-member testing was also conducted to develop guidelines for converting conventional orthogonal 3D seismic geometries into EcoSeis geometries. This work proved to be extremely valuable as it led to a better understanding of both how best to implement EcoSeis and how the sparseness of the data impacts rock property analysis.

Evaluation of Field Acquisition Datasets

All seismic data acquired in Milestone 1 was processed and interpreted. Dispersed source array research continued with the PhD candidate at the University of Alberta and a MSc student from the University of Calgary was hired for a summer term to help with the analyses of the 3D seismic datasets. Conventional 2D and dispersed array 2D processing was successfully completed with results presented at several conferences in Calgary and internationally (See Section J for more information).

Combinations of the conventional 3D and EcoSeis 3D seismic datasets were processed to assess both geometry and equipment variation. Since the 3D EcoSeis dataset was acquired with three-component geophones, this dataset was also successfully processed through PS (converted wave) seismic processing.

Finally, since the location of the 3D technical field test was at a site where a previous 3D baseline had been acquired to steam injection for SAGD (Steam Assisted Gravity Drainage) oil sands production, 4D processing, interpretation, and inversion analyses were also successfully completed.

Environmental Studies

Re-growth Study

Results from the regrowth study were analyzed to determine the impact of seismic cutlines on various types of habitats. A report was prepared for the sponsoring companies and funding organization (PTAC). Plans are underway to have this study published in a peer-reviewed journal. This work was completed at OptiSeis and subcontractor offices in Calgary, Alberta.

Line Cutting Test

A location for the revised line cutting test in northern Alberta on a host-company 3D seismic program was selected and assessed based on imagery and ecosite mapping. The line cutting test was scheduled to mobilize to the field in February 2024, and all preparations were ready between OptiSeis, the subcontractor, and the host operator for that to happen. However, due to an unseasonably warm winter, no snow was on the ground at the beginning of February. As a result, a decision was made to delay the testing to next year since the line would either have been cut too low to provide useful data (some snow is necessary to increase the height of stems), or if cut high enough to generate larger stems for regrowth comparison, would have represented a safety risk for line travel after mulching. It was felt that proceeding under non-optimal conditions would potentially bias the test against the alternative cutting methods being evaluated and that it would be best to delay until the following season in order to conduct the test under standard operating conditions. Nonetheless, the detailed planning has provided value in determining the feasibility of conducting alternative line cutting operations, both from an operational perspective and a safety perspective.

Software & Data Analytics

Software

Development work on the software continued with a coding update based on results from the field seismic acquisition, geophysical analyses (dispersed arrays), processing, QI, and statistical analyses. Various EcoSeis geometries were coded into the software and optimizing algorithms were developed for effectively modifying lines around sensitive habitats and other constraints. Updates were made to both the main package and the input modules to enable better tracking of field emissions, linear km cut, and other field attributes. Learnings from processing were incorporated in the form of station and line numbering optimization algorithms.

Data Analytics

A complete analysis of all data collected during the Milestone 1 3D/4D field trial was conducted in order to accurately quantify the difference between the EcoSeis and the conventional 3D seismic program. All tracked data was analyzed with a focus on three key metrics: linear km cut, ha cut, and GHG emissions. A third-party subcontractor specializing in GHG emissions calculations evaluated both the direct emissions associated with fuel usage and the emissions associated with biomass cutting and decomposition based on forest type.

E. PROJECT RESULTS

Key Results

Project results and lessons learned from both milestones have been published in detail in two journal articles and 32 technical conference abstracts. References and links for these publications are provided in Section J. Specific results by category include:

Geophysics

EcoSeis Phase 2 Technical Field Trial

The technical field trial provided verification of the EcoSeis method for acquiring high-quality, cost-effective subsurface images with a reduced land footprint and GHG emissions (Crook, 2024). The EcoSeis geometry utilized in the 3D technical field trial compared favourably with the conventional 3D orthogonal geometry typically utilized at the site. Subsurface imaging results were similar for both datasets with good ties to well logs and little difference in steam chamber imaging. Unexpectedly, observations from processing & interpretation indicate that EcoSeis methods are compatible with time-lapse (4D) over legacy surveys. This has significant impact on the acquisition of future 4D seismic surveys since it indicates that if designed and processed correctly, a 4D survey may not need to repeat the exact same source and receiver locations as the original baseline 3D. This has led to a new and exciting area of research into sparse 4D acquisition for cost-effective measurement, monitoring, and verification (MMV) for carbon capture and storage (CCS) projects.

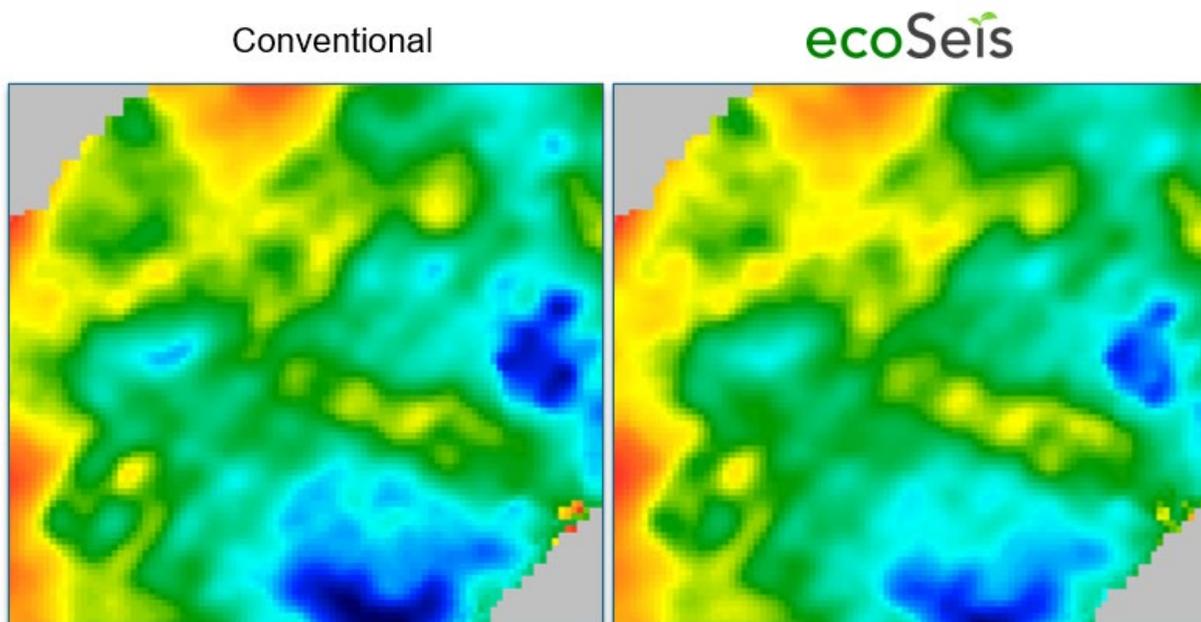


Figure 2: Seismic time slice from the conventional 3D (left) and the EcoSeis 3D (right) showing excellent.

Geometry Analyses

Alternative linear geometries, such as EcoSeis, can provide a new way to acquire seismic data with a lower overall land footprint. Depending on the method of implementation, reductions in linear kilometers over 50% can be achieved. In non-forested areas, the reduction in linear kilometers can increase operational efficiencies, resulting in cost savings and reduced emissions. Subsurface imaging with EcoSeis geometries is comparable to conventional orthogonal geometries (Figure 2). However, converting a conventional orthogonal geometry to an alternative linear geometry requires careful consideration to ensure adequate imaging at all targets. The distance between lines, amplitude, and frequency of line variations (sinusoidal aspect) and the distribution of stations along the line play a part in determining the ultimate subsurface resolution (Naghizadeh et. al., 2023).

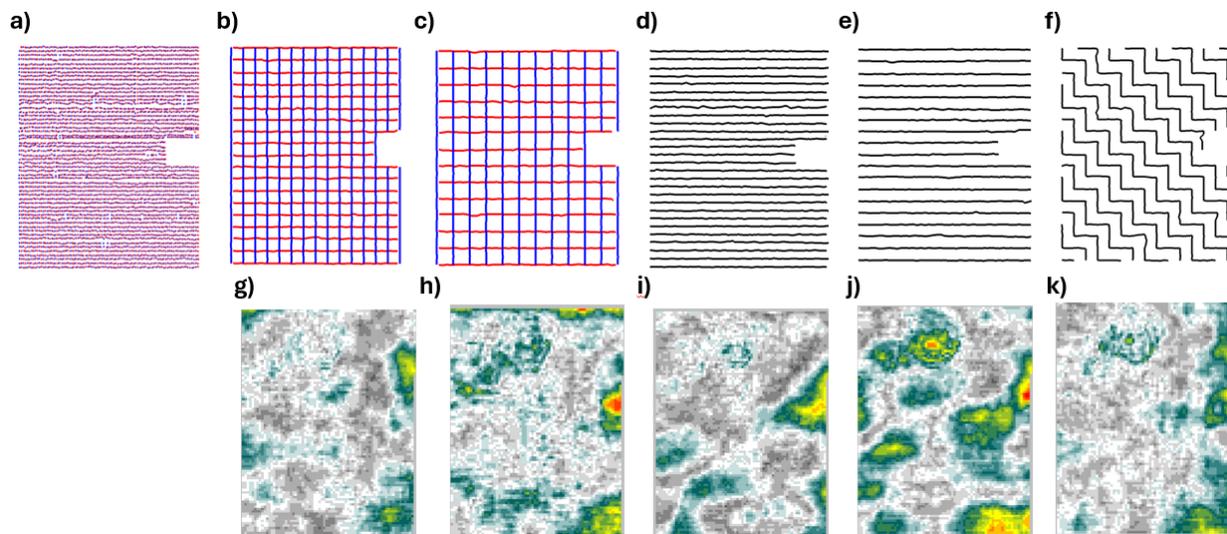


Figure 3 a) Original full grid real seismic dataset (fully sampled). b) to f) Five decimated geometries from original full grid. g) to k) NRMS difference plots of target time-slices with respect to the full grid dataset. Grey and white colours indicate a good match to the fully sampled dataset. Greens show some differences, which may or may not be acceptable. Yellows and reds show areas with unacceptable differences.

Seismic Equipment Analyses

All equipment tested during the project performed well with comparable results achieved from all geophone and sensor types. Miniature source tests were limited due to the unavailability of one piece of equipment. However, tests conducted during the project indicate that shallow deployment of a small seismic source can provide sufficient energy and resolution for imaging oil sands seismic targets (Figure 3). By utilizing a shallow, miniaturized source, the width of source cut lines can be decreased to 1.75m, which will reduce the environmental impact of acquiring seismic data in these sensitive habitats. Furthermore, this may translate to potentially reducing operational time along with cost savings due to less line cutting, surveying, and drilling (Crook et. al., 2023). Although miniature sources generally performed well for shallow targets, deeper targets benefited from incorporating miniature sources with conventional sources in a disperse source array configurations to achieve broader bandwidth at depth (Naghizadeh et. al., 2024).

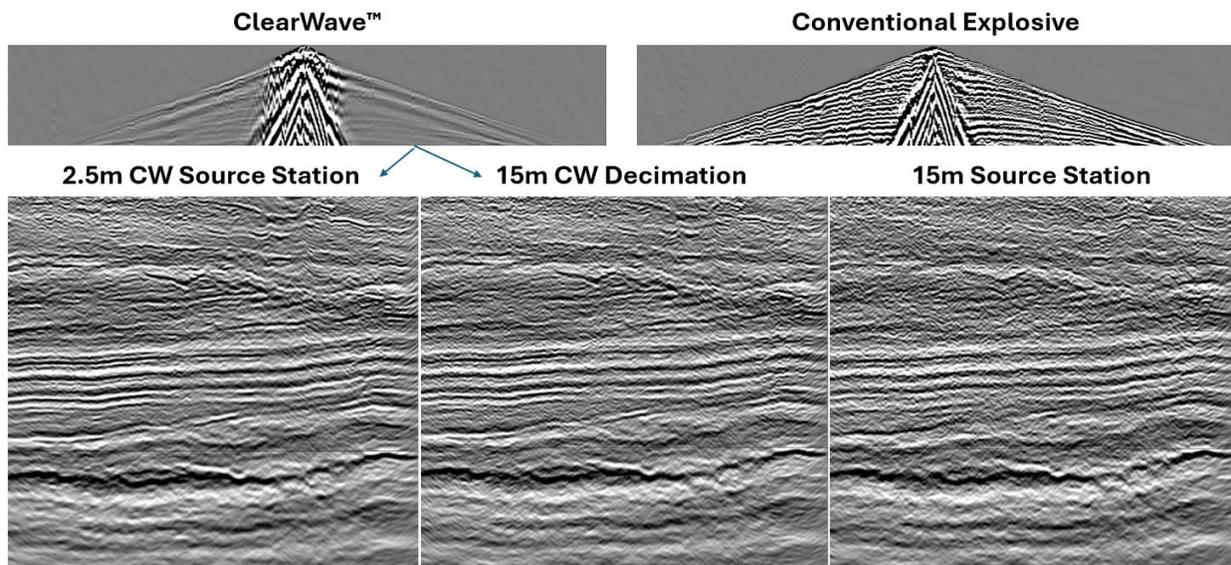


Figure 4: The directional explosive, ClearWave™ by Orica was tested at several locations. This example shows results from a 2D line where it was deployed every 2.5m at depth of 1 m. The conventional explosive was 125 g of dynamite deployed every 15 m at a depth of 6m. Datasets were processed independently with the ClearWave™ also decimated to the same sampling as the conventional explosive. Despite the small size and shallow depth, excellent imaging was obtained for the target (oil sands).

Environment

Re-growth Study

The analysis of the data collected during the regrowth study shows good recovery on the seismic lines that were cut ~18-20 years ago utilizing low-impact seismic (LIS) line cutting methods. Overall, comparison of LIS vs Reference for all 12-strata investigated reveals a high recovery rate for all ecosites as every ecosite showed no significant difference between LIS and reference for 10 or more of the structural strata evaluated. Although there are differences between the transitional (C and G) and wetter ecosites (I, J, and K), these are most evident higher off the ground (Figure 4). Given the stand ages at reference sites, it was not surprising that for all ecosites, mean tree height was significantly higher on reference plots than on either fire or LIS plots. Additionally, there were no significant differences between LIS and reference plots in any ecosite for either of the lower stratum/ground cover variables with the exception of other moss in the D ecosite.

Ecosite A - Jack Pine - lichen



Ecosite D – Aspen/White Spruce



Figure 5: Seismic line regrowth showing recovery in two different ecosites. In Ecosite A, seismic lines recover fully as avoidance cutting (lines meander around larger trees) results in minimal disturbance. Ecosite D has rapid recovery with nearly full regrowth on previously cut seismic lines.

GHG Emissions Reduction

Comprehensive analysis of emissions reductions with EcoSeis was undertaken utilizing data acquired in the EcoSeis Phase 2 field demonstration as well as the results of the regrowth study. Separate algorithms for calculating emissions from line clearing, fuel use, and increased methane from peatlands were developed (Figure 5). Since the lines were pre-existing and shared between the conventional and EcoSeis surveys, a model survey was created assuming a new project done either conventionally or with EcoSeis. Applying the method shows that the largest emissions source by almost two orders of magnitude is the net loss of ecosystem carbon from line clearing, emphasizing the importance of methods that dramatically reduced line clearing like EcoSeis. Savings in the EcoSeis case for land use are estimated at 46%, and emissions savings are estimated to be around 36-50%, depending on line widths, equipment chosen, and line design choices. Results have been incorporated into OptiSeis software for designing EcoSeis programs.

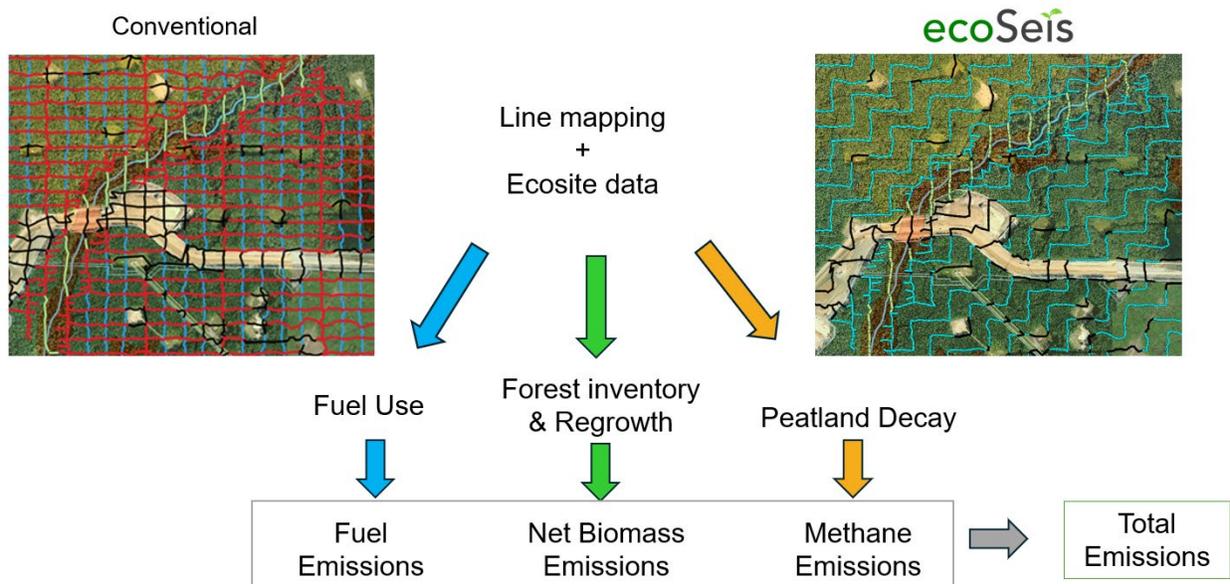


Figure 6: Methodology for determining emissions related to conventional and EcoSeis seismic acquisition.

Software

The osDesign™ software package and associated modules were developed to design and evaluate seismic surveys and generate new seismic geometries that can provide accurate subsurface images while also reducing the environmental impact associated with seismic acquisition. Various seismic acquisition geometry layouts including new alternative and EcoSeis methods were coded and incorporated into the software. New methods for survey evaluation such as Fresnel Fold were developed and incorporated into the software code (Naghizadeh et. al., 2022, Hons et. al., 2023). These enable rapid assessment and comparison between various conventional, alternative, and EcoSeis geometries. Learnings from the technical field trial were also incorporated into the software including algorithms for optimizing field layout for reduced environmental impact and tracking field acquisition activities for calculating GHG

emissions associated with seismic acquisition activities. An example of the software analysis and outputs is provided in Figure 6.

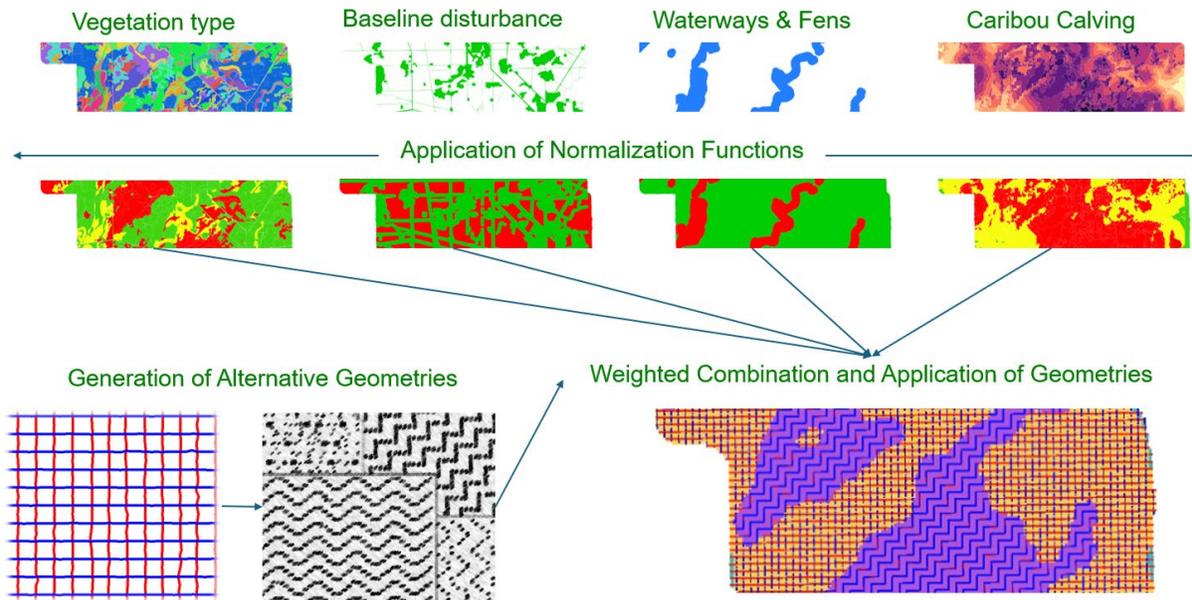


Figure 7 This is a real-world application of a combined EcoSeis and conventional seismic program. Inputs include various constraint maps that are normalized and then weighted based on sensitivity priority. EcoSeis geometries are generated and then applied in the most sensitive areas. Given the success of EcoSeis geometries in imaging the subsurface, combination programs are not required, and EcoSeis-only geometries may be deployed without loss of data quality.

Project Specific Metrics

The specific environmental performance metrics for the program are listed in the table below. These were set at the beginning of the program, and due to the success of the EcoSeis method, all project targets were exceeded with a 42% reduction in linear km and 37% reduction in total disturbance area achieved during the technical field trial. The GHG emissions were also estimated to be reduced by 36% relative to the conventional seismic program based on total emissions (direct from fuel and biomass decomposition), which is more than double the project target. However, even better results are expected on future projects since the results of this test were in part limited due to the existing geometry and large existing footprint in the area. Additional modeling suggests in a new-cut scenario the savings would be at least 46% for linear km, 42% for disturbance area, and 41% for GHG emissions utilizing similar equipment and in a similar operating environment.

Estimates were necessary since the conventional program was a permanent installation and the field operations between the conventional and the EcoSeis programs could not be fully separated. Normalizations were done to determine direct emissions reductions under similar operating conditions.

Furthermore, the geometry analyses indicate that land disturbance area reductions and GHG emissions reductions of over 50%, are possible, depending on the program area (forested, open, marsh, etc.) and equipment type (conventional vs. miniaturized, explosive/VibroSeis/alternative source, etc.).

Performance Metrics Summary

Success Metric	Commercialization Target	Project Target	Achievements to Date
Reduction in Linear km with maintenance of data quality	> 40%	> 35%	Results indicate 42% linear km reduction, with potential to optimize nearer 50%
Reduction in Disturbance Area (ha)	>35%	>20%	37% achieved in the field trial, with modeled potential of over 50% reduction with miniaturized sources.
Reduction in Emissions	>35%	>15%	36% reduction in the field trial, with potential to achieve or even exceed 50% with miniaturized sources
Reduction in Cost	5-10%	0%	Overlapped operations and existing lines in field trial did not allow clear separation of costs between conventional and EcoSeis operations, but estimates based on field rates suggest savings of at least 5%, based only on reduced cut kilometers

F. KEY LEARNINGS

The three primary goals of the project were to:

- (1) Complete technical validation of the EcoSeis methodology through a field trial that compared an EcoSeis seismic program with a conventional 3D seismic acquisition program. This was successfully achieved with full technical evaluation through processing, interpretation, and inversion.
- (2) Quantify the reduction in land footprint and GHG emissions achieved with EcoSeis. This was successfully achieved with EcoSeis exceeding the original performance metrics for reducing linear km and disturbance area while maintaining data quality. In fact, GHG emissions reductions were more than double the expected amount outlined in the project targets.
- (3) Implement the solution in OptiSeis' proprietary software. This was successfully completed with a commercial software package developed and new modules created for evaluating seismic acquisition parameters.

Key learnings beyond the three primary project goals include:

- The discovery that 4D (time-lapse) seismic surveys may not require the repetition of the exact same pattern of source and receiver deployment. This means that for 4D seismic surveys where the baseline was a conventional orthogonal, future repeat surveys do not need to re-cut all the original baseline seismic lines. This change could enable immediate recovery of up to 50% of the 3D baseline. Additionally, this discovery has opened the possibility of utilizing sparse 4D repeat surveys to more cost-effectively monitor carbon capture and storage (CCS) projects. Further work is underway to fully evaluate this potential new application of EcoSeis.
- Due to linear geometries such as EcoSeis being more dependent on seismic processing interpolation algorithms, new methods for evaluating and comparing geometries based on interpolation requirements were needed. Industry standards do not yet exist for this. The utilization of Fresnel fold (Monk, 2010) was examined during the project, which enabled OptiSeis to develop and publish new methods for evaluating and normalizing the Fresnel Fold calculation. These new methods enable a direct link between conventional 3D fold and Fresnel fold and are described in detail in the two project publications from the May 2023 GeoConvention in Calgary, AB: (1) Choosing the Right Seismic Acquisition Geometry for Your Survey: Line Intervals & Distribution Comparison, Mostafa Naghizadeh and (2) does Fresnel Fold mean?, Michael Hons. Links to abstracts for these talks can be found in Section J.
- Learnings from miniaturized source use that were first tested in Phase 1 include how reducing the widths of seismic cutlines helps to minimize the environmental impact of acquiring seismic surveys (Crook et. al., 2023). However, not all small sources provide sufficient energy for imaging deeper targets at the required resolution. Dispersed source array configurations with 2 to 1 ratio of miniature to conventional sources were examined through processing and interpretation. The dispersed array configuration was able to utilize a wider bandwidth of conventional explosive

sources to fill in and remediate the low amplitude frequency components of the miniature sources. Results were presented at the April 2024 CSEG Symposium in Calgary, AB (Naghizadeh et. al., 2024)

- The regular deployment of EcoSeis surveys will require slight modifications to government approval processes since EcoSeis geometries are not currently a selection option when submitting for seismic approvals in Alberta. Results of the project were presented to government regulators at the 2023 CAGC (Canadian Association of Geophysical Contractors) meeting in Red Deer, Alberta. Discussions with regulators indicate that conditional approval can be granted to EcoSeis programs, and once commercial use is established, a review of geometry selection options on the government approval forms is possible.

G. OUTCOMES AND IMPACTS

Project Outcomes and Impacts

The project met or exceeded all expectations for the technology development and identified several new areas of research which are actively being pursued. TRL level was advanced from 6 to 8 and the technology is ready for a full-scale, independent commercial demonstration project.

Clean Energy Metrics

The key clean energy metrics are to reduce the environmental impact and GHG emissions associated with the acquisition of subsurface images (seismic). To evaluate this, an EcoSeis and a conventional seismic program were acquired jointly in Q4 2022. Analysis of the field data has shown that the EcoSeis program reduced the land footprint by 37% while maintaining data quality. This translates to a reduction in project related GHGs of 36%. All the project Clean Energy Metric targets have been exceeded, with land footprint and GHGs exceeding the target by approximately double. Further optimizations are possible as the technology heads toward commercial implementation.

Program Specific Metrics

Investment in 4 Core Strategic Technology Areas

The goal of the project was to advance both the Digital Transformation for Business Innovation through advances in Geospatial technology as well as advance Emissions Reduction Clean Technology through the acquisition of a field test program. Advances in Digital Transformation included the development of EcoSeis optimization algorithms for field implementation and tracking, and advances in Emissions Reduction Clean Technology is outlined above in the Clean Energy Metrics.

Collaborators

The project began with the goal of including six collaborators (five industry partners and the University of Alberta), but far exceeded this goal with over 43 companies (including numerous SMEs) and 14 consultants directly involved in the project for a total of 61 collaborators.

Publications

The project far exceeded the planned 10 publications with 2 journal publications and 32 conference publications as of June 30, 2024. Please see details in Section J for further details.

Clients selling goods or services domestically

The project is increasing OptiSeis' ability to generate revenue from software and services via the development of new software modules and algorithms. This is increasing the applicability of the software and the potential market size.

Clients selling goods or services internationally

The project is increasing OptiSeis' ability to generate revenue from software and services.

Knowledge Mobilization

As of June 30th, 2024, 225+ formal communications have been made about EcoSeis. This includes journal and other publications, technical presentations at conferences and workshops, non-technical presentations, courses/workshops conducted, pitch competitions, online through our website and LinkedIn, and at booths OptiSeis has had at conferences and tradeshows. In total, the project has been shared at more than 40 conferences in five different countries. Please see details in Section J.

Students Trained

The project provided employment for one PhD student during the 2022 summer term and has provided data for that student to complete their Ph.D. Additionally, OptiSeis hired a second M.Sc. Student for the summer of 2024.

New products/services

A new software package for evaluating surveys is nearly ready for launch (expected timeline is Q4 2024) and new EcoSeis seismic acquisition design and modeling services have been added.

Existing Sector HQP Jobs Retained

Although difficult to estimate, the EcoSeis project has provided direct work and training for HQPs at 43+ different organizations along with work for 14+ consultants.

Jobs: Actual new jobs created from the project

OptiSeis hired 9 new employees over the course of the project with a net gain of 5 new permanent jobs.

Rural and Indigenous communities

OptiSeis was not directly involved in First Nations consultation on the projects as this was handled by internal teams at each host company. However, the intention is to utilize EcoSeis in remote communities where rural and Indigenous groups will benefit from the work. OptiSeis did provide support in the form of technology validation for a new source technology (e-Vibe) licensed by a First Nation band (Summit Geo) to supplement their seismic acquisition line clearing services. OptiSeis will continue to provide support for this source during commercialization activities in the form of providing opportunities for further testing in different terrain types.

Project Outputs

During the project, Optiseis filed two patents and three trademarks. The patents are currently pending. Trademarks for OptiSeis™, EcoSeis™, and osDesign™ have either been granted or are in review in various jurisdictions around the world.

Additionally, OptiSeis published two technical journal articles and two general publication articles and completed 33 technical conference presentations based on work conducted during the project. Full details including reference links are provided in Section J.

OptiSeis supported one PhD project at the University of Alberta. Results from this project will be published within the next year.

In addition, OptiSeis has two publications pending, one technical publication detailing the results from the field trial that will be published in a leading geophysical journal, and one general publication that will be published by COSIA.

H. BENEFITS

Economic

The project resulted in the creation of 9 new full-time and part-time positions at OptiSeis over the course of the project. This has resulted in a net gain of 5 new permanent jobs at OptiSeis and 9 new consulting positions. The project has also increased OptiSeis software sales both domestically and internationally and resulted in the development of a new software product.

For future projects, the reduction in both land footprint and GHG emissions achieved with EcoSeis is a key economic benefit since environmentally conscious seismic acquisition provides the social license necessary to develop oil and gas prospects in society today. Without a focus on reducing the environmental impact of oil & gas operations, the industry will not prosper in the future, which has economic impacts such as loss of industry contribution to GDP. By using EcoSeis to acquire seismic with reduced GHG emissions, Canadian oil and gas operators can become low carbon from the very beginning of the exploration cycle. As the need for metals and minerals for the energy transition increases, there will be an increase in seismic programs for mining, which will also benefit from reduced land footprint and emissions with EcoSeis. Another economic benefit is that exploration and development projects within Canada for both oil and gas and mining are often evaluated relative to international projects. By reducing environmental impacts and the cost of acquiring a seismic program in Canada, EcoSeis will improve project competitiveness encouraging more investment in Canada. Potential cost savings on EcoSeis projects range from 10 to 30% depending on the method of implementation.

Environmental

Results of the project (EcoSeis algorithm and methodology) provide a new way to acquire seismic data with up to a 50% reduction in land footprint (depending on the method of implementation) and the possibility of over 50% reduction in GHG emissions associated with seismic acquisition.

EcoSeis also aims to reduce the high-connectivity nature of seismic lines, which causes significant fragmentation of the forest, by reducing the number/width of lines and utilizing irregular line patterns which will result in less forest cover lost. The reduction in seismic line frequency and continuity, when applied using constraint mapping, also has the potential to lessen fragmentation effects which will benefit key wildlife species negatively affected by anthropogenic edge and those requiring larger interior forest patches. Additionally, by optimizing the seismic program layout using the EcoSeis algorithm, the interconnectivity of seismic lines can potentially be reduced, and the program can be designed to avoid areas with high biodiversity or sensitive habitats.

Social

The project involved direct collaboration between 70 companies, including 5 oil companies, 36 SMEs and medium-sized corporations (27 directly involved and 9 indirectly involved), 14 consultants, 5 cleantech accelerators, 2 federal and 1 provincial funding agency, 2 industry associations, 4 not-for-profits, and 1 university. This has created a platform for future research initiatives both within industry and academia.

Future use of EcoSeis will encourage the acquisition of more affordable, environmentally friendly seismic programs, which will result in additional job creation. Many of these seismic programs will be acquired in remote locations and provide needed employment for people living in these areas. Employment opportunities with the various contractors (surveying, line clearing, drilling, recording) often provide work for under-employed individuals and the hiring of First Nations individuals and contracting companies is commonplace. Since the technology can be used anywhere in Canada, the acquisition of more seismic programs near small town and in remote communities will bring increased cash-flow into these smaller communities, not only through job opportunities, but also by providing revenue in these communities through the seismic crew's use of local housing, hotels, restaurants, groceries, and other amenities.

The EcoSeis algorithm includes an optimization for safe access throughout the seismic program area. This combined with fewer personnel moving less equipment throughout the program area improves the health and safety of all personnel working on the seismic programs. EcoSeis aims to find a balance between complete avoidance of tree clearing and safe access through a forest in order to prevent injuries such as slips, trips, and falls, which are the largest safety risks during seismic field operations.

Building Innovation Capacity

The project increased the innovation capacity of OptiSeis and resulted in the training of more than 61 HQSPs both internally at OptiSeis and at other companies. As well, five HQSPs had their jobs retained because of the project. Finally, the project has significantly expanded OptiSeis' research capacity.

The successful implementation of this technology or use of the knowledge generated could result in:

- Reduction of up to 50% in the amount of tree cutting on seismic programs in Alberta,
- Reduction in the amount of GHG generated during seismic operations,
- Protection of sensitive habitats by avoiding and/or limiting access to sensitive areas and/or areas with high biodiversity located within the program area, and
- Policy development guidelines for achieving high quality subsurface seismic images while maintaining biodiversity and protecting sensitive habitats.

I. RECOMMENDATIONS AND NEXT STEPS

The next step is to demonstrate that EcoSeis provides equal or superior subsurface information in all types of geological settings and is both operationally efficient and safe to deploy on a commercial scale as well as operationally ready for commercialization. To achieve this, OptiSeis has secured a \$5,000,000 grant from Emissions Reduction Alberta (ERA) to complete a \$16,200,000 project that will involve completing phased testing to validate three key outstanding technical and operational questions:

- (1) Does the technology work for all subsurface targets, whether shallow or deep, and can it reduce the cost of Carbon Capture and Storage (CCS) monitoring,
- (2) Can the technology be deployed safely according to industry safety standards, and
- (3) Is the technology more efficient than conventional operations providing a cost-savings incentive for operators?

The phased approach enables development of proper safety procedures without compromising the technical or operational results, which is critical for industry acceptance. Based on the direction of project partners and their input with respect to the design of the project, upon completion, the technology will be ready for immediate, full-scale commercial implementation.

This project will involve collaboration with industry and not-for-profit organizations, and is expected to be funded by Optiseis, Industry partners, ERA, and other provincial and federal funding agencies. To date, two universities, four industry partners, and six SMEs will be directly contributing funding and in-kind contributions to the project.

J. KNOWLEDGE DISSEMINATION

As of June 30th, 2024, we have formally communicated on EcoSeis 226+ times through journal and other publications, technical presentations at conferences and workshops, non-technical presentations, courses/workshops conducted, pitch competitions, online through our website ([Optiseis Solutions Ltd. – Subsurface Imaging & Analytics](#)) and LinkedIn (<https://www.linkedin.com/company/optiseis-solutions-ltd/>), and at booths at more than 40 conferences in five different countries (Canada, USA, Australia, Colombia, and Argentina). This has helped to increase awareness of EcoSeis, which will help with large-scale adoption. Feedback has been positive with high engagement, and the project has been recognized with the following awards and honours:

- 2024 (June): Global Energy Show, Calgary, AB: OptiSeis won the 2024 Collaborative Trendsetter Award for the EcoSeis project. <https://www.globalenergyshow.com/special-features/global-energy-show-canada-awards/2024-winners/>
- 2023 (April): CSEG Symposium, Calgary, AB: Andrea Crook was the 2023 Honoree. Sustainable and Innovative Geophysics. <https://cseg.ca/professional-development/cseg-symposium/>
- 2022 (November): Foresight Top 50. OptiSeis was one of Foresight Canada’s 50 most investible companies for 2022 and one of the top five selected to present at the event. [Foresight 50 - Meet Canada's Most Investable Companies - Foresight \(foresightcac.com\)](#)

As a result of this research project, the science of geophysics subsurface sampling has been significantly advanced. The publication pending article, Land 3D acquisition design: Theory of wavefield sampling and case study of AVO and Inversion as a tool to assess the impact of sparse cost-efficient environmentally responsible land 3D survey designs on AVO amplitude fidelity, co-authored by the original developer of linear land geometries, by Bill Goodway, P.Geoph (MegaBin, 1996 Canadian Patent 5787051) and the team at OptiSeis, outlines the history of linear geometries, provides new methods for assessment, and provides case study details on the benefits of utilizing methods such as EcoSeis to reduce the land footprint associated with seismic acquisition while maintaining high quality subsurface imaging.

The following is a list of all project communications as of June 30th, 2024.

- 2 journal publications
 - 2023 (January): First Break, Vol. 41, No. 1: 77-86. The use of miniaturised seismic sources for reduced environmental impact. https://issuu.com/eage/docs/23046-fb23_january_complete
 - 2023 (January): The Leading Edge, Vol. 42, No. 1: 61-68. EcoSeis: A novel acquisition method for optimizing seismic resolution while minimizing environmental footprint. [EcoSeis: A Novel Acquisition Method for Optimizing Seismic Resolution While Minimizing Environmental Footprint – Optiseis Solutions Ltd.](#)
- 2 other publications
 - 2023 (March): PPDM article. Land Seismic Data: Why you should keep everything you paid for! <https://optiseis.com/2023/03/land-seismic-data-why-you-should-keep-everything-you-paid-for/>
 - 2022 (August): Alberta Innovates Public Report on Phase 1 – submitted February, publication was scheduled for 6 months later. <https://albertainnovates.ca/impact/publications/>
- 33 technical presentations at conferences and workshops

1. 2024 (June): GeoConvention, The Impact of 3D Sampling on McMurray Formation Imaging, Andrea Crook, <https://site.pheedloop.com/event/geoconvention2024/schedule>
2. 2024 (June): GeoConvention (Calgary), Multi-Technology Imaging for Efficient & Effective MMV Plans, Andrea Crook, <https://site.pheedloop.com/event/geoconvention2024/schedule>
3. 2024 (June): GeoConvention (Calgary), Reducing the Impact of Seismic: Our primary subsurface tool, Michael Hons, <https://site.pheedloop.com/event/geoconvention2024/schedule>
4. 2024 (June): A Solution for Low-Impact Seismic Imaging, Global Energy Show Canada 2024, Andrea Crook, [2024 Technical Program \(globalenergyshow.com\)](https://www.globalenergyshow.com/2024-technical-program)
5. 2024 (May): The Evolution of Seismic Acquisition, CSEG GIFT 2024, Andrea Crook, <https://cseg.ca/wp-content/uploads/Schedule-GIFT-2024.pdf>
6. 2024 (May): Sustainable Solutions for CCS Monitoring, AAPG Canada workshop, Andrea Crook, <https://www.aapg.org/career/training/in-person/workshops/workshop-details/articleid/66145#program>
7. 2024 (May): Canada Gas Exhibition and Conference (Vancouver), Carbon capture and sequestration in Canada - application of new seismic technologies for injection hub planning, target reservoirs monitoring, Mostafa Naghizadeh, <https://canadagaslng.com/about/schedule-at-a-glance/>
8. 2024 (April): Next Generation Geophysical Land & Shallow Water Acquisition (Oman, Virtual Presentation), Minimizing the Impact of Explosive Sources Utilizing Miniaturization of Equipment and Dispersed Arrays Andrea Crook, <https://seg.org/wp-content/uploads/2024/04/GALS-Technical-Program.pdf>
9. 2024 (April): CSEG Symposium (Calgary), Miniaturized seismic sources and dispersed source arrays, Mostafa Naghizadeh, <https://cseg.ca/professional-development/cseg-symposium/symposium-schedule/>
10. 2024 (February): CSEG-CHOA Joint Symposium (Calgary), Cost-effective 4D solutions for low-impact seismic imaging, Andrea Crook, <https://cseg.ca/cseg-choa-joint-symposium/>
11. 2023 (December): URTEC LATAM (Argentina), Decarbonization of seismic survey acquisitions, Mostafa Naghizadeh, <https://urtec.org/latinamerica/2023/Program/Technical-Program/Monday-Program>
12. 2023 (September) - SEG Women's Network (Virtual), Decarbonizing Subsurface Imaging, Andrea Crook Recorded: <https://www.youtube.com/watch?v=fjz5NAtdPAM>
13. 2023 (September): EOR, Decarbonizing Subsurface Imaging, Andrea Crook, <https://www.eortcp2023.com/conference/agenda/>
14. 2023 (September): CAGC (Red Deer), Maintaining seismic as the primary subsurface imaging tool by reducing environmental footprint, Michael Hons and David Simmons.
15. 2023 (September): IMAGE (Houston), Designing alternative 3D seismic surveys for reduced environmental footprints using the seismic trace density parameter, Mostafa Naghizadeh, <https://imageevent.aapg.org/portals/26/3907102.pdf>
16. 2023 (May): GeoConvention (Calgary), Evaluating Innovations in Geophysical Acquisition, Andrea Crook, <https://geoconvention.com/wp-content/uploads/abstracts/2023/11115-sustainable-and-innovative-geophysics-acquisition.pdf>

17. 2023 (May): GeoConvention (Calgary), EcoSeis: Seismic Surveys for Reduced Environmental Impact, Alyson Birce, <https://geoconvention.com/wp-content/uploads/abstracts/2023/91521-ecoseis-can-lower-environmental-fo.pdf>
18. 2023 (May): GeoConvention (Calgary), Choosing the Right Seismic Acquisition Geometry for Your Survey: Line Intervals & Distribution Comparison, Mostafa Naghizadeh, <https://geoconvention.com/wp-content/uploads/abstracts/2023/91485-choosing-the-right-seismic-acquisi.pdf>
19. 2023 (May): GeoConvention (Calgary), What does Fresnel Fold mean?, Michael Hons, <https://geoconvention.com/wp-content/uploads/abstracts/2023/91516-what-does-fresnel-fold-mean.pdf>
20. 2023 (May): WBPC (Regina), Carbon Capture and Sequestration in Alberta - injection hub planning, target reservoirs, and the application of new seismic technologies, Andrea Crook, Henry Williams, Mostafa Naghizadeh, Alyson Birce, and Michael Hons, <https://www.wbpc.ca/conference/technical-program/>
21. 2023 (March): AEGC (Australia). Designing Seismic Surveys for Reduced Environmental Impact. <https://2023.aegc.com.au/cms/wp-content/uploads/AEGC-2023-Detailed-Program-3.3.23.pdf>
22. 2023 (March): AEGC (Australia). Using seismic trace density for optimal 3D seismic survey design. <https://2023.aegc.com.au/cms/wp-content/uploads/AEGC-2023-Poster-Program.pdf>
23. 2023 (February): AAPG Workshop (Barranquilla). Sustainable Subsurface Imaging Technology Part 1: Design, Processing, and Interpretation. <https://optiseis.com/2023/02/caribbean-2023-geosciences-technology-workshop-february-8-2023/>
24. 2023 (January): ACGGP Workshop (Bogota). Reducing the environmental impact of acquiring seismic data. <https://www.linkedin.com/feed/update/urn:li:activity:7026918017326350336>
25. 2022 (November) – CHAO/CSEG Symposium (Calgary). EcoSeis – Reducing the environmental impact of acquiring seismic while maintaining data quality <https://optiseis.com/2022/10/cseg-choa-joint-symposium/>
26. 2022 (November) – EAGE Near Surface (Colombia, Virtual). <https://optiseis.com/2022/10/second-eage-conference/>
27. 2022 (November) – GSH 3D Design Symposium. Reducing the Environmental Impact Of Acquiring Seismic Data: An EcoSeis case study. https://www.gshtx.org/SharedContent/Events/Event_Display.aspx?EventKey=2ffd2ae2-32d0-4fd5-9341-6e2bbeb3c3e2&iSearchResult=true&WebsiteKey=955f17e6-46ad-4401-acbd-2af6c393752b
28. 2022 (September) – Carbon Capture Canada (Edmonton), EcoSeis: A Solution for Lowering the Environmental Footprint of Seismic Imaging Carbon Capture Canada Sept. 20-22, 2022 – Optiseis Solutions Ltd. <https://www.carbonexpocanada.com/>
29. 2022 (August): IMAGE '22 Joint AAPG-SEG-SPE conference (Houston), Workshop; Evaluating Acquisition Innovations: A Guide for Accurate Assessments.
30. 2022 (August): IMAGE '22 Joint AAPG-SEG-SPE conference (Houston), Technical Presentation; Optimal Infilling of seismic station using Fresnel zone binning analysis. <https://library.seg.org/doi/10.1190/image2022-3750648.1>

31. 2022 (June) – GeoConvention Conference (Calgary). Turn your seismic program into a lean, green, resolution machine. <https://optiseis.com/2022/06/turn-your-seismic-program-into-a-lean-green-resolution-machine/>
 32. 2022 (June): GeoConvention (Calgary). Fresnel zone binning analysis for determining optimal seismic infill stations. <https://optiseis.com/2022/06/fresnel-zone-binning-analysis-for-determining-optimal-seismic-infill-stations/>
 33. 2022 (April) – ICE AAPG Conference (Cartagena, Colombia), Miniaturized Sources and Their Applications. <https://cartagena2022.iceevent.org/program/technical-program/on-demand-only>
- 24 General EcoSeis Presentations, Panel Discussions, Pod Casts, and Pitches
 1. 2024 (June): GeoConvention, Showcase Stage 1: Is exact source and receiver repeatability necessary for timelapse (4D) seismic surveys: Learnings from EcoSeis phase II, Andrea Crook, <https://geoconvention.com/wp-content/uploads/documentation/2024/2024-showcase-stage.pdf>
 2. 2024 (June): GeoConvention, Showcase Stage 1: Understanding Linear Seismic Acquisition Geometries, Andrea Crook, <https://geoconvention.com/wp-content/uploads/documentation/2024/2024-showcase-stage.pdf>
 3. 2024 (March): Ecoseis, Trade mission Colombia-Canada, Jason Dagenais, <https://export.alberta.ca/event-items/approved-events/2023/colombia-and-guyana-energy-trade-mission/>
 4. 2024 (February): Innovation Day: Forging the future: where digital innovation meets mining excellence. Andrea Crook, PlugandPlay Mica. <https://www.plugandplaytechcenter.com/events/innovation-day/>
 5. 2023 (November) PTAC Ecological Forum presentation. Andrea Crook, <https://www.ptac.org/current-events/2023-ecological-forum/>
 6. 2023 (November) CRIN Interview for COP 28 <https://www.dropbox.com/scl/fi/z41r4a07zvw13xgnqjx8k/18-OptisSeis-Third-Delivery-V01-Subtitles.mp4?rlkey=uxry268fdgvuod09od4xuevxq&dl=0>
 7. 2023 (November) Platts Capital Crude podcast with S&P , New underground mapping may mean more oil and gas, fewer cut trees. Andrea Crook, <https://www.spglobal.com/commodityinsights/en/market-insights/podcasts/crude/231120-underground-mapping-oil-gas-cut-trees-optiseis-canada-seismic-survey>
 8. 2023 (October) PTAC Digital Innovation Forum, Andrea Crook, <https://www.linkedin.com/events/digitalinnovationforum7084969631806877696/comments/>
 9. 2023 (September): WPC, Clean Resource Innovation Network: Cleaner Fuels, Land Theme Overview & Innovator presentations, Andrea Crook, Carbon Tech Expo: CRIN booth #3317
 10. 2023 (September): WPC, CEO Strategic Session 6: Driving Innovation in a Net Zero World, This panel addressed research and development of next-generation technologies and investment in breakthrough research across a broad spectrum of other energy technologies and across sectors, Deborah Yedlin, President and CEO - Calgary Chamber of Commerce (moderator), Matthew Crocker, Senior Vice President, Product, Strategy and New Assets – ExxonMobil, USA, Andrea Crook, Co-Founder and CEO - OptiSeis Solutions Ltd., Canada, Tiago Homem, Head of Reservoir Management – Petrobras,

Brazil, and Elizabeth Rogo, Founder and CEO, TSAVO Oilfield Services, Kenya,

<https://www.24wpc.com/congress-programme>

11. 2023 (September): WPC, Pathways Alliance: CEO Strategic Session 6: Driving Innovation in a Net Zero World - Q&A with Andrea Crook, Pathways booth #2015,
 12. 2023 (September): WPC, Pathways Alliance: Subsurface Imaging + Net Zero, Andrea Crook, Pathways booth #2015
 13. 2023 (September): WPC, B2B Program - Cleantech Pitches: Digital Solutions Theme. The path to net zero is challenging, and it's also filled with opportunity, Andrea Crook, <https://www.24wpc.com/b2b-programme-details>, <https://www.linkedin.com/feed/update/urn:li:activity:7110439824200798208> <https://www.linkedin.com/feed/update/urn:li:activity:7110303400763805696>
 14. 2023 (September): WPC, Carbon Tech Expo Session 6: Commercializing CCUS technologies. The panel discussed key challenges faced by technologies as they move to commercialization and what the process looks like, Breanne O'Reilly, Communications and Marketing – Carbon Management Canada (moderator), Greg Maidment, Director, Operations and Applied Research – Carbon Management Canada, Andrea Crook, CEO and Co-founder – Optiseis, Rob Baillargeon, Innovation Lead – Cenovus, Brett Henkel, Co-founder and SVP – Svante, <https://www.24wpc.com/carbon-tech-expo-details>
 15. 2023 (May): GIFT, Geophysical Innovations for the New Energy Economy, Andrea Crook.
 16. 2023 (May): GIFT, Seismic reflection Acquisition: Sampling, Sources, and Sensors. Mostafa Naghizadeh
 17. 2023 (March): Crownsmen Partners's Interview. Optimizing Seismic surveys and the application of seismic methods in carbon capture and storage.
 18. 2023 (January): GeoWomen. <https://www.linkedin.com/feed/update/urn:li:activity:7022279371965038592>
 19. 2023 (January): Pathways-COSIA
 20. 2022 (November) – CSPC Panel <https://optiseis.com/2022/10/canadian-science-policy-conference/>
 21. 2022 (August): IMAGE '22 Joint AAPG-SEG-SPE conference; Presentation; reducing environmental impact of Acquiring Seismic – The EcoSeis Approach.
 22. 2022 (August): IMAGE '22 Joint AAPG-SEG-SPE conference; Panel Discussion; Imaging Acquisition and Interpretive Technologies: Surface and Subsurface.
 23. 2022 (August): Crowsmen interview. <https://optiseis.com/2023/02/building-energy-optiseis-solutions-is-changing-seismic-exploration-landscape/>
 24. 2022 (March) – CRIN Announcement. <https://cleanresourceinnovation.com/news/new-technologies-funded-by-crin-competition-to-address-environmental-and-economic-challenges-of-canadas-oil-and-gas-industry>
- 1 Workshops
 - 2023 (March): Workshop at AEGC. Advances in Seismic Acquisition: Innovations, Resolution, and Sustainability Applications for Mining. <https://2023.aegc.com.au/workshops/>
 - 9 pitches
 1. 2023 (October) CarbonNEXT – Foresight Pitch: EcoSeis <https://www.youtube.com/watch?v=f3dZUuND50M>

2. 2023 (September): WPC, 2023 PROPEL Energy Tech Forum, Andrea Crook, CEO and Co-founder, Optiseis, <https://www.24wpc.com/programming>
<https://www.linkedin.com/feed/update/urn:li:activity:7110439824200798208>
 3. 2023 (May): Plug & Play, Reducing the environmental impact of subsurface seismic imaging, Andrea Crook.
 4. 2023 (April): Foresight Pitch event, Reducing the Environmental Impact Of subsurface imaging, Andrea Crook. <https://www.youtube.com/watch?v=nktIsoLKHwQ>
 5. 2023 (March): HETI Pitch Competition & Award. <https://optiseis.com/2023/03/heti-energy-ventures-pitch-competition-march-8-2023/>
 6. 2023 (January): Plug and Play. <https://www.plugandplaytechcenter.com/startups/our-startups/>
 7. 2022 (November) – Foresight Demo Day
 8. 2022 (November) - Foresight Top50 [Foresight 50 - Meet Canada's Most Investable Companies - Foresight \(foresightcac.com\)](https://foresightcac.com)
 9. 2022 (August): IMAGE '22 Joint AAPG-SEG-SPE conference; U-pitch New Technology Showcase; EcoSeis: A lower Carbon Solution for Seismic Acquisition
 10. 2022 (June) – Propel Conference <https://propelenergytech.com/>
- 105 announcements/updates on OptiSeis linked in and 40 on OptiSeis website since June 2022 when we began tracking.
 - 10 conference booths showcasing EcoSeis. Numerous presentations on EcoSeis were given at each conference:
 1. 2024 (June) Booth at GeoConvention in Calgary, AB
 2. 2024 (April) Booth at CSEG Symposium in Calgary, AB
 3. 2023 (September): Booth at Carbon Capture Canada in Edmonton, AB
 4. 2023 (August): Booth at IMAGE '23 in Houston TX
 5. 2023 (April) Booth at CSEG Symposium in Calgary, AB
 6. 2023 (May) Booth at GeoConvention in Calgary, AB
 7. 2023 (March): Booth at 3D Seismic Symposium in Denver, CO
 8. 2023 (February): Booth at AAPG Workshop in Barranquilla, Colombia
 9. 2022 (August): Booth at IMAGE '22 in Houston, TX
 10. 2022 (June) Booth at GeoConvention in Calgary, AB

K. CONCLUSIONS

The focus of this project was to advance the EcoSeis methodology, which reduces the total amount of line clearing within a seismic program by up to 50%, and software implementation. This is accomplished by utilizing irregular and alternative geometries that minimize the amount of line clearing all while maintaining subsurface data quality and reducing costs. Additionally, EcoSeis has the potential to reduce seismic data acquisition costs by up to 25%. Activities performed during the project included a full-scale technical field comparison, which involved environmental studies, seismic acquisition of 2D, 3D, and 4D datasets, and statistical tracking of all field equipment, followed by analysis of the results through seismic data processing, quantitative interpretation, and statistical analysis to determine land footprint and GHG emissions reductions. The purpose of the project was to demonstrate that EcoSeis provides equal to or superior subsurface information while reducing the environmental footprint and meeting industry standards for safety. The project results include: 1) a technically proven method to reduce both the land footprint and the emissions associated with seismic acquisition without compromising subsurface data quality, (2) the generation of high-quality datasets for additional environmental studies, and (3) job creation & retention.

All project targets were exceeded with a 42% reduction in linear km and 37% reduction in total disturbance area achieved during the technical field trial. The GHG emissions were also estimated to be reduced by 36% relative to the conventional seismic program based on total emissions (direct from fuel and biomass decomposition), which is more than double the project target. However, even better results are expected on future projects since the results of this test were in part limited due to the existing geometry and large existing footprint in the area. Additional modeling suggests in a new-cut scenario the savings would be at least 46% for linear km, 42% for disturbance area, and 41% for GHG emissions utilizing similar equipment and in a similar operating environment. Furthermore, the geometry analyses indicate that land disturbance area reductions and GHG emissions reductions of over 50%, are possible, depending on the program area (forested, open, marsh, etc.) and equipment type (conventional vs. miniaturized, explosive/Vibroseis/alternative source, etc.).

The benefits to the oil and gas industry include acquiring cost-effective, high-quality subsurface data needed for business-critical decisions while reducing the environmental impact and ensuring workforce safety standards during field operations. These benefits can accrue to any company with subsurface operations including critical mineral mining, geothermal well placement, and in the nascent carbon capture & storage sector, where it can be utilized for more cost-effective monitoring. By using EcoSeis to acquire seismic with reduced GHG emissions and less land footprint, Canadian O&G operations can become lower carbon from the very beginning of the exploration cycle meeting their GHG emissions reduction goals. EcoSeis benefits Canada by enabling ethical and sustainable resource development in all sectors that require accurate subsurface imaging. The EcoSeis software and processes provide an opportunity for highly skilled environmental and geo scientists to work collaboratively in collecting and analyzing data for ecological development of resources. Additionally, the data collected during the project will provide opportunities for further research in the fields of geophysics, environmental science, and data analytics.