ASSESSING THE ECOSYSTEM SERVICE BENEFITS OF THE COSIA LEAP PROGRAM

Phase 2: Interim Report 2 of 3

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Executive Summary

This project is part of a multi-phase, multi-year research initiative. Phase 1 of 'Assessing the Ecosystem Services of the Algar Landscape Ecological Assessment and Planning (LEAP) Project' (Algar ES Phase 1) was a proof of concept pilot program, established in 2013 and designed to assess the ecosystem service benefits derived from linear restoration in species at risk habitat (i.e. the East Side Athabasca River caribou range). Algar ES Phase 1 provided a critical perspective on how projects that seek to derive ecosystem services and biodiversity benefits perform under a rigorous environmental and economic assessment. The findings of the pilot revealed that there are gains to be realized from undertaking linear restoration. Results of Phase 1 spurred interest in pursuing additional research into understanding the selection of ES, underlying model assumptions, and scalability of assessment results.

Phase 2 of this project is a multi-year project, launched in 2015 that seeks to further the development of a repeatable, transferable, and implementable approach to evaluating the net benefits of restoration activities in the boreal region and assess the potential for conservation offsets from the restoration of legacy seismic lines. As part of the success of this project, a repeatable framework will be developed to incorporate ES concepts into linear restoration projects and upcoming conservation offset policy. Furthermore, methods will be developed to prioritize areas for restoration based on the suite of ecosystem services provided by the landscape, rather than focusing on just one land value (e.g. species at risk).

Phase 2 has been set up to meet three distinct goals for each year of the project:

1. Develop a repeatable process to identify the appropriate ES to evaluate a management plan and its alternatives (i.e. restoration or development);
2. Test the compatibility and transferability of methodologies for assessing ES to other areas of the province; and
3. Evaluate how this assessment fits into the Government of Alberta policy such as the ES framework and offset policies.

Goal 1 was met in 2015 with the release of *Interim Report 1 of 3* and the development of the 7-Step Selection Criteria Process that links community values directly to ecosystem change and the services that are provided from that change.

To meet the objectives of Goal 2, Silvacom, with project partners ABMI, Government of Alberta, and InnoTech scaled up the analysis from the Algar region, a six township region southwest of Fort McMurray, to the Southern Athabasca Oil Sands region as well as the entire Lower Athabasca watershed. Lessons learned from the Phase 1 pilot project and the *Interim Report 1 of 3* were employed to the larger landscape to assess the scalability of results.

Results of the analysis showed that large-scale linear restoration can generate ecosystem service benefits including timber supply, carbon sequestration, and caribou habitat. Other measured ecosystems services including water quality, biodiversity intactness, and moose habitat showed little to no change from large-scale restoration. As such, mapping potential benefits and costs indicators from linear restoration

programs can help prioritize areas for restoration across large landscapes. This will focus restoration efforts and investments in high-value areas that are important to stakeholders in the region.

Scaling the analysis to the Lower Athabasca watershed highlighted a number of data constraints when modeling at such a large scale, including discrepancies in model results between different modeling platforms. Understanding the limitations of the modeling approach, including the model inputs, the model itself, and its outputs, when interpreting ES benefits will be essential for conservation offset planning.

Lastly, the Government of Alberta has sent many signals with the release of the draft LSALP caribou range plan that large-scale linear restoration will occur imminently and over a short time-span (e.g. over 5 years). This will affect how local communities benefit from restoration in terms of ecosystem services, while also creating a number of jobs. If restoration is postponed in the Lower Athabasca watershed or completed over a longer timeframe than the LSALP region, benefit estimates may be affected by the time value of money. All valuation estimates currently used a risk-free rate of 4%, but this may be changed based on the risk of the linear restoration program and community and/or industry needs.

Moving into 2017, the project will shift its focus to the impending release of the conservation offset framework. The hope is to use the lessons learned through the pilot project and the first two years of this deeper dive to understand how ecosystem services will fit into future conservation offset policy. This may include, but is not limited to, alternative funding models, including green bonds as outlined in the Denhoff (2016) report.

Using the results from the past two years of research, the project team will meet the last goal of the project by identifying policy implications and key conditions to use an ES approach to linear restoration in the province. These conditions may include:

- Technical modeling conditions (taken from 2016 work)
- Challenges moving from local to regional restoration benefit measurements
- Amount of restoration required to see a meaningful change in different ES (taken from 2016 modeling results)
- How to interpret modeling results so the benefits are not misrepresented (over or understated) (taken from 2015 work)
- Additional conditions to be determined.

1 Introduction

The Lower Athabasca watershed in northeastern Alberta is a busy landscape with multiple competing land uses across approximately 10.6 million hectares (Figure 1). The region overlaps the Athabasca Oil Sands formation including the mineable oil sands area, a portion of the Cold Lake Oil Sands formation and over half of the Alberta Pacific Forest Industries Forest Management Agreement (FMA) area. Additionally, the watershed is home to 32 communities, including the city of Cold Lake and Fort McMurray and also overlaps, at least partially, with 11 different caribou ranges, all with declining or data deficient population trends. [1]

The watershed has been fragmented by years of resource exploration and development. In addition, natural disturbances like fire have left a significant mark on the landscape. Recent improvements in oil and gas exploration techniques and the uptake of Integrated Land Management have allowed for faster recovery of the forest from human-caused activities, but there remain thousands of hectares of legacy footprint (e.g. legacy seismic lines) with poor natural recovery. Unlike other human-caused footprint, seismic lines historically have not been required to be reclaimed. Industry and the Government of Alberta are now looking to design restoration programs to encourage reforestation on these seismic lines. Over the past five years, there have been 10 restoration programs focused on linear restoration, implemented by oil and gas.[2] Additionally, the Government of Alberta recently highlighted large-scale linear restoration in the Little Smoky/A La Peche Caribou Range Plan. Implementation of large-scale restoration will significantly increase caribou habitat, reduce wildlife access on legacy seismic lines, and reduce line of sight and predator success of caribou and other ungulates. Furthermore, restoration will add a suite of additional ecosystem services to the landscape, providing various benefits to local communities.

This project is part of a multi-phase, multi-year research initiative. Phase 1 of 'Assessing the Ecosystem Services of the Algar Landscape Ecological Assessment and Planning (LEAP) Project' (Algar ES Phase 1) was a proof of concept pilot program, established in 2013 and designed to assess the ecosystem service benefits derived from linear restoration in species at risk habitat (i.e. the East Side Athabasca River Caribou range). Algar ES Phase 1 provided a critical perspective on how projects that seek to derive ecosystem services and biodiversity benefits perform under a rigorous environmental and economic assessment. The findings of the pilot revealed that there are gains to be realized from undertaking linear restoration. Results of Phase 1 spurred interest in pursuing additional research into understanding the selection of ES, underlying model assumptions, and scalability of assessment results.

Algar ES Phase 2 was launched in the spring of 2015. Phase 2 is a three-year initiative, with the first interim report released in December of 2015. Project partners are working with the Government of Alberta to

[1] Environment Canada (2012). Recovery Strategy for the Woodland Caribou (Rangifer tarandus, caribou), Boreal population in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. Retrieved from: http://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=33FF100B-1#_docInfo
[2] Fuse Consulting (2014). Linear feature restoration in caribou habitat: A summary of current practices and a roadmap for future programs. Prepared for Canada's Oil Sands Innovation Alliance. Downloaded from: http://www.cosia.ca/uploads/documents/id24/COSIA_Linear_Feature_Restoration_Caribou_Habitat.pdf

develop key conditions required to successfully implement an ecosystem service approach to linear restoration. The purpose of the project is to show how an ecosystem service based approach can encourage industry uptake of linear restoration by identifying the supplementary benefits (e.g. water purification, carbon storage, etc.), in addition to caribou and other species at risk habitat enhancements.

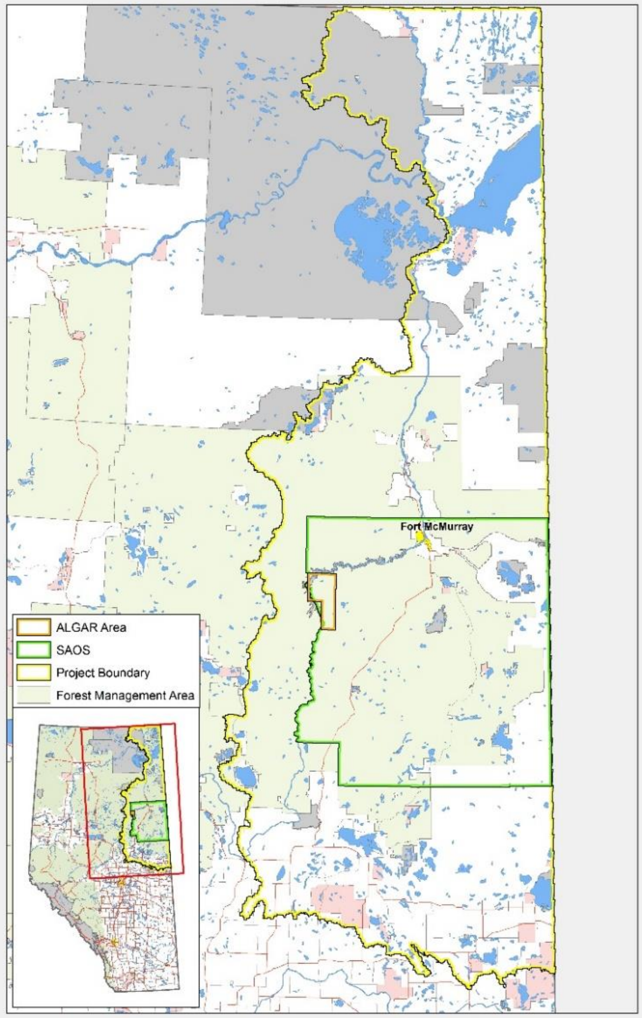

Figure 1 Overview Map

1.1 Project Outcomes

The desired outcome of this project is to further the development of a repeatable, transferable, and implementable approach to evaluating the net benefits of restoration activities in the boreal region and assess the potential for conservation offsets from the restoration of legacy seismic lines. As part of the success of this project, a repeatable framework will be developed to incorporate ES concepts into linear restoration projects and upcoming conservation offset policy. Furthermore, methods will be developed to prioritize areas for restoration based on the suite of ecosystem services provided by the landscape, rather than focusing on just one land value (e.g. species at risk).

1.1.1 Report Objectives

To meet project outcomes, the purpose of this report is to test the transferability and scalability of the 2015 methodologies on another site in Alberta. In transferring ecosystem services assessment methodologies to a new site, the following four questions were proposed:

1. What are the ecosystem service benefits of large-scale linear restoration?
2. How can ecosystem service concepts be used to prioritize areas for restoration?
3. Do different modeling platforms provide similar, repeatable results?
4. How can ecosystem services be used to assess the value of restoration in conservation offset planning?

Answers to these questions are outlined in the report.

1.2 Project Approach

To meet project objectives, Silvacom will continue to work with project partners, the Alberta Biodiversity and Monitoring Institute (ABMI), Alberta Environment and Parks (AEP) and InnoTech Alberta. The project will be completed by meeting three distinct goals:

1. Develop a repeatable process to identify the appropriate ES to evaluate a management plan and its alternatives (i.e. restoration or development);
2. Test the compatibility and transferability of methodologies for assessing ES to other areas of the province; and
3. Evaluate how this assessment fits into the Government of Alberta policy such as the ES framework and offset policies.

Goal 1 of this project was met in 2015 with the release of interim report 1 of 3. Results of Goal 2 will include identification of high priority restoration areas in the Southern Athabasca Oil Sands region and Lower Athabasca watershed, assessment of the amount of restoration required to see a change in ES, looking at both scales, and discussions on how the scale of linear restoration can affect benefit estimates and employment. These results will feed into the last stage of the project. Goal 3 will involve identifying policy implications and key conditions to use an ES approach to linear restoration in the province. These conditions may include:

- Technical modeling conditions (taken from 2016 work);
- Challenges moving from local to regional restoration benefit measurements;
- Amount of restoration required to see a meaningful change in different ES (taken from 2016 modeling results);
- How to interpret modeling results so the benefits are not misrepresented (over or understated) (taken from 2015 work); and
- Additional conditions to be determined.

Throughout the project, team members will continue to meet regularly to share information and expertise. Furthermore, the project team will engage with the advisory committee, established in 2015, to share relevant information and project outcomes across sectors. A scientific advisory panel was also established in 2015 to critique methods and provide guidance at specific points throughout the project (Table 1). Additionally, to ensure project results remain relevant, periodic public release of status updates, interim results, among others, have been and will continue to be posted through project partner websites, the Ecosystem Service and Biodiversity Network (ESBN), and conference presentations.

Table 1 Advisory Committees

Advisory Committee		Scientific Committee	
Name	**Affiliation**	**Name**	**Affiliation**
Dave Poulton	AACO	Tim Vinge	AEP
Dan Farr	AEP	Anne Naeth	University of Alberta
Jerome Cranston	ABMI	John Parkins	University of Alberta
Tom Habib	ABMI	Peter Boxall	University of Alberta
Anish Neupane	AEP	Scott Nielsen	University of Alberta
Angele Vickers	AEP	Stan Boutin	University of Alberta
Brian Makowecki	AEP	Vic Adamowicz	University of Alberta
Kim LaLonde	AEP		
Scott Milligan	AEP/Land Use Secretariat		
Carol Bettac	Alberta Innovates		
Marian Weber	InnoTech Alberta		
Marius Cutlac	InnoTech Alberta		
Jeremy Reid	Devon Energy		
Gord Whitmore	DMI		
Carolyn Tralnberg	Land Use Secretariat		
Simon Dyer	Pembina Institute		
Avelyn Nicol	Independent		

1.3 Background

The first interim report of Phase 2, released in December of 2015, reviews the framework developed to select regionally appropriate ES and indicators through a repeatable, transferable and transparent approach. The Selection Criteria Process revealed that the ES identified in Phase 1 were defendable ES to be assessed in the Algar region. It also revealed that stakeholders in the region also highly value moose for the provision of wild foods and hunting opportunities.

Including moose as an indicator species for the provision of wild foods allowed the ES assessment for the Algar region to identify trade-offs that may occur between stakeholder values. Both caribou and moose provide benefits to communities by their presence (e.g. just knowing they exist), their ability to provide wild foods and the recreational opportunities they provide. However, improving caribou habitat in the region has the potential to reduce the habitat available for moose, and vice versa. Identifying these trade-offs highlighted that regional stakeholders may have differing values and that not all benefits from linear restoration programs can be additive.

Furthermore, a review of Phase 1 methodologies and assumptions identified a number of opportunities to improve future analyses. These recommendations will be taken into account throughout the remainder of the project and in future ES assessments.

Lastly, it was highlighted by advisory committee members that it is important to not misrepresent the benefits gained through linear restoration. This will be imperative for the successful launch of conservation offsets in the province, should the government of Alberta adopt conservation offset banking as a tool to reduce land disturbances in the boreal region. The interim report 1 of 3 discusses the challenges associated with ES modeling and makes recommendations so that the benefits are not misrepresented.

2 Testing the Transferability of Methods

Until now, the focus of the Algar ES project, Phase 1 and 2, has been on the six township region in northeast Alberta, where approximately 350 km of legacy seismic lines were restored over four years by a group of COSIA companies (Figure 1). This area has been treated as a proof of concept to include ES assessments in linear restoration projects. Moving forward, the purpose of the analysis is to identify how the flows of ES are affected through linear restoration on multiple scales and to estimate the amount of linear restoration required to see a change in ES.

Changes in ecosystem function as a result of a management alternative (e.g. linear restoration) can affect multiple intermediate ecosystem services (Figure 2). These interactions result in final ecosystem services that have the potential to affect human well-being. The change in human well-being is what is valued by society (i.e. the net benefits of linear restoration) and can have different impacts depending on the scale in which ecosystem function changes.

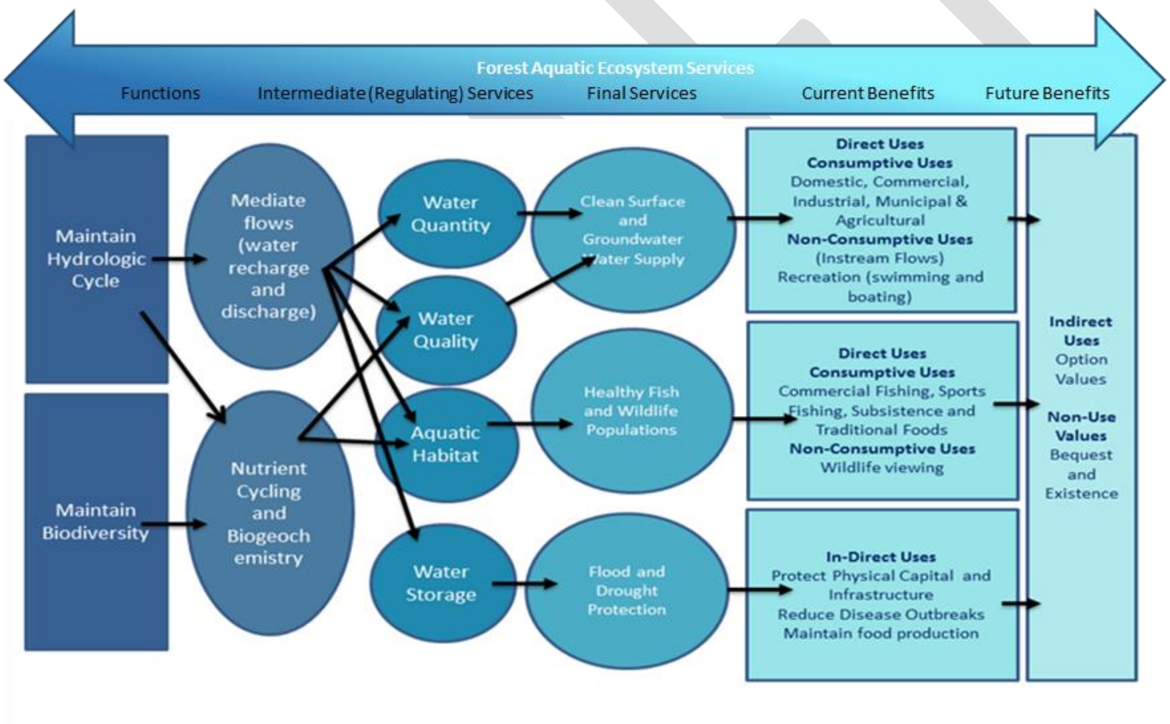

Figure 2 Example of Aquatic Functions, Services, and Benefits (Personal Comm. M. Weber)

In addition, the type of final ES being measured can flow to society in different ways. For example, linear restoration at a sufficient scale may improve downstream water quality, or increase the value of habitat for species at a broader regional scale that is hunted or culturally significant (Figure 3). There are many possible relationships between where ES are produced (in this case where linear restoration occurs (P), and where those actions benefit people (B)). Only in a few cases do the benefits accrue at the site at which restoration takes place.

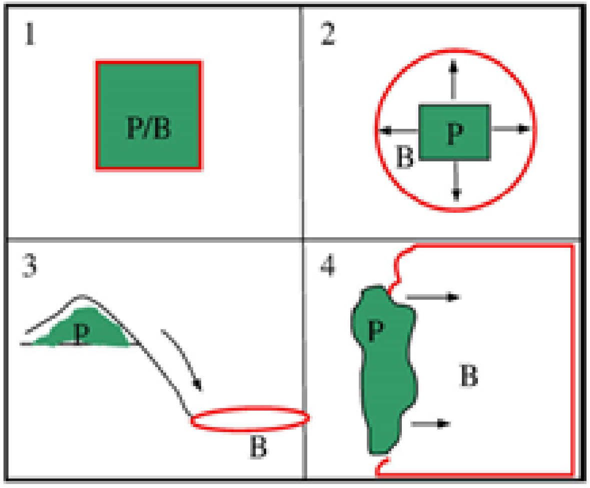

Figure 3 Possible Spatial Relationships between supply (production areas (P)) and demand (service benefit areas modified from (Fisher et al. 2009) (B))[3]

To assess the effect of scale on linear restoration benefits, identification of high priority restoration areas in the Southern Athabasca Oil Sands region and Lower Athabasca watershed were identified and restoration efforts were hypothetically increased, assessing the amount of restoration required to change the flow of ES to communities.

2.1 Scaling Up

The Algar area was chosen collaboratively with six COSIA members looking at areas:

- Off their existing leases
- With low future development potential
- With lowland conditions requiring treatment
- In critical caribou habitat

Over four years, approximately 350 km of legacy seismic lines were treated with winter planting or natural regeneration protection.

While the findings of Phase 1 revealed that linear restoration can provide a number of additional ecosystem services not originally accounted for, scaling up the analysis to a larger area of interest will help identify if these results were repeatable and scalable.

Looking at the potential to scale up linear restoration, Silvacom, with project partners, prepared a list of theoretical areas for restoration within the Southern Athabasca Oil Sands Area (SAOS) and the greater Lower Athabasca Watershed (LAW) (Figure 4) that will provide a suite of ecosystem services (ES). These

[3] Fisher, B., Turner, R. K., and Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological economics, 68(3): 643-653.

two areas were chosen as areas with similar stakeholder values and ecological indicators to the Algar region.

The scaling up analysis seeks to answer the following questions:

1. What are the timing effects of restoration (e.g. if all legacy seismic lines were restored over the next 5 years) on the benefits provided from ES and employment;
2. Where are the least cost areas for restoration?
3. Where are the high priority caribou areas?
4. Where would restoration occur if prioritizing on a basket of ES?

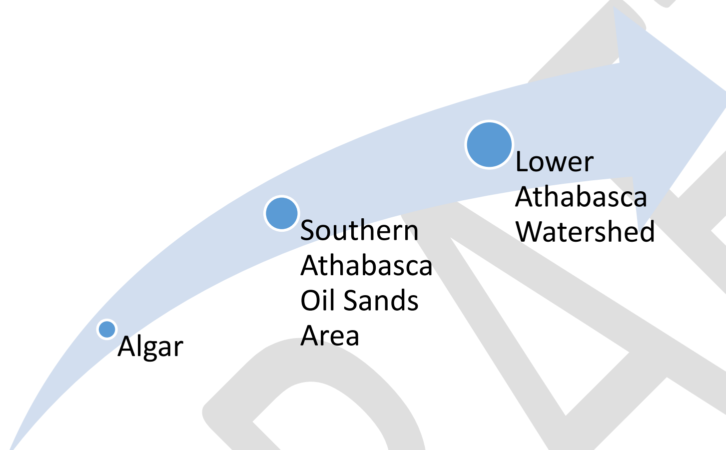

Figure 4 Scaling Up

2.1.1 Area of Interest

The two areas of interest that were chosen to scale up the analysis are both significantly larger than the Algar region. One is an area of intense industrialization and the other, larger region, follows a similar boundary to the Lower Athabasca Planning Region.

The Southern Athabasca Oil Sands Area, formerly known as the OSLI area of interest, is approximately 3.7 million hectares of land within the Lower Athabasca watershed, including townships 72-90, ranges 1-18, west of the 4th meridian (Figure 1). The area encompasses the majority of in-situ development in the Athabasca Oil Sands formation and is just south of the mineable oil sands area. The majority of the area is also shared with a forest management area, currently held by Alberta Pacific Forest Industries. Lastly, Fort

McMurray is on the northern border of the SAOS area, which has had a 28.7% population increase from 2006-2011[4], putting even more pressure on an already heavily disturbed landscape.

The larger Lower Athabasca watershed follows loosely the same boundaries at the Lower Athabasca Regional Planning area (Figure 1). The watershed is approximately 10.6 million hectares and must meet multiple competing land uses, similar to the SAOS. The area overlaps the mineable oil sands area, the Athabasca Oil Sands formation, a portion of the Cold Lake Oil Sands formation and over half of the Alberta Pacific Forest Industries forest management area. Additionally, the watershed is home to 32 communities, including the City of Cold Lake and Fort McMurray and overlaps, at least partially, with 11 different caribou ranges, all with declining or data deficient population trends.[5]

2.1.2 Identifying Stakeholder Values

The interim report 1 of 3 completed in 2015 describes the *Ecosystem Service and Indicator Selection Process* developed as a part of the project.[6] Using the *Ecosystem Services and Indicators Selection Process*, the project team identified six ecosystem services to assess for the Algar region. These included:

- Provision of wild foods (moose populations);
- Provision of raw materials (timber supply);
- Climate regulation (carbon sequestration);
- Regulation of water quality (N, P, TSS);
- Maintenance of genetic diversity (biodiversity intactness) and;
- Supporting habitats/Cultural services (caribou habitat)

As restoration is scaled up to larger regions, it is recognized that it may impact communities differently. Leveraging the selection criteria process developed in 2015, it was determined that on top of the six ES assessed in the Algar region (Phase 2), an additional ES should be included in the assessment. Several reports and policy documents were identified to gather information on stakeholder values.[7] Through this document review, the project team identified maintenance of air quality as a value to be considered in landscape decisions as an important ecosystem service to stakeholders. A literature review identified a

[4] Statistics Canada (2012). Fort McMurray, Alberta (Code 0292) and Alberta (Code 48) (table). Census Profile. 2011 Census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. Released October 24, 2012. http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E (accessed October 28, 2016).
[5] Environment Canada (2012). Recovery Strategy for the Woodland Caribou (Rangifer tarandus, caribou), Boreal population in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. Retrieved from: http://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=33FF100B-1#_docInfo
[6] Silvacom (2015). Assessing the Ecosystem Service Benefits of the COSIA LEAP Program. Phase 2: Interim Report 1 of 3.
[7] Ibid

number of indicators available to measure air quality including leaf area index and air quality amplitudes[8], the flux in atmospheric gasses and atmospheric cleansing (tropospheric oxidizing).[9]

Regulation of air quality was not originally assessed for the Algar region because there were no communities in close proximity to where the restoration had occurred. Furthermore, there is a lack of quantifiable effects on air quality resulting from small-scale restoration (e.g. 350 km of legacy seismic lines). As restoration is scaled up to the SAOS area, approximately 25,400 ha (42,300 km)[10] of legacy seismic lines (ABMI Human Footprint, 2012) could potentially be restored. The Lower Athabasca watershed has almost 50,000 ha (83,300 km) of legacy seismic lines (ABMI Human Footprint, 2012) that may be eligible for restoration. This type of large-scale restoration has a much higher potential to affect the regulation of air quality.

Air quality is mentioned as a concern for stakeholders in the region. There are 32 communities within the Lower Athabasca watershed, including two cities. The Lower Athabasca Regional Plan outlined air quality as a key consideration in land use decisions in the region. The Fort McKay First Nation Consultation (2012) and Fort McMurray First Nation Consultation (2012) note maintenance of air quality as an important value. The Government of Alberta is also closely monitoring air quality in SAOS. Furthermore, there are models focused on air quality and air quality relevant to the quality of life in the area being used.

A number of relevant policies and regulations provide insight into the types of considerations for air quality that are important to the government. These include but are not limited to:

- Alberta Ambient Air Act
- Clean Air Strategy
- Alberta Ambient Air Quality Objectives and Guidelines Summary
- Canadian Ambient Air Quality Standards
- Canadian Environmental Protection Act, 1999
- Pollution Prevention - https://www.ec.gc.ca/p2/

Regulation of air quality was identified as the project scaled up which demonstrates the ability to scale up and down the 7-Step Selection Criteria Framework. However, for the remainder of the assessment, the scope of the project is focused on scaling up the modeling frameworks of the previously identified ES for the Algar region. Therefore, air quality will not be modeled at this time. Future analysis should consider regulation of air quality as an ecosystem service to model and assess. Table 2 shows the ecosystem service selection criteria template for air quality regulation completed by the project team.

[8] Muller, F., and Burkhard, B. (2012). The indicator side of ecosystem services. Ecosystem Services, 1:1, pp 26-30.
[9] Layke, C. (2009). Measuring nature's benefits: A preliminary roadmap for improving ecosystem service indicators. World Resources Institute, Working Paper.
[10] Assuming an average width of 6 meters.

Table 2 Ecosystem Service Selection Criteria– Air Quality Regulation

Ecosystem Service Characteristics				
Ecosystem Service:	Air Quality Regulation			
Stakeholder Value:	Maintain current air quality;[11,12]			
Description:	Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality [13]			
Stakeholders				
Are there stakeholders within the defined region?	☒Yes ☐ No ☐Unconfirmed	• General Public • First Nations • Industry		
Ecosystem Service Type		**Market Prices**		
☐ **Provisioning**	☒ **Regulating**	**Is there a market price available?**	☒ Yes	☐ No ☐Unknown
☐ **Cultural**	☐ **Supporting**	**If no, can a market price be created?**	☐ Yes	☐ No ☐Unknown
Timeline		**Scale of Benefits**		
Estimated time until benefits are received:	1+ years	**In-situ** ☐	**Larger than Area of Interest** ☒	**Down-stream** ☐
Ecosystem Service Selection Criteria				
How many times the stakeholder value was identified	2	**Can we model a change in defined indicators for the ES?**	☒ Yes ☐ No	
Does the ES clearly link to the stakeholder value?	☒ Yes ☐ No	**Is there available input data for the model?**	☒ Yes ☐ No	
Is the ES currently relevant to policy (current or upcoming)	☒ Yes ☐ No	**If yes, is the data freely available?**	☒ Yes ☐ No	
If yes, specify which policy: Alberta Ambient Air Act, Clean Air Strategy		**Is the model transparent and easy to understand?**	☒ Yes ☐ No	
Additional comments: Market price for air quality is assumed to be the market price of carbon.				
Approvals				
Include on Final ES List:	☐**Yes** ☒ **No**	**If yes, continue to indicator section**		
Reason for in/exclusion:	The effect of linear restoration in the region will likely cause a change in air quality; there remains the potential to double count ES, depending on the indicator chosen (cannot be a CO2e) as is measured for climate regulation			

[11] Fort McKay First Nation Consultation (2012)
[12] Fort McMurray First Nation Consultation (2012)
[13] Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

3 Prioritizing Areas for Restoration

3.1 Objectives

The timing and location of where restoration is to occur on the landscape may have the potential to affect the flow of benefits to stakeholders in the region. The purpose of this analysis was to:

- Identify how to prioritize seismic restoration to address ES benefits;
- Identify what the timing effects of restoration (e.g. if all seismic lines were restored over the next 5 years) would be on the benefits provided from ES; and
- Identify how we can use ES to assess the value of restoration for conservation offsets.

3.2 Prioritizing Restoration to Address ES Benefits

The Lower Athabasca watershed (LAW) is approximately 10.6 million hectares. The area was rasterized into townships (approximately 9,900 ha), with the assumption that townships will be grouped together to choose a restoration area large enough to see an increase in ES benefits.

In the past, restoration projects have been chosen based on either cost-effectiveness of the program, ecological priority (e.g. in species at risk habitat), or a combination of both. To prioritize areas in the Lower Athabasca watershed, a number of indicators were chosen to identify high ecological value and low-cost areas within the watershed. These include:

- Caribou ranges
- Riparian areas
- Lowland/Upland sites
- High-value ES locations
- Seismic density
- Accessibility
- Probability of future development
- Existing restoration projects
- Fire events over the past 10 years

3.2.1 Indicators

Multiple factors require consideration when deciding on the location, timing, and methodologies for linear restoration. For the purposes of the project, indicators were divided into three categories to represent different values on the landscape.

- Ecological Indicators
- Cost Savings Indicators
- Additional Considerations

Ecological indicators are considered when prioritizing restoration to help link ecological changes to human well-being. Each ecological indicator is linked to an ES identified as high-value through our literature review of stakeholder values. Furthermore, some ecological indicators help identify where seismic lines may be slow to revegetate on their own (e.g. lowland areas), increasing the need for intervention.

Following the original objectives of linear restoration in the Algar region and the release of the Little Smoky and A La Peche Range Plan, caribou habitat restoration was identified as a driving factor for selecting legacy seismic lines for linear restoration. To incorporate caribou habitat, caribou ranges are included in the analysis. Caribou are often associated with lowland areas like muskegs and peatlands[14],[15],[16] and these areas are typically slow to revegetate on their own, making intervention necessary to improve caribou habitat over time. Riparian areas also contribute significantly to biodiversity. [17] Furthermore, high-value ecosystem service sites were calculated as in Constanza et al., and de Groot et al., studies. [18],[19] to account for commonly valued landscape features for ecosystem services.

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[14] Adam R. C. James, Stan Boutin, Daryll M. Hebert, and A. Blair Rippin (2004). Spatial Separation of Caribou from Moose and Its Relation to Predation by Wolves. *The Journal of Wildlife Management*. Vol. 68, No. 4, pp. 799-809.
[15] W. James Rettie, François Messier (2000). Hierarchical habitat selection by woodland caribou: its relationship to limiting factors. *Ecography: Pattern and Process in Ecology.* Vol. 23, No. 4, pp. 466–478.
[16] Environment Canada (2012). Recovery Strategy for the Woodland Caribou (Rangifer tarandus caribou), Boreal population, in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. xi + 138pp.
[17] Government of British Columbia (1998). Riparian Areas: Providing Landscape Habitat Diversity PART 5 of 7. Ministry of Forests Research Program.
[18] Robert Costanza, Rudolf de Groot, Paul Sutton, Sander van der Ploeg, Sharolyn J. Anderson, Ida Kubiszewski, Stephen Farber, R. Kerry Turner (2014). Changes in the global value of ecosystem services. *Global Environmental Change*. Vol. 26, pp. 152-158.
[19] Rudolf de Groot, Luke Brander, Sander van der Ploeg, Robert Costanza, Florence Bernard, Leon Braat, Mike Christie, Neville Crossman, Andrea Ghermandi, Lars Hein, Salman Hussain, Pushpam Kumar, Alistair McVittie, Rosimeiry Portela, Luis C. Rodriguez, Patrick ten Brink, Pieter van Beukering (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services*. Vol. 1, pp. 50-61.

In summary, ecological indicators chosen were:

- Caribou ranges;
- Riparian areas;
- Lowland sites and;
- High-value ecosystem service sites.

The expected costs associated with a restoration program are also important. To increase the realism of the analysis, low-cost landscape indicators were included in the model.

Experience working on seismic restoration projects allowed the project team to identify landscape based cost factors for seismic restoration. High seismic density and upland sites are typically less expensive per km to treat. For instance, the higher density of seismic lines in an area, the less time and effort is required to access and work on lines. This allows more kilometers of lines to be restored relative to a project with fewer lines per square kilometer for the same amount of effort. Upland sites are also easier to access and require less specialized equipment than lowland sites. To limit damage to soil and vegetation, lowland sites usually require the ground to be frozen to conduct seismic restoration. Lastly, proximity to access like roads and highways makes seismic restoration less time consuming and less expensive. Access to other infrastructure can also limit the need for additional lodging (e.g. camps) which are time-consuming and expensive.

In summary, cost indicators included were:

- Seismic density;
- Upland sites and;
- Proximity to access and infrastructure.

Other considerations were also included in the analysis to best represent the landscape and ensure a better understanding of the effects of development and seismic restoration on ecosystem services. Further to the outlined ecological indicators and cost indicators were some limiting factors that were considered. If a site was identified to have a high probability of future development, seismic restoration would not likely achieve the outlined goals of the restoration project. Existing restoration project sites were also removed, as these projects have been implemented after the vintage of the land base data. Finally, recent fires will have burned areas around seismic lines thus resetting the stage of forest growth in the area.

In summary, other considerations included in the analysis are:

- Probability of Future Oil and Gas Development;
- Existing Restoration Projects and;
- Recent Fire Events (within 10 years).

The following sections describe each of the aforementioned indicators and considerations.

3.2.1.1 Ecological Indicators

3.2.1.1.1 Caribou Ranges

Woodland Caribou is designated as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is listed under the Species at Risk Act (SARA). Under SARA, the federal government released a recovery strategy in 2012 with a goal of achieving self-sustaining populations in all ranges across Canada. The recovery strategy outlines a target of 65% undisturbed habitat to improve the likelihood of herd survival.

In Alberta, many of the caribou populations are in steep decline due to both natural and anthropogenic pressures on the landscape. In the recovery strategy, the federal government requested the provincial and territorial governments develop range specific recovery plans by 2017. With linear fragmentation having a significant impact on the probability of herd survival in the province, it is predicted large-scale linear restoration will be necessary to see improvements in Alberta populations.[20, 21]

There are a number of caribou ranges that fall within the Lower Athabasca watershed. In total, approximately 36% of the area is within a range (Figure 5).

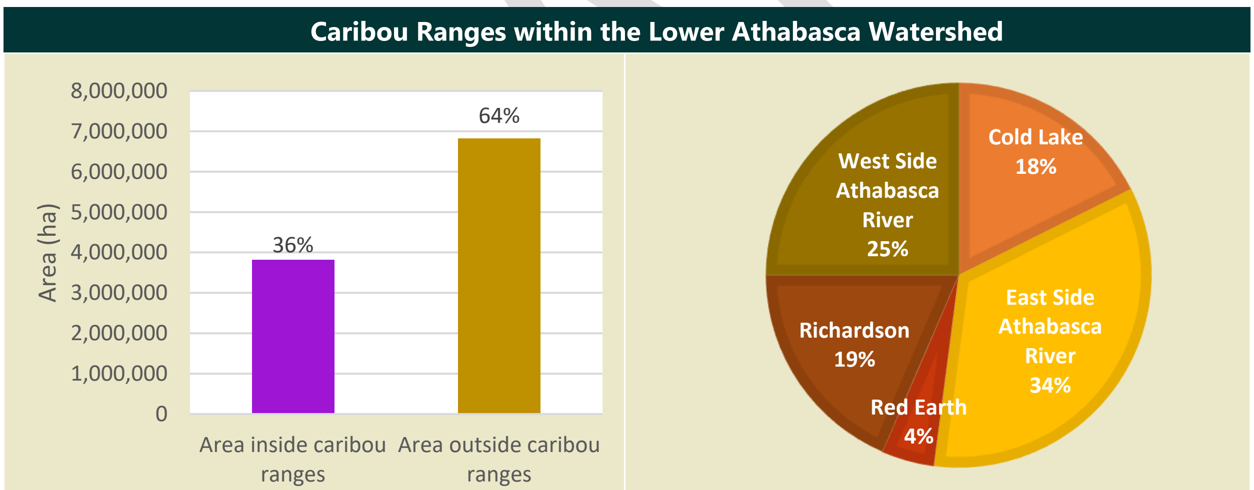

Figure 5 Caribou Ranges within the Lower Athabasca Watershed

To prioritize areas within a caribou range, townships were split into four categories and rated respectively:

(3) Completely within a caribou range
(2) Over 50% within a caribou range
(1) Less than 50% within a caribou range
(0) Not within a caribou range

[20] Denhoff (2016). Setting Alberta on the Path to Caribou Recovery. Downloaded from: http://aep.alberta.ca/fish-wildlife/wildlife-management/caribou-management/caribou-action-range-planning/documents/OnThePathtoCaribouRecovery-May-2016.pdf
[21] Government of Alberta (2016). Little Smoky and A La Peche Caribou Range Plan (DRAFT).

3.2.1.1.2 Riparian Areas

Riparian areas are ecologically significant areas that, when healthy, are covered in lush trees, shrubs, and grasses. These areas are the last line of defense to filter out sediments and other pollutants from waterways. They also contribute to soil erosion control and plant diversity, to name a few. These areas provide a number of values to people in the form of ecosystem services, highlighting their importance for consideration as high priority areas for restoration.

For this analysis, riparian areas were defined by buffering watercourses. Following the Alberta Timber Harvest Planning and Operating Ground Rules, based on the type of watercourse, the buffer varied. Streams were buffered 30m, rivers were buffered 60m and lakes were buffered 100m.[22]

Townships were flagged if they contained legacy seismic lines within these buffered areas, then prioritized based on the relative amount within the watershed. Townships were split into four categories and rated respectively:

- (3) Above average seismic density within riparian areas
- (2) Average seismic density within riparian areas
- (1) Below average seismic density within riparian areas
- (0) No seismic within riparian areas

3.2.1.1.3 Lowland Sites

Legacy seismic lines within lowland sites naturally regenerate much slower than upland sites. Some legacy seismic lines in low-lying areas have been on the landscape for upwards of 50 years.[23] Because restoration of seismic lines is currently not required under current regulations, these areas that are slow to naturally regenerate are contributing a significant amount to the linear fragmentation of the boreal forest. These sites are also much more difficult to access and rely heavily on innovative techniques such as winter planting for linear restoration.

Land cover was used as a proxy to identify lowland sites within a township. If the forested area was identified as conifer, black spruce leading or the land cover was defined as shrub in the ABMI Land Cover (2010), these areas were flagged as lowland. Furthermore, riparian areas, as defined above, were also flagged as lowland. All other forested types were considered upland. Townships were split into four categories and rated respectively:

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[22] Alberta Environment and Sustainable Resource Development (2012). Alberta Timber Harvest Planning and Operating Ground Rules Framework for Renewal. Forestry Division. Forest Management Branch.
[23] Van Rensen, C. K. (2014). Predicting patterns of regeneration on seismic lines to inform restoration planning in boreal forest habitats. Thesis submitted to the Department of Renewable Resources. University of Alberta.

(3) Over 50% Lowland
(2) Over 25% Lowland
(1) Less than 25% Lowland
(0) No Lowland

3.2.1.1.4 High-Value ES Sites

Healthy ecosystems provide a suite of benefits to people in the form of ecosystem services. Placing a dollar value on these benefits can help identify high priority areas and ecological hot spots in a way that is easily understood by decision makers. Furthermore, regional aggregates can also be useful for assessing land use change scenarios.[24]

Costanza et al. (1997) applied a benefits transfer approach to estimate the value of 17 ES that were provided by different land cover types (e.g. forested areas, coastal systems, wetlands, etc.) globally.[25] De Groot et al. (2012) followed a similar approach, where the value provided by 10 different land cover types was estimated.[26]

Following a parallel approach, using the ABMI Land Cover (2010) map and a literature review of ES valuation studies, the ES value was mapped for the watershed, based on land cover types (e.g. rivers and lakes, grasslands, and forests). Townships were then split into four categories and rated respectively, based on the estimated sum of ES values in the area:

(3) Above average ES value
(2) Average ES value
(1) Below average ES value
(0) No, or negative ES value

3.2.1.2 Cost-Savings Indicators

3.2.1.2.1 Seismic Density

Overall cost per kilometer can be reduced in areas with dense seismic lines by creating operational efficiencies and improving access to remote areas. For example, the amount of time needed to transport equipment from one treatment line to the next is dramatically reduced when treatments lines are grouped close together.

Relative seismic density was calculated to estimate the amount of historic linear footprint within a township. The ABMI Human Footprint Map (2012) was used to identify legacy seismic lines, and a width of 6m was assumed to calculate density. Rather than choosing a discrete amount of km/km2 that would be

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[24] Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S., Kubiszewski, I., Farber, S., Turner, R.K. (2014). Changes in the global value of ecosystem services. Global Environmental Change 26 152-158.
[25] Constanza, R. et al. (1997). The value of the world's ecosystem services and natural capital. Nature 387 253-260
[26] De Groot, R. et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services 1 50-61.

considered "high", above average to below average was calculated for the entire watershed. The highest density township was approximately 10.74 km/km^2, with the average much lower at 0.92 km/km^2. Townships were split into four categories and rated respectively:

(3) Above average density
(2) Average density
(1) Below average
(0) No legacy seismic lines present

3.2.1.2.2 Upland Sites

Upland sites can be accessed in the summer months, which can reduce the amount of preparation time needed to enter an area (e.g. winter roads and line freezing are not required). These areas also tend to naturally regenerate much faster than their lowland counterpart, therefore natural regeneration protection may be the most suitable treatment for these areas, further reducing the cost.

Land cover was used as a proxy to identify upland sites within a township. If the forested area was identified as deciduous dominated or mixed wood these areas were flagged as upland, unless within a riparian area. Townships were split into four categories and rated respectively:

(3) Over 50% Upland
(2) Over 25% Upland
(1) Less than 25% Upland
(0) No Upland

3.2.1.2.3 Proximity to Access and Infrastructure

Proximity to current infrastructure is currently the most cost intensive variable. The further away from all season access, the longer it will take workers to arrive at a restoration site. Furthermore, there may be a need for a camp if the restoration site is in a remote area, where no infrastructure is present.

To estimate proximity, all season roads, which included paved and gravel roads within the ABMI Human Footprint Map (2012), were buffered 10 km on each side. Each active oil sands project within the LAW was also buffered 10 km. Any township that fell within these buffers was identified as a relatively accessible township. Additional townships were split into categories as follows and rated respectively:

(3) Easily accessible (completely within 10km of a road or active project)
(2) Somewhat accessible (at least 50% within 10km of a road or active project)
(1) Not accessible (less than 50% within 10km of a road or active project)

3.2.1.3 Other Considerations

3.2.1.3.1 Probability of Future Oil and Gas Development

The probability of future development is a special concern within the Lower Athabasca region, where the entire Southern Athabasca Oil Sands area falls within it. To estimate the vulnerability of areas to be developed in the future, a hypothetical build-out was completed under an aggressive production simulation scenario.

The production scenario follows the CAPP outlook (2015), which uses the current capacity of operating and in construction projects, along with approvals and market factors to estimate the amount of barrels per day (b/d) the oil sands areas are likely to produce up to 2030. Following 2030, the rate of change estimated by CAPP from 2020-2030 was continued to extrapolate production until 2065 (50 years from today).

Using the bitumen pay thickness layer, available from AER, the future location of oil sands projects was estimated. The estimation is based on the assumption that projects go where bitumen pay is thickest first. This analysis does not account for individual company operating plans or lease boundaries.

For a more detailed review of this analysis, refer to Section 4.2.

If any part of the township is simulated to have future development, it is not considered for linear restoration at this time.

3.2.1.3.2 Existing Restoration Projects [27]

There are a number of active linear restoration projects occurring within Alberta. When prioritizing new areas for restoration, these projects were considered to reduce the duplication of effort. Current restoration projects include:

- Algar Linear Restoration Program
- Cenovus Linear Deactivation (LiDea) Program
- Dillon Wildlands Caribou Restoration Project
- MEG Energy Christina Lake
- Shell Grosmont
- Suncor Firebag

There are other active linear restoration programs that were not considered in this analysis as the scope of the restoration did not cover enough area within a township to justify exclusion, or the goal of the project was different than revegetation.

[27] Fuse Consulting (2014). Linear feature restoration in caribou habitat: A summary of current practices and a roadmap for future programs. Prepared for Canada's Oil Sands Innovation Alliance. Downloaded from: http://www.cosia.ca/uploads/documents/id24/COSIA_Linear_Feature_Restoration_Caribou_Habitat.pdf

3.2.1.3.3 Fire Events

There have been two significant fire events with the LAW over the past 10 years (Figure 6).

With fire resetting the ecological clock in many cases, it can be assumed that the legacy seismic lines within these fire boundaries have likely been erased from the landscape.

3.2.1.4 Combining Indicator Values

Indicator values were combined to identify high-value ecological areas and low restoration cost areas. Each indicator was weighted equally (Figure 7).

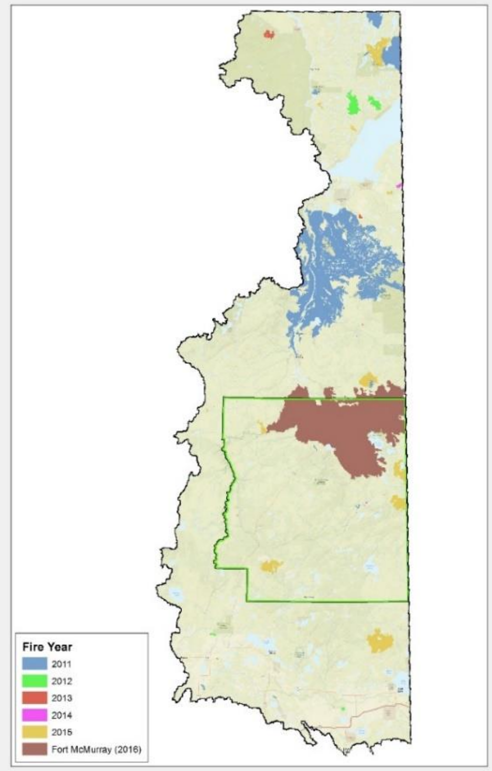


Figure 6 Fire Distribution within the Lower Athabasca watershed from 2011-2016

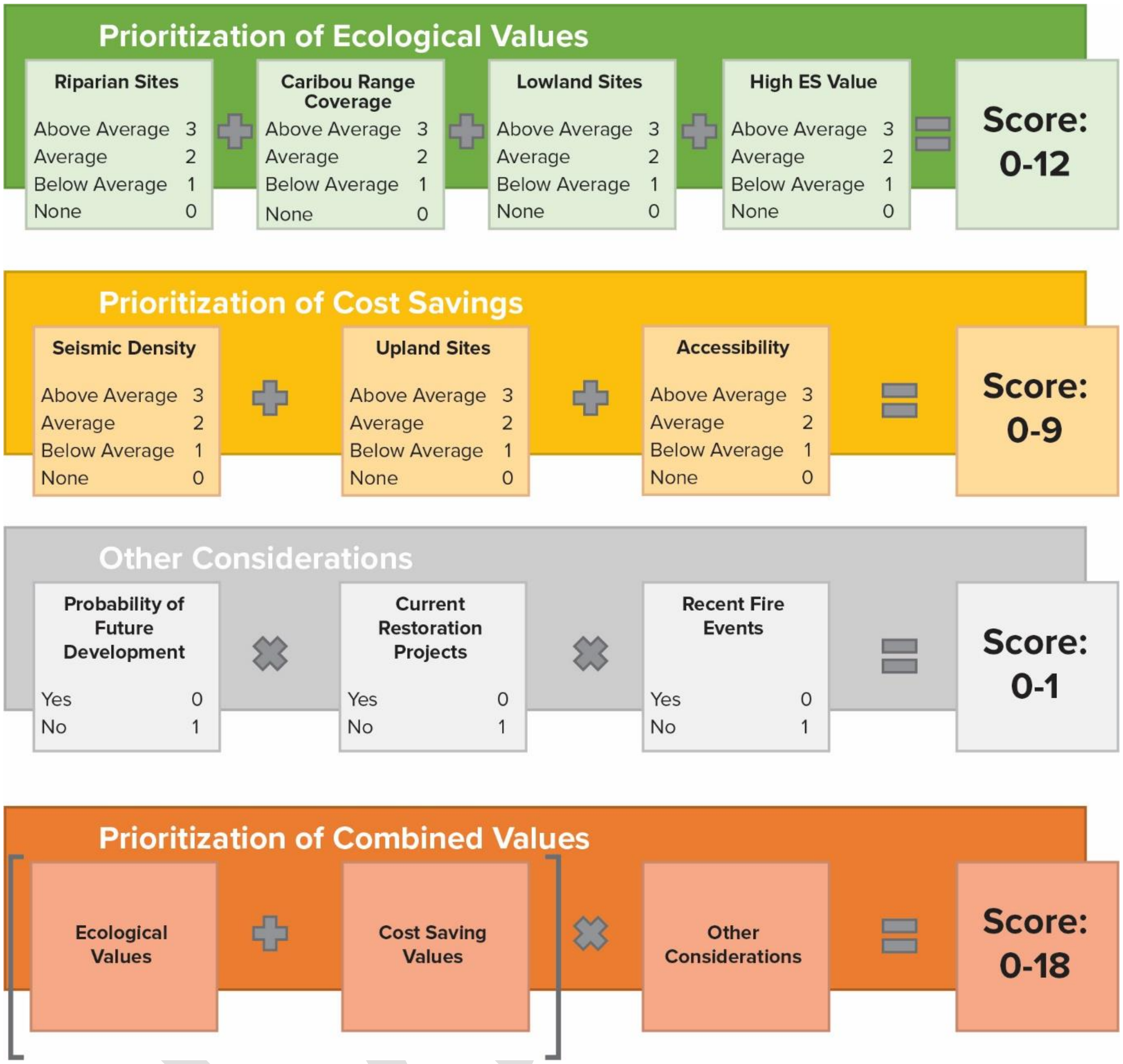
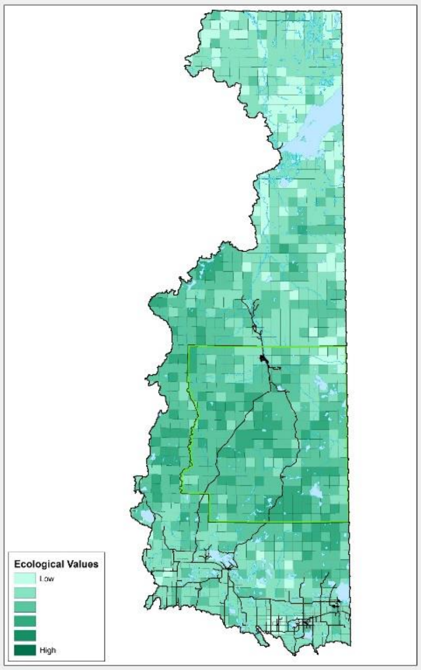
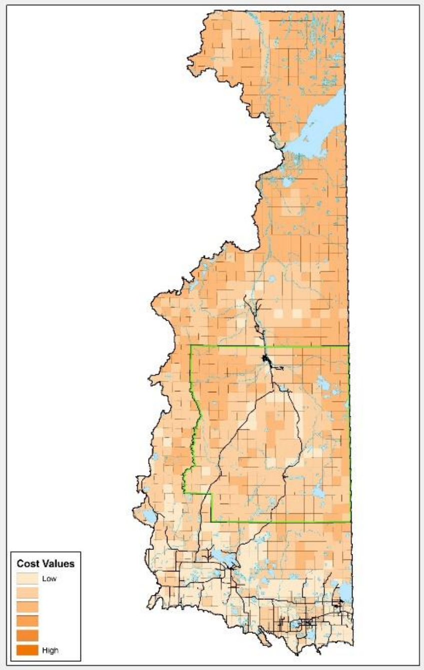
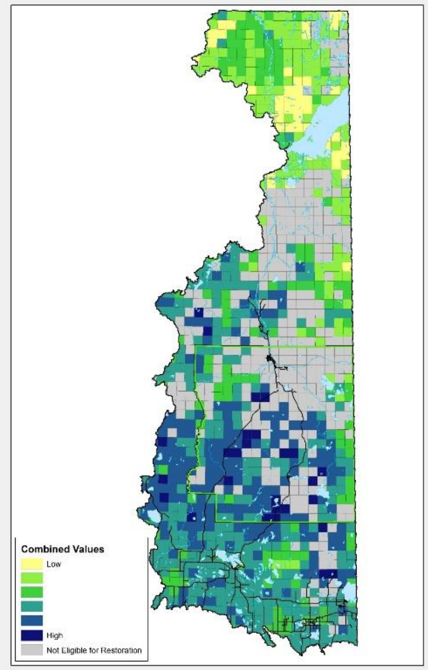


Figure 7 Combining Ecological and Cost-Savings Values for township level linear restoration prioritization

3.2.2 Results

Ecological Values	Cost Values	Combined Values
		

3.3 Timing of Restoration

The government of Alberta released the draft caribou range plan for the Little Smoky/A La Peche caribou ranges in west-central Alberta this June.[28] The plan outlines large-scale linear restoration of legacy seismic lines within five years to maintain and increase effective habitat over the next 50 years. It can be assumed that a similar approach will be taken with the caribou ranges in the Lower Athabasca watershed, where the legacy footprint is a driving factor for habitat alteration and population declines.

Three restoration scenarios were developed in partnership with the advisory committee and project team that follow a similar approach to the Little Smoky/A La Peche range plan. These scenarios were developed to address the effects of the amount, location, and timing of restoration on the flow of benefits to beneficiaries.

1. All legacy seismic lines within caribou ranges in the Lower Athabasca watershed are restored over five years, following the draft Little Smoky/A La Peche range plan directly.
2. 50% of legacy seismic lines within caribou ranges in the Lower Athabasca watershed are restored over five years. Restoration is targeted toward low linear density areas first, where the biggest impact can be made on intactness within the caribou ranges.

[28] Government of Alberta (2016). Little Smoky and A La Peche Caribou Range Plan (DRAFT).

3. Five focused restoration projects are completed, one every year. These projects are five to six townships in size and identified as high-value, low-cost areas for restoration.

3.3.1 Assumptions

Each restoration scenario assumes all legacy seismic lines, identified by the ABMI Human Footprint Map (2012) are eligible for restoration. Further strategic to tactical planning will be needed to identify which lines are currently on a natural trajectory to recovery and do not require additional restoration treatments. To ensure the benefits of the three restoration scenarios are not misrepresented, it will be important to identify these assumptions and discount the benefits accordingly. For example, Lee and Boutin (2006) estimate that approximately 65% of legacy seismic lines remain non-forested after 35 years, these typically being in lowland conditions.[29]

While this analysis does take into account seismic lines that have been or will likely be converted to other uses (e.g. pipeline right-of-way), it does not account for recreational and off-highway vehicle use of the lines, which is expected to impede natural regeneration, even if restoration treatments were to occur. However, a recent study by K. Pigeon et al. (2016)[30] found that seismic lines that facilitate ease of travel are more likely to be accessed for OHV use. Other landscape attributes like the proximity to campgrounds and other infrastructure are not likely to increase the probability of use. It can be argued, that if restoration treatments are focused on reducing ease of access, with mounding, coarse woody debris placement, etc. access for recreational uses may be limited following restoration treatments.

Furthermore, the probability of future oil and gas development was considered when prioritizing areas for restoration, but forestry operations were omitted. This assumption was made because restoration is to occur over the next five years. The amount of overlap between harvest blocks and seismic lines eligible for restoration is likely to be minimal in such a short timeframe. In other areas of the province, where forestry is the dominant industry, or if restoration is to occur over a longer timeframe, this assumption would likely need to be revisited.

It was also assumed that without intervention seismic recovery would take upwards of 50 years, except for seismic lines running through black spruce stands, which would take 70 years to recover naturally. For more details on footprint recovery, please see Table 8 and Section 4.2.2 Footprint Assumptions.

Finally, because the focus of this analysis is on the linear restoration of legacy seismic lines, the baseline developed to test how restoration scenarios perform under the ecosystem service framework (see Section 4) follows the legal requirements for restoration. For example, all oil and gas development that has a legal requirement to be reclaimed over the life of the project still occurs. The additionality of the restoration

[29] Lee and Boutin (2006). Persistence and developmental transition of wide seismic lines in the western Boreal Plains of Canada. Journal of Environmental Management 78 (2006) 240–250.
[30] K. Pigeon et al. (2016). Toward the restoration of caribou habitat: Understanding factors associated with human motorized use of legacy seismic lines. Environmental Management. Volume 58:5 pp 821-832.

work is caused by legacy seismic line restoration going above and beyond current regulatory requirements.

3.3.2 Results

The timing of restoration was estimated by rasterizing the landscape by townships and grouping each township into years one through five for restoration. Further strategic to tactical planning will be needed to group the townships into operational units, however, this should not change the results of the ES benefit analysis, since all restoration is to occur within five years.

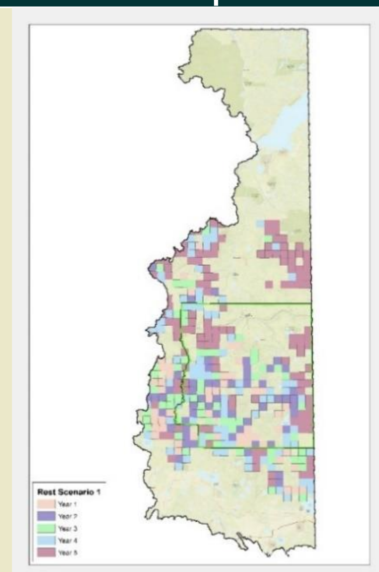
3.3.2.1 Scenario 1: All legacy seismic lines within caribou ranges are restored within five years

This restoration scenario follows the same guidelines as the Little Smoky/A La Peche caribou range plan where 100% of legacy seismic lines within caribou ranges will be restored within five years. Below is a summary of the townships eligible for restoration, grouped into years one through five (see colored map).

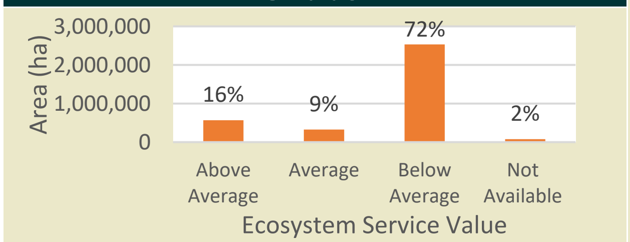
Land Cover

Category	Area (ha)	Percent
Forested	2,697,491	77%
Water	140,233	4%
Shrub/Grassland	557,841	16%
Crops/Pasture	11,205	0%
Exposed Land	20,165	1%
Anthropogenic Footprint	78,194	2%
No Data	53	0%
Total Area	**3,505,181**	**100%**

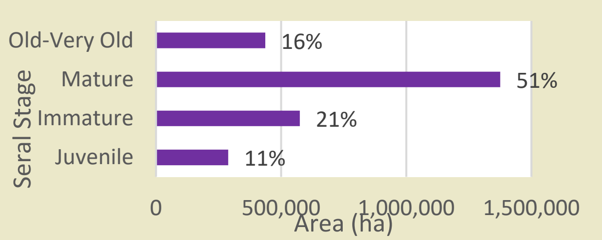
Map



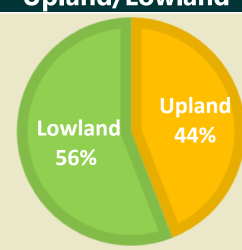
ES Value[31]



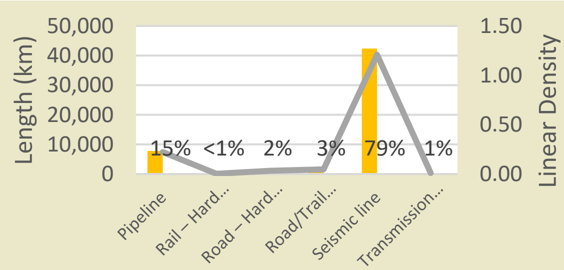
Seral Stage



Upland/Lowland



Linear Density



Total Linear Density:
1.52 km/km^2

Total Km of Seismic Lines:
42,382 km

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[31] Using the ABMI Land Cover (2010) map and a literature review of ES valuation studies, the ES value was mapped for the LAW, based on land cover types (e.g. rivers and lakes, grasslands, and forests).

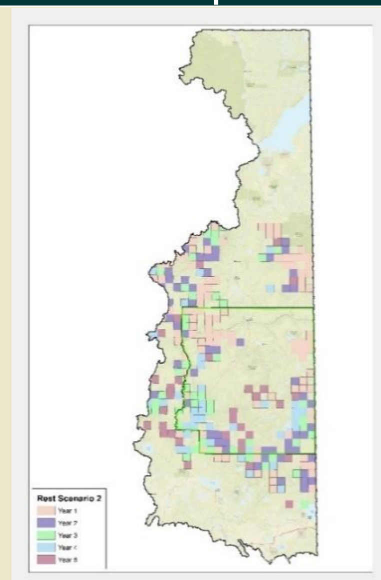
3.3.2.2 Scenario 2: 50% of legacy seismic lines within caribou ranges are restored within five years

Under this restoration scenario, townships were chosen for restoration based on low seismic density areas and location within a caribou range. Below is a summary of the townships eligible for restoration, grouped into years one through five (see colored map below).

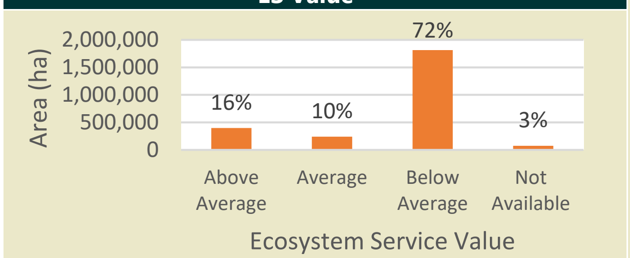
Land Cover

Category	Area (ha)	Percent
Forested	1,945,936	77%
Water	112,087	4%
Shrub/Grassland	398,533	16%
Crops/Pasture	10,920	0%
Exposed Land	18,594	1%
Anthropogenic Footprint	44,401	2%
No Data	38	0%
Total Area	**2,530,508**	**100%**

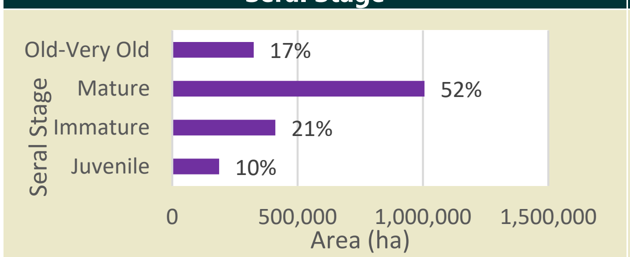
Map



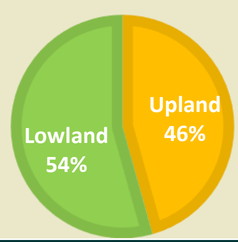
ES Value[32]



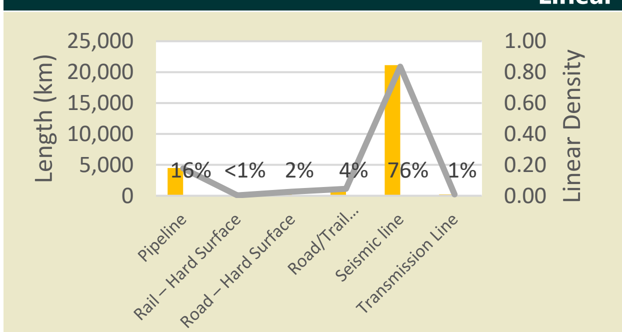
Seral Stage



Upland/Lowland



Linear Density



Total Linear Density:
1.09 km/km^2

Total Km of Seismic Lines:
21,144 km

[32] Using the ABMI Land Cover (2010) map and a literature review of ES valuation studies, the ES value was mapped for the LAW, based on land cover types (e.g. rivers and lakes, grasslands, and forests).

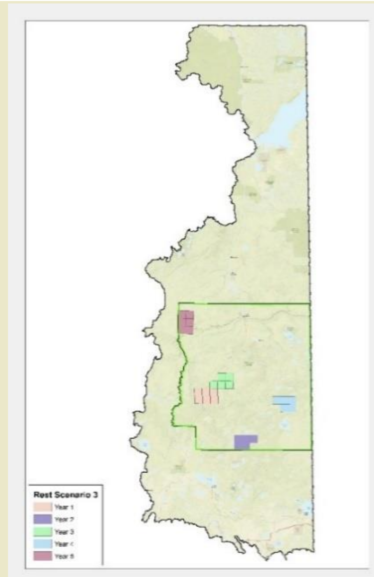
3.3.2.3 Scenario 3: Five focused restoration projects are completed over five years

Under this restoration scenario, areas were chosen based on low-cost, high ecological value regions. Below is a summary of the townships eligible for restoration, grouped into years one through five (see colored map below).

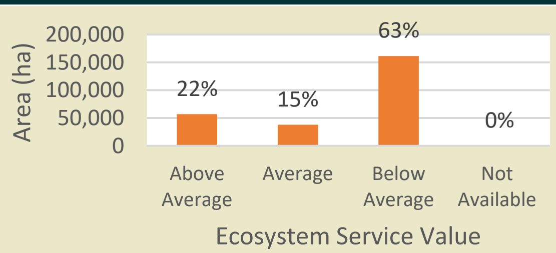
Land Cover

Category	Area (ha)	Percent
Forested	215,456	84%
Water	9,683	4%
Shrub/Grassland	24,071	9%
Crops/Pasture	3	0%
Exposed Land	171	0%
Anthropogenic Footprint	6,806	3%
No Data	0	0%
Total Area	**256,190**	**100%**

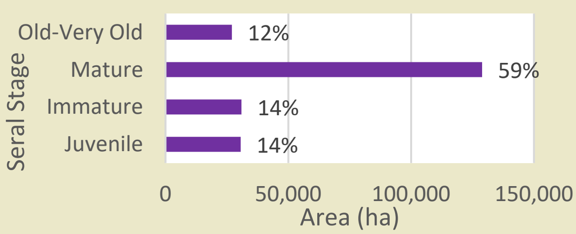
Map



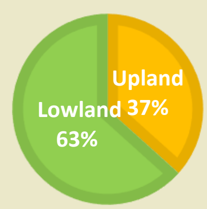
ES Value[33]



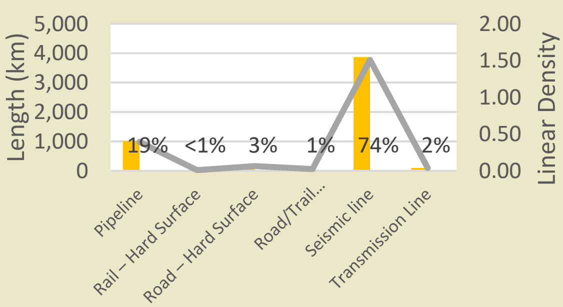
Seral Stage



Upland/Lowland



Linear Density



Total Linear Density:
2.04 km/km^2

Total Km of Seismic Lines:
3,864 km

[33] Using the ABMI Land Cover (2010) map and a literature review of ES valuation studies, the ES value was mapped for the LAW, based on land cover types (e.g. rivers and lakes, grasslands, and forests).

4 ES Indicator Modeling

Following a similar ES benefits framework developed by Keeler et. al (2012)[34] (Figure 8), the first step in the modeling approach was to identify the action (e.g. reforestation of legacy seismic lines), then assess how this action changes the supply in biophysical indicators (e.g. caribou habitat). This change in supply is then linked to a change in ecosystem services (e.g. the cultural values linked to sustainable caribou populations), and this change is valued to estimate a change in human well-being.

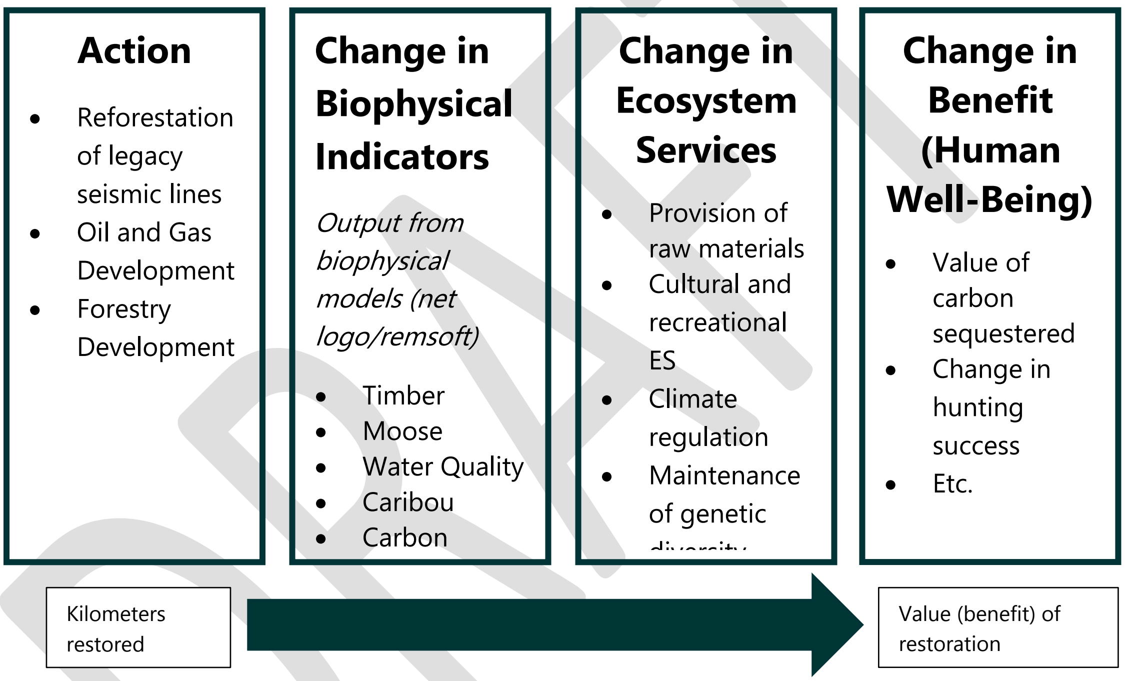


Figure 8 ES Benefits Framework Modified from Keeler et al. (2012).

4.1 Modeling Approach

The ecosystem service assessment approach estimates the change in the supply of six ecosystem service indicators over 50 years. These indicators were identified through the 7-Step Selection Criteria Process developed in 2015.[35]

[34] Keeler et. al (2012). Linking water quality and well-being for improved assessment and valuation of ecosystem services. *PNAS* doi: 10.1073/pnas.1215991109
[35] Silvacom (2015). Assessing the Ecosystem Service Benefits of the COSIA LEAP Program: Phase 2. Interim Report 1 of 3.

The assessment compares the change in the supply of ES in a no intervention state (i.e. natural regeneration, status quo) and with linear restoration (Figure 9).

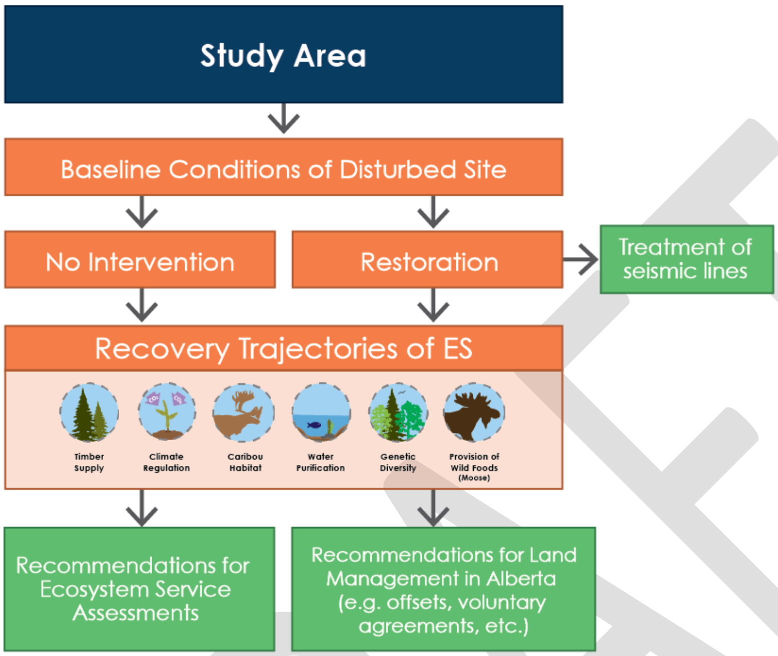


Figure 9 Ecosystem Service Assessment Approach

Furthermore, this approach looks at two different scales of analysis: operational and landscape effects. Figure 10 illustrates how the project team conducted hypothetical footprint and linear restoration ecosystem service assessment modeling.

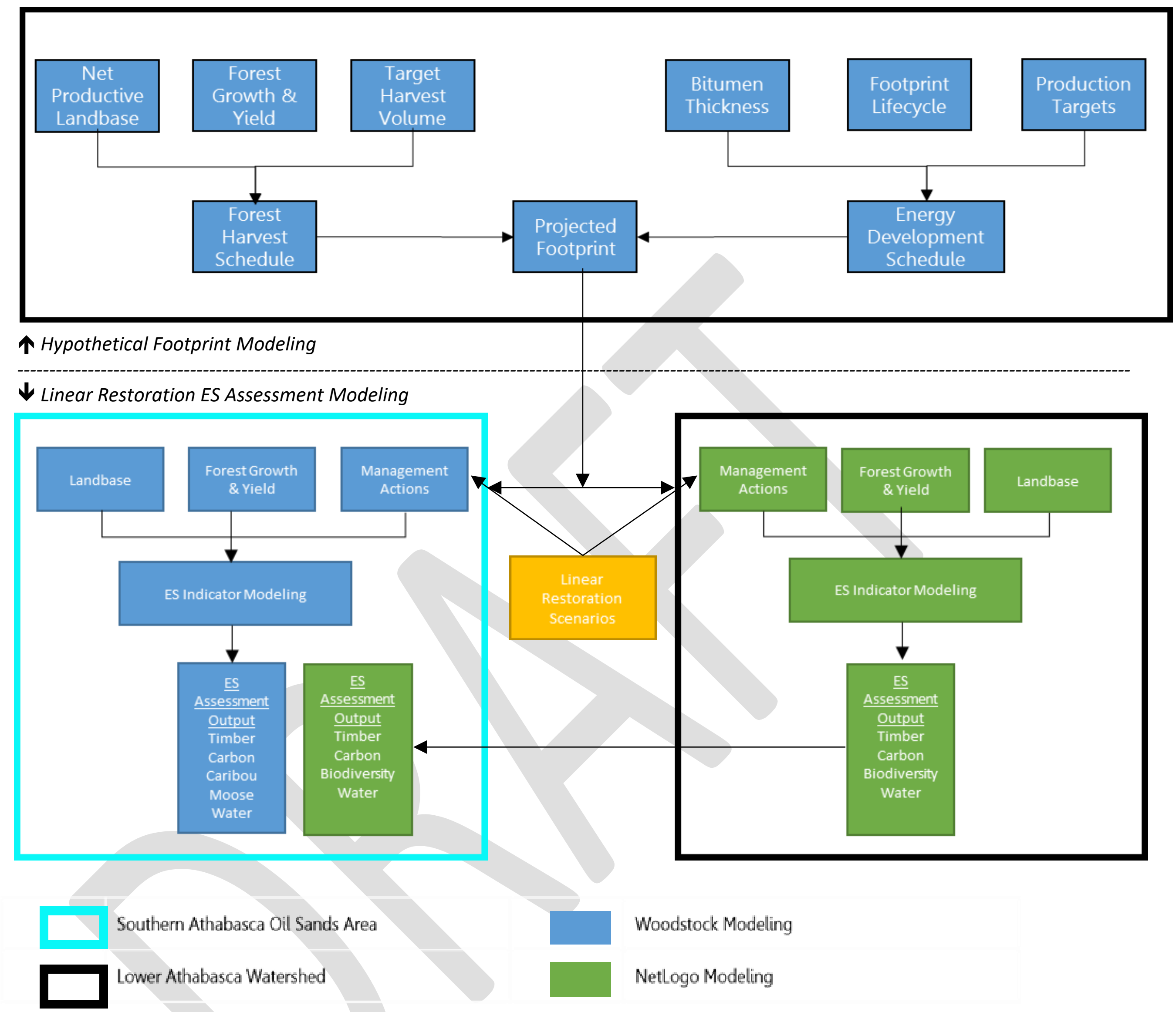


Figure 10 Modeling Approach to Compare both Operational and Landscape Modeling Platforms

The operational model uses the Woodstock forest modeling system, developed by Remsoft. Woodstock can be used for a wide variety of applications, including wildlife management, forest ecosystem analysis, and forestry applications. This platform is widely accepted by industry to assess optimal solutions in forest planning. Woodstock also uses vector inputs, improving the amount of landscape detail embedded into the model, making it more efficient to use at the operational scale. Because this platform was built to meet forest operation needs, it performs best on landscapes less than three million hectares large.

The landscape model uses the province-wide ecosystem service models developed by ABMI under the *Ecosystem Service Assessment Project*. The purpose of the project is to assess and map ES across the province to aid in land use planning. The models leverage the net logo modeling platform, where the landscape is rasterized into 800m cell grid. This allows the models to perform better at larger landscape scales, however, some of the operational efficiencies are lost through rasterization. These models are built to run most efficiently at the watershed scale.

Results from both modeling platforms will be compared to identify differences in modeling approaches under different scales of linear restoration. The purpose is to distinguish changes in ES supply from linear restoration with a models ability to quantify the change.

4.2 Landscape Analysis

Landscape modeling was carried out to identify expected changes to the land base based on management activities including future oil and gas development and forestry activities. Restoration scenarios were then carried out to estimate the amount of development that can be offset by linear restoration of legacy seismic lines.

4.2.1 Baseline Conditions of Disturbed Site

The baseline condition of the landscape was estimated for 50 years under multiple potential futures. Projecting future footprint needs to be considered for two reasons:

1. To estimate the effect future development may have on a suite of ecosystem services
2. To estimate how linear restoration can offset and/or interact with this effect.

Without proper consideration of what the future landscape will look like if linear restoration was not to occur, we cannot accurately estimate what the effects of restoration will be at a future time period.

There are two main industries operating on the Lower Athabasca watershed landscape: oil and gas and forestry. Both industries are considered to project footprint into the future (Figure 11).

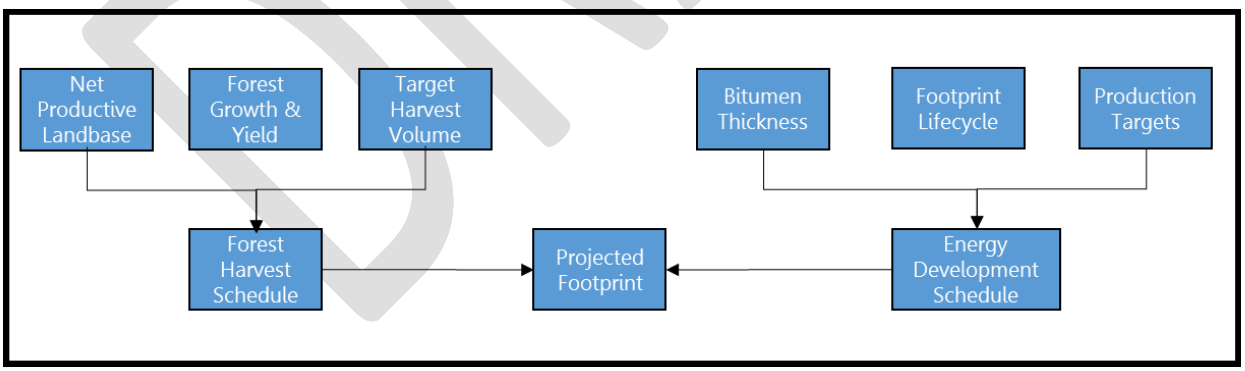


Figure 11 Hypothetical Footprint Approach

Future oil and gas development in Alberta is heavily dependent on the price of a barrel of oil. To counteract the market volatility, three hypothetical development scenarios were established to baseline the future footprint on the landscape. Forecasting oil and gas development under different scenarios is completed by both the Canadian Association of Petroleum Producers (CAPP) and the National Energy

Board. Both consider the current economic climate and market trends to estimate projections. Both also highlighted in their most recent reports that current pipeline and rail capacity may be a limiting factor in future production if more infrastructure is not built. Table 3 highlights the multiple scenarios developed by both organizations.

Table 3 CAPP Forecast (2015) [36] and National Energy Board Scenarios (2016) [37,38]

CAPP Forecast		
Growth	Considers growth, but at a lower rate than first anticipated in 2014.	The average rate of change for oil sands production is 168,000 b/d to 2019 and then reduced to 86,000 b/d for 2020 to 2030.
Operating & In Construction	Only considers projects that are currently operating or in construction.	No additional projects are added to the land base except ones in construction
National Energy Board Scenarios		
Baseline	Economic growth continues and energy prices are moderate	• Crude Oil is $82 in 2020 and increases to $107 in 2040 • Markets exist for Canadian energy exports and the required infrastructure is built
Price Uncertainty	High Price Case	• Crude oil reaches $105 in 2020 and increases to $134 in 2040
	Low Price Case	• Crude oil reaches $56 in 2020 and increases to $80 in 2040
Pipeline Uncertainty	No new major crude oil pipelines are built	• Canadian crude oil export pipeline capacity is limited to 4.0 million b/d after 2019

Following a similar approach to the NEB and CAPP examples, the development scenarios modeled for the Lower Athabasca watershed are:

- Growth – Follows the CAPP growth projections and rate of change following 2030
- Short Term Growth – Only active and constructed projects will continue to operate into the future
- Constrained Growth – Production will only maintain current pipeline capacity

[36] CAPP (2015). Crude Oil Forecast, Market & Transportation.
[37] Exploring Canada's Energy Future (2016). Methodology. National Energy Board. Downloaded from: https://apps.neb-one.gc.ca/dvs/PDF/Methodology_ENG.PDF
[38] Canada's Energy Future (2016). National Energy Board. ISSN 2369-1479

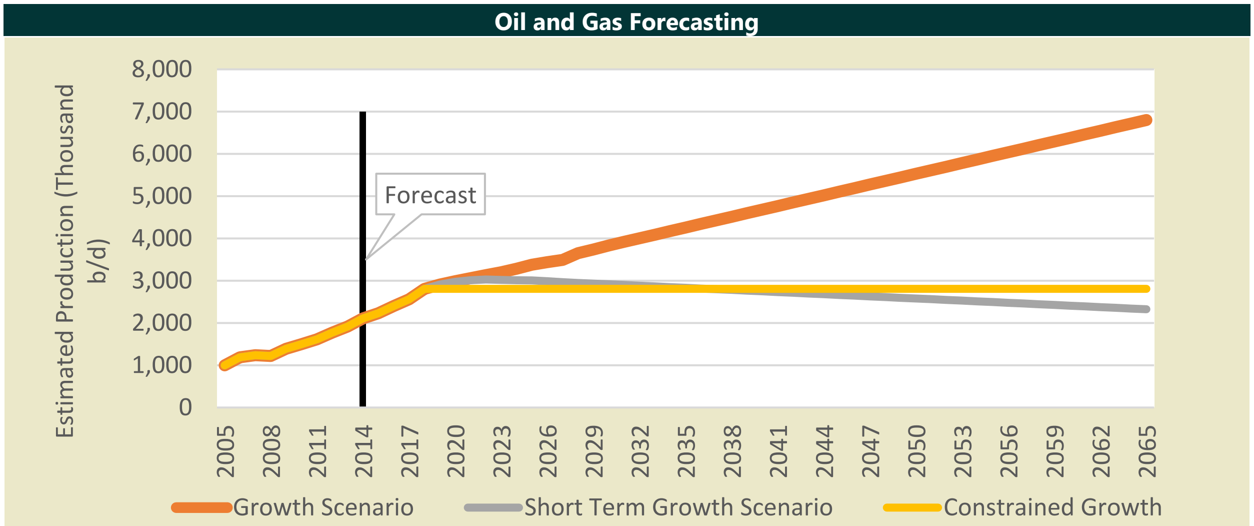


Figure 12 Oil and Gas Development Scenarios

The forest harvest sequence follows the annual allowable cut (m3) for each forest management unit (FMU) in the watershed. Future harvest blocks also assume that linear footprint (e.g. legacy seismic lines) will be revegetated when the block is planted, following the harvest.

4.2.2 Footprint Assumptions

Future footprint was projected over 50 years under the three development scenarios. Following the methodology used in the Algar proof of concept, the trajectory of the six ecosystem services was estimated at time 0, time 25, and time 50. A baseline condition in which no development occurs beyond what is currently on the landscape was also considered, which accounts for the growth of the forest along with any legally required restoration and remediation. All other changes to the landscape are not included. For example, fires, oil and gas development, forestry development and municipal or provincial infrastructural growth are not included. Once the baseline for the six ES was established under no intervention, restoration scenarios were developed to estimate their effect on the future landscapes, taking an ecosystem service approach. Lessons learned from the 2015 review of methodologies were incorporated to ensure benefit estimates are not misrepresented.

Appendix A reviews the methodology of the future footprint modeling in more detail.

4.2.2.1 Mining Assumptions

The project team worked with the government of Alberta to secure life of mine closure plans. In doing so, the team was able to rely on mine-specific reclamation data, rather than making assumptions on how the mines will be reclaimed over time. Once reclaimed, the area will regenerate to the pre-footprint condition (naturally non-forested or forested).

4.2.2.2 In Situ Assumptions

The Terrestrial Ecosystem Management Framework (TEMF) was developed as part of cumulative effects modeling under various scenarios in the oil sands region.[39] The framework developed a hypothetical footprint stamp for a 25,000 bpd oil sands project. This stamp was used to project footprint over 50 years to meet the production requirements under the three scenarios outlined above. The model forces in situ projects to be built where bitumen pay is thickest first, moving toward less economical regions as time progresses.

Bitumen pay thickness refers to the weighted average thickness of a bitumen pay deposit that is considered commercially viable using today's technologies. Townships were rasterized into the weighted average bitumen thickness and then grouped into "thick" versus "thin" pay thickness (Figure 13).

Bitumen thickness layer | **Area weighted project bitumen thickness** | **Thin pay / thick pay netdown**

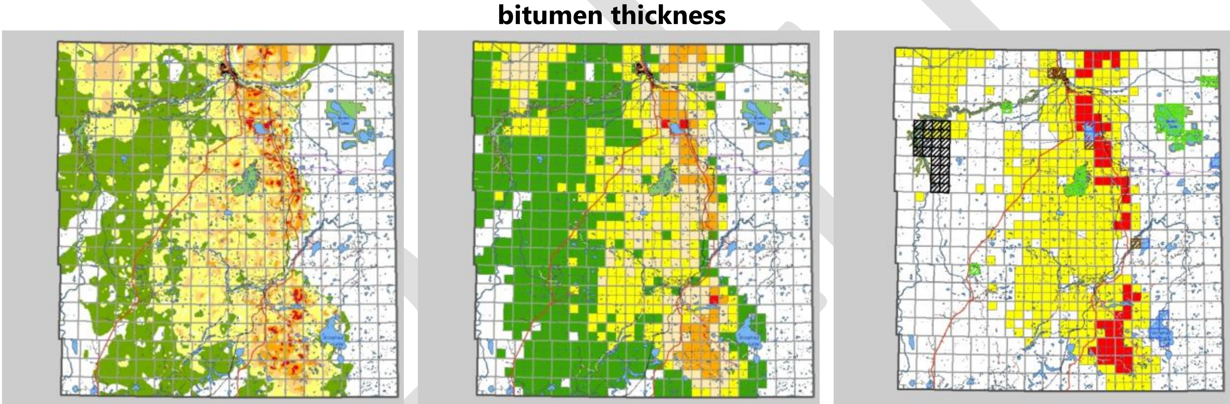


Figure 13 Bitumen Pay Thickness for the Southern Athabasca Oil Sands Region

Differentiating between thick and thin pay is essential because the TEMF follows different footprint timing assumptions for each.

[39] Silvatech Team (2008). SEWG Workplan Facilitation and Modelling Project: Data Inputs and Assumptions Report.

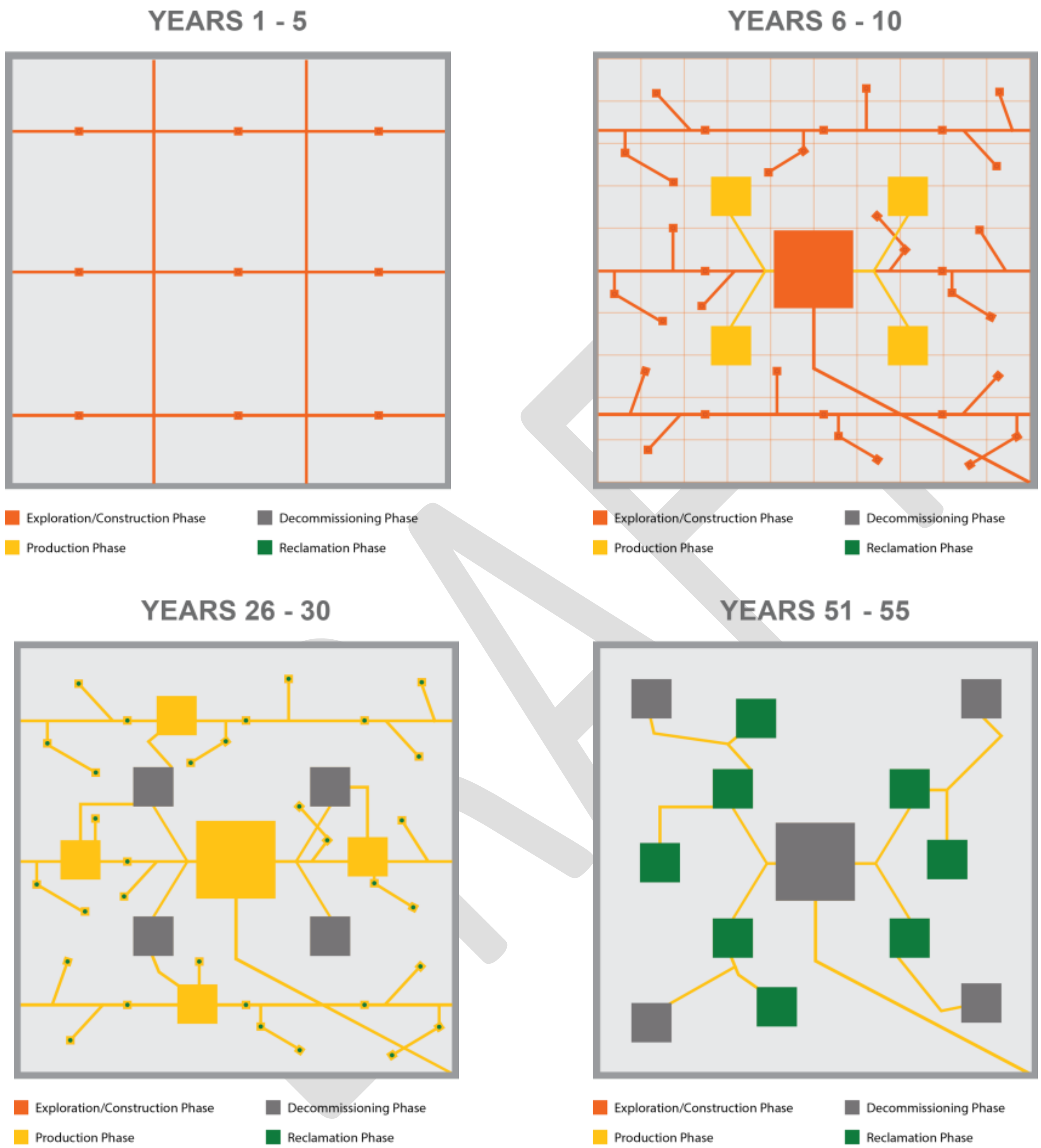


Figure 14 Hypothetical Footprint based on TEMF assumptions for a 25,000 bpd project[40]

[40] This figure is a modified version of the TEMF in situ spatial representation designed by the Silvatech Team. It is for illustration purposes only and is not drawn to scale.

Table 4 Footprint Assumptions

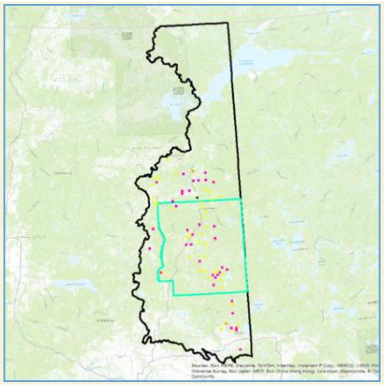
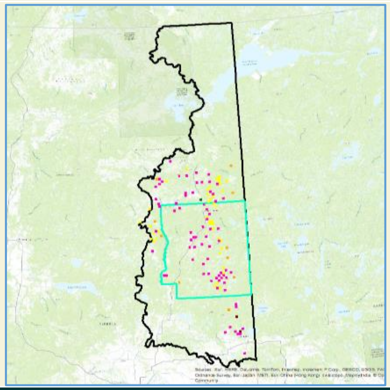
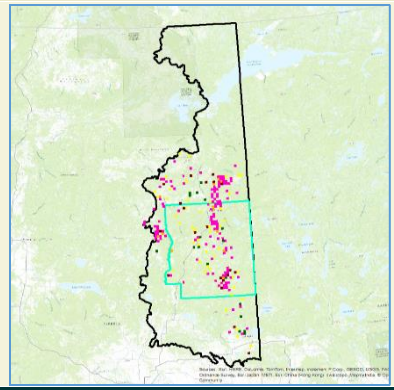
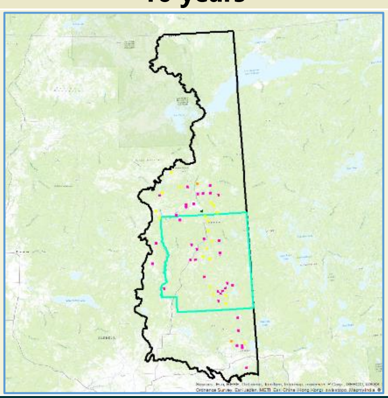
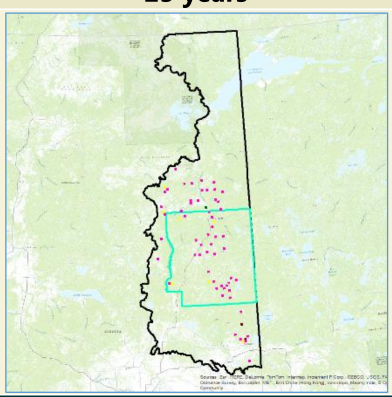
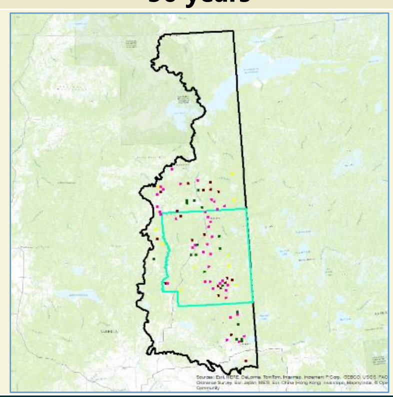
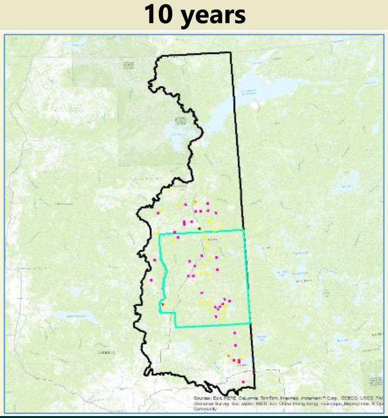
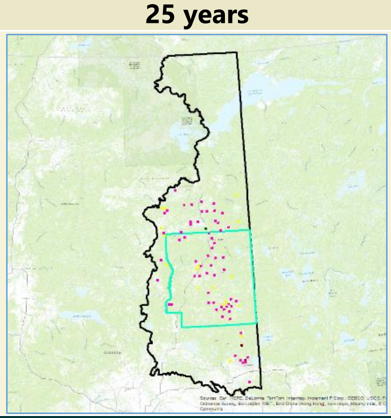
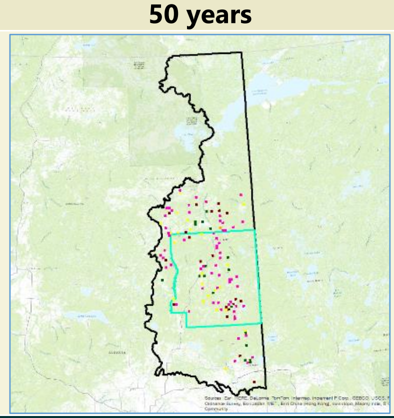
Feature	Assumption
1 In Situ Project	• ¼ TWP (2,300 ha) • 25,000 bpd • Footprint lifespan of 65 years
Horizontal Well Pads	• 3 sets over the life of the project • 12-year persistence for each set • 8.26ha/pad
Plant Site	• 25 ha • Production lifespan of 35 years
Delineation Wells	• 63 wells • 0.49 ha/well
Exploration Wells	• 9 wells • 0.49 ha/well
2D Seismic	• m wide • 28.8 km
3D Seismic	• Source line: 2.75 m wide • Receiver line: 1.75 m wide • 921.6 km
Pipelines	• 111ha • Operating life of 45 years
Production Well Access	• 1.24 km/pad x 45 m width

Table 5 Timing of Footprint

TEMF FOOTPRINT ASSUMPTIONS															
Road3															
Road2															
Road1															
Pads3															
Pads2															
Pads1															
Plant															
Delineation Access															
Delineation Well															
Exploration Access															
Exploration Well															
3D Seismic															
2D Seismic															
Model Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Years	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
TEMF Period	N/A	N/A	1	2	3	4	5	6	7	8	9	10	11	12	13

Construct — Thin Pay Construct (if different than thick pay)
Reclaim — Thin Pay Reclaim (if different than thick pay)

Table 6 In situ development modeled over time

Long-Term Growth Strategy		
10 years	**25 years**	**50 years**
		
Short-Term Growth Strategy		
10 years	**25 years**	**50 years**
		
Constrained Growth Strategy		
10 years	**25 years**	**50 years**
		
legend		
Exploration	Construction	Production
Decommission	Reclamation	

4.2.2.3 Forestry Assumptions

There are 10 active forest management units that fall at least partially within the Lower Athabasca watershed. The area-weighted annual allowable cut (AAC) was calculated for each and harvest blocks were modeled over a 50-year planning horizon. The probability of future in situ development was also included in this analysis to account for any footprint overlap.

Table 7 Annual Allowable Cut by FMU[41]

FMU	Total Area	% within Watershed	Conifer AAC (m^3)	Deciduous AAC (m^3)	Conifer Watershed Target (m^3)	Deciduous Watershed Target (m^3)
A10	380,681	43%	8,400	0	3,600	0
A14	1,181,059	100%	219,000	166,000	218,000	165,000
A15	1,440,732	98%	358,000	477,000	350,000	467,000
L1	357,811	100%	86,000	177,000	86,000	177,000
L11	1,050,841	100%	185,000	345,000	184,000	344,000
L2	299,314	86%	115,000	145,000	99,000	125,000
L3	589,630	100%	172,000	98,000	172,000	98,000
L8	127,079	100%	40,000	66,000	39,000	66,000
S18	610,998	21%	215,000	280,000	44,000	58,000
S22	803,072	16%	177,000	376,000	29,000	62,000

Cutblocks were considered in the productive forest land base, therefore they were not considered footprint for the landscape analysis. They will, however, have adverse effects on some of the ecosystem services, which varies by indicator (Table 8). This distinction is necessary to estimate the impact of future development on the supply of ecosystem services (Section 4.3).

Table 8 Time needed to consider a cut block regenerated

Indicator	Time for cutblock removal
Carbon	Continuous
Timber	Continuous
Moose	70 years
Caribou	40 years
Water	24 years for deciduous leading sites 42 years for coniferous leading sites
Genetic Diversity	24 years for deciduous leading sites 42 years for coniferous leading sites

[41] AAC values rounded to the nearest 1,000.

4.2.2.4 Linear Restoration Assumptions

Recent improvements in oil and gas exploration techniques and uptake of Integrated Land Management have allowed for faster recovery of the forest from human-caused activities, but there remain thousands of hectares of legacy footprint (e.g. legacy seismic lines) with poor natural recovery. Unlike other human-caused footprint, seismic lines historically have not been required to be reclaimed. According to Lee and Boutin (2006), it is estimated that approximately 65% of legacy seismic lines remain non-forested after 35 years, these typically being in lowland conditions. [42]

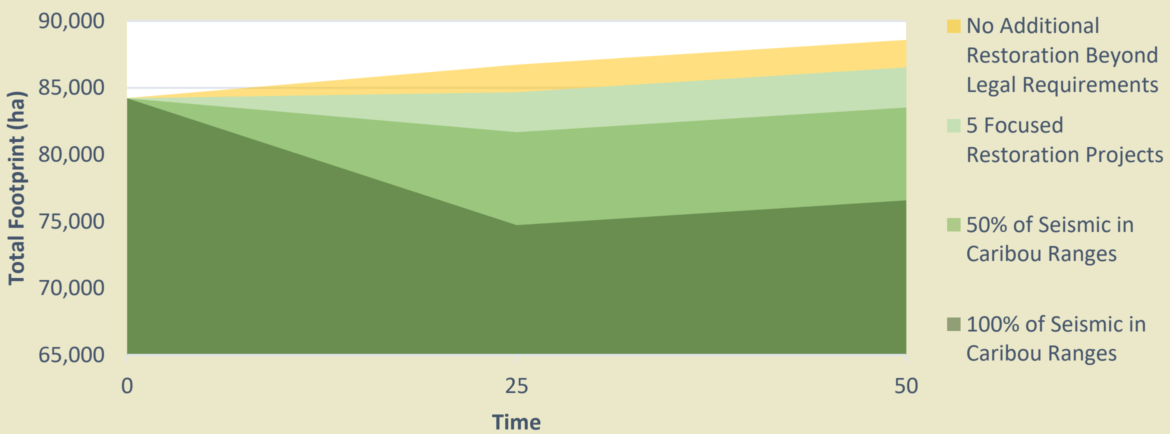
It was assumed that all seismic lines identified in the ABMI Human Footprint Map (2012) were eligible for restoration. Further strategic to tactical planning will be required to identify lines that are regenerating on their own or have been converted to other uses (e.g. other anthropogenic uses such as roads, pipelines, trap lines, etc.). It was also assumed that without intervention all seismic lines would remain on the landscape for the following 50 years (70 years for black spruce leading sites).

Once treated, seismic lines are immediately assumed to no longer be footprint and transition to their pre-footprint condition.

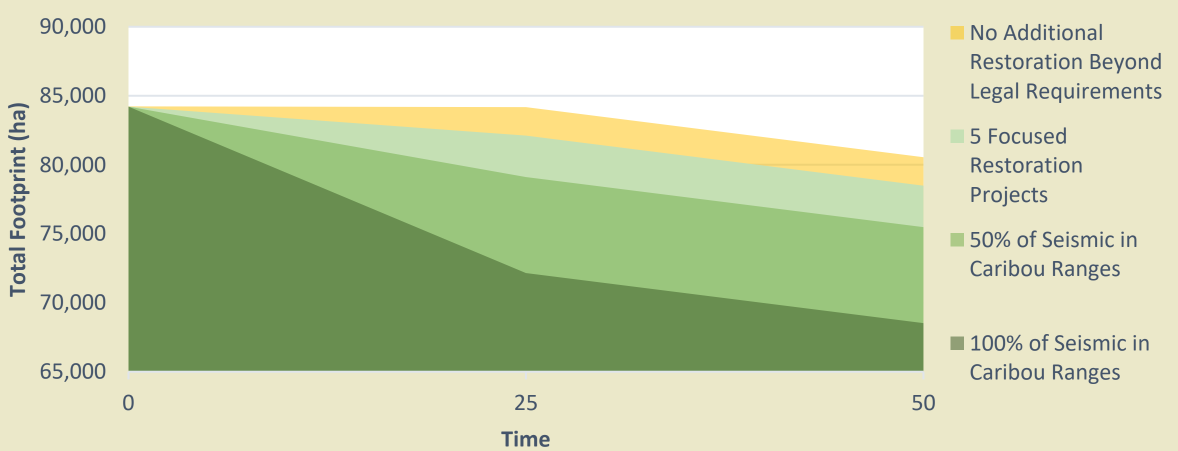
[42] Lee and Boutin (2006). Persistence and developmental transition of wide seismic lines in the western Boreal Plains of Canada. Journal of Environmental Management 78 (2006) 240–250.

Table 9 Footprint changes over time

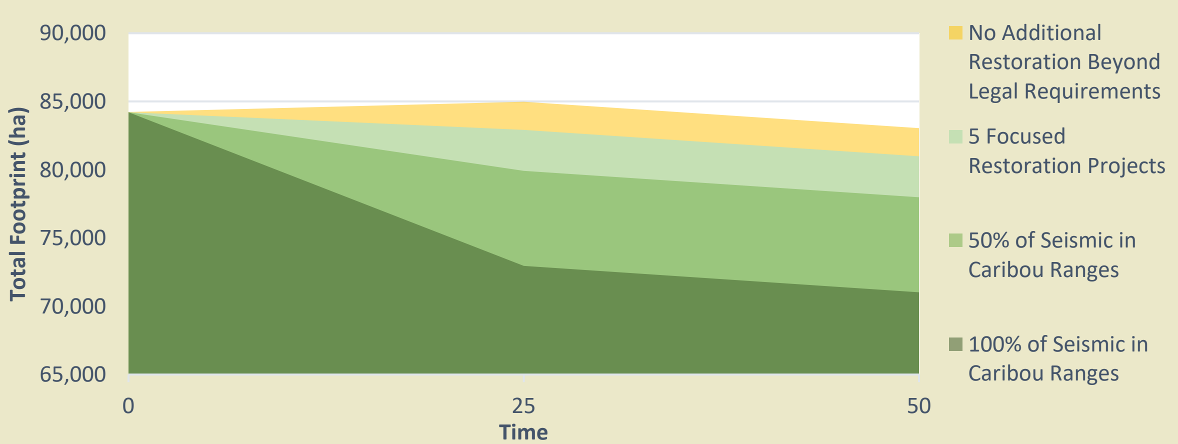
Long-Term Growth Strategy



Short-Term Growth Strategy



Constrained Growth Strategy



4.3 Future Supply of Ecosystem Services

The change in the supply of ecosystem services from development and restoration activities over time were estimated at two different scales: The Southern Athabasca Oil Sands area and the Lower Athabasca watershed. The two scales were assessed to:

- Identify how the supply of ES changes as restoration is scaled up to the watershed;
- Identify how two different modeling platforms perform at the operational and landscape scale – are the results comparable? and
- Identify how the changes in the supply of ES flow to beneficiaries in the watershed.

Due to data availability, the ecosystem service indicators varied slightly between scales (Table 10).

Table 10 Ecosystem Service Indicators

Southern Athabasca Oil Sands Area	Lower Athabasca Watershed
Timber Supply	Timber Supply
Carbon Sequestration	Carbon Sequestration
Caribou Habitat	Biodiversity Intactness
Relative Moose Abundance	Water Quality Improvements (N, P, TSS)
Water Quality Loading Potential (N, P, TSS)	

Each ES indicator was assessed under different future states:

- No future development or restoration (baseline);
- Future development under multiple development scenarios; and
- Three linear restoration scenarios.

	Development intensity		
Baseline	**Constrained Growth Scenario**	**Short-Term Growth Scenario**	**Long-Term Growth Scenario**
Restoration (km/year)	**5 Focused Restoration Scenarios**	**5 Focused Restoration Scenarios**	**5 Focused Restoration Scenarios**
	50% of Seismic within Caribou Ranges in 5 Years	**50% of Seismic within Caribou Ranges in 5 Years**	**50% of Seismic within Caribou Ranges in 5 Years**
	All Seismic within Caribou Ranges in 5 Years	**All Seismic within Caribou Ranges in 5 Years**	**All Seismic within Caribou Ranges in 5 Years**

Figure 15 Multiple Future States

A number of models were used to estimate the biophysical response to linear restoration. The interim report 1 of 3, released in December 2015 reviews these models in detail.

4.3.1 Linking Changes to Human Well-Being

Linear restoration affects how an ecosystem functions by moving it to a more natural state, changing the way water flows over the landscape and limiting human use. These changes can be linked to benefits provided to people (i.e. ecosystem services). To identify how much people benefit (or are hindered) from these changes, we can assess the changes to human well-being through economic valuation. There are 32 communities in the Lower Athabasca watershed who may benefit from the flow of ES to their communities (Figure 16).

There are many methods for assessing the changes in human well-being from a management alternative. These can be as simple as using a market price (e.g. carbon tax) or more complex analysis using a number of case studies to create a demand curve for a product not traditionally bought and sold (e.g. benefit transfer meta-analysis). The Phase 1, proof of concept report describes the different methodologies in more detail.[43]

Table 11 highlights how each ES indicator was linked to what people value in the region. Some indicators were valued using a direct use method (e.g. a market price), others used a stated preference technique or benefits transfer to capture the entire value of the service (e.g. use and non-use values).

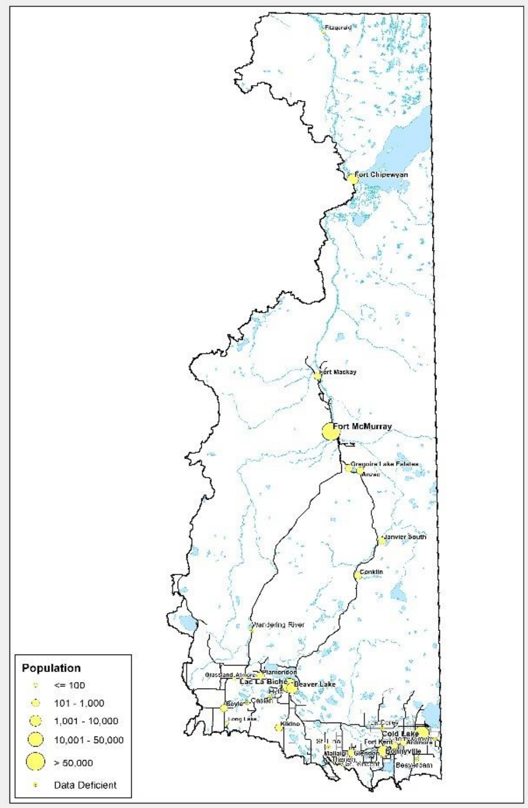


Figure 16 Communities by Population Size

[43] Team Silvacom (2014). Assessing the Ecosystem Service Benefits of the Algar LEAP Project.

Table 11 Linking Biophysical Indicators to Changes in Human Well-Being[44]

Ecosystem Service Type	Biophysical Indicator	Value to People	Valuation Method	Beneficiaries
Provisioning	Timber Supply	Direct Use	Market (Timber Pricing)	Local businesses, local communities
Regulating	Water Quality	Direct and Indirect Use	Non-Market (Willingness to Pay)	Local and downstream users
Regulating	Carbon Sequestration	Indirect Use	Market (Carbon Tax)	Global
Cultural & Spiritual	Moose Hunting	Direct	Market & Non-Market (Travel Costs & Willingness to Pay)	Recreational hunters (local and visitors)
Cultural & Spiritual	Caribou Habitat	Existence	Non-Market (Willingness to Pay)	Alberta Residents
Supporting	Biodiversity Intactness	Existence	Non-Monetary	Alberta Residents

4.3.1.1 Timber Supply

The timber supply indicator estimated a predicted future state of conifer growing stock (m3) and deciduous growing stock (m3) as well as the area by timber damage assessment (TDA) strata (ha). These results can be used to estimate the value of the trees added to the land base from linear restoration by using the TDA tables provided by the Government of Alberta.

Timber Damage Assessments (TDAs) are the basis for determining compensation when merchantable timber is affected by industrial development on the landscape. TDAs are developed by the Joint Energy/Utility and Forest Industry Management Committee (JMC) and updated annually.[45] The tables consider pricing information obtained from Agriculture and Forestry's Coniferous Timber Permit and Deciduous Timber Permit auctions as well as information obtained on the pricing of arms-length private timber transactions for the previous two years. The full TDA value is the sum of the standing timber value, reforestation value, and annual allowable cut value, where:

- The standing timber value provides an estimate of the average value of coniferous and deciduous standing timber damages alone;
- The reforestation value provides an estimate of the average value of coniferous and deciduous future reforestation costs that the JMC has agreed to include; and
- The annual allowable cut (AAC) value provides an estimate of the average value of coniferous and deciduous lost from the AAC.

[44] Modified from personal communication with Marius Cutlac (2016).
[45] Alberta Forest Products Association. https://www.albertaforestproducts.ca/our-industry/forestry/timber-damage-assessments

Because TDA tables are directly linked to the price of lumber, the values can vary significantly from year to year. A sensitivity analysis was completed to estimate overall trends over the past seven years.

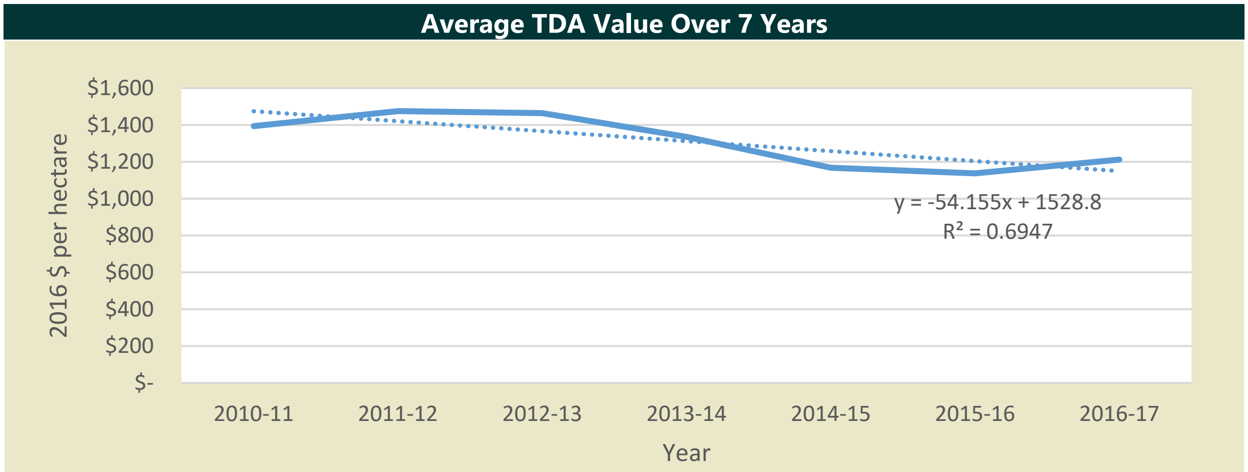
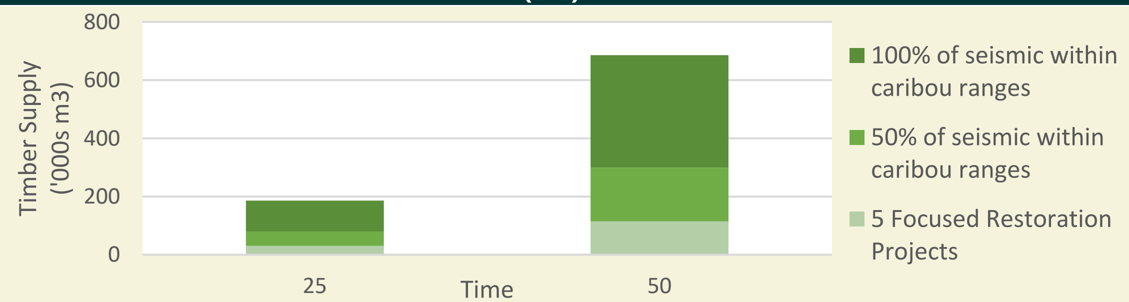


Figure 17 TDA Value Trends

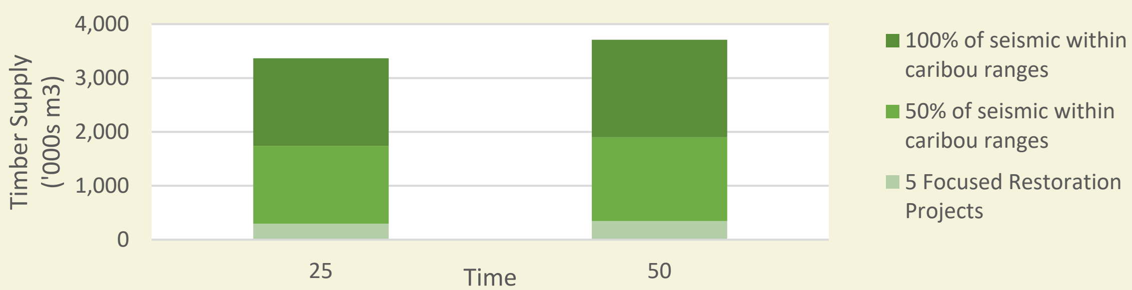
To ensure the benefits of future timber supply are not overstated, the discount rate applied should account for the downward trend of market prices.

Table 12 Southern Athabasca Oil Sands Area Timber Supply Results

Additional Timber Supply from Restoration in the SAOS (m3)

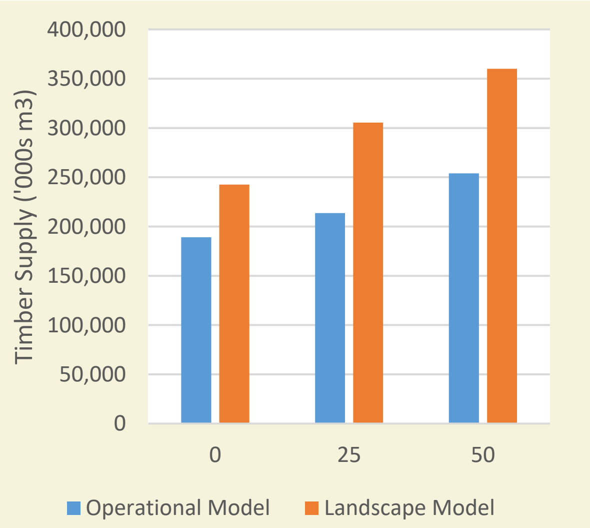


Additional Timber Supply from Restoration in the Lower Athabasca Watershed (m3)

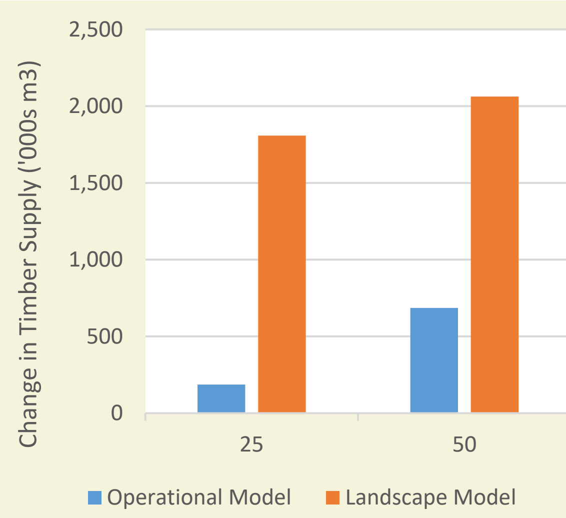


Results Comparison for the SAOS region

Baseline (No Restoration)



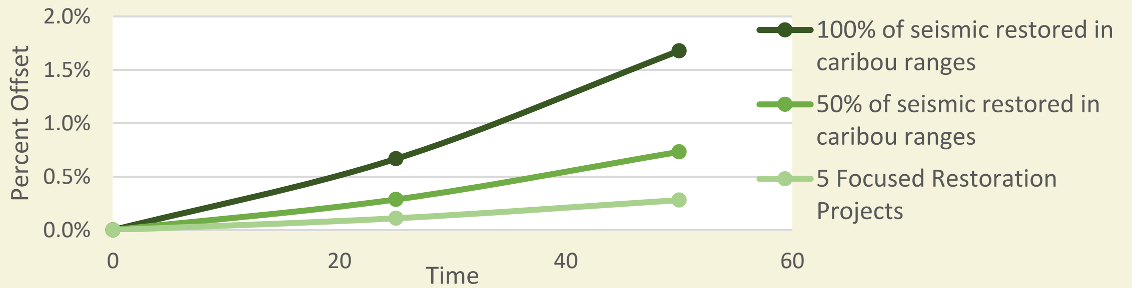
Change from Restoration[46]



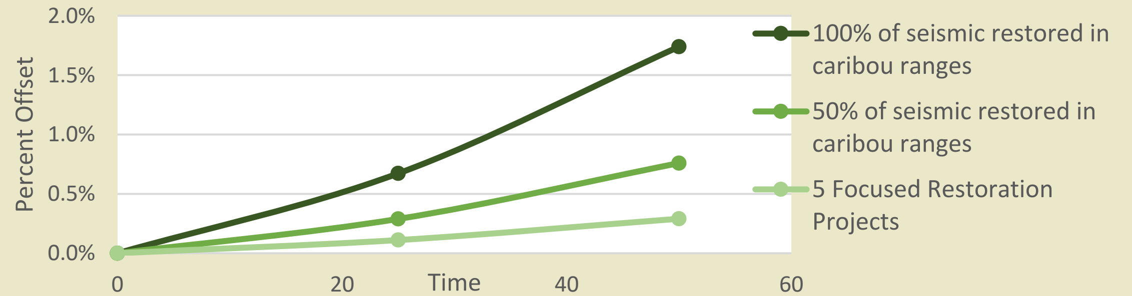
[46] Assuming 100% seismic restoration in caribou ranges

Table 13 Offset Analysis for the SAOS Region

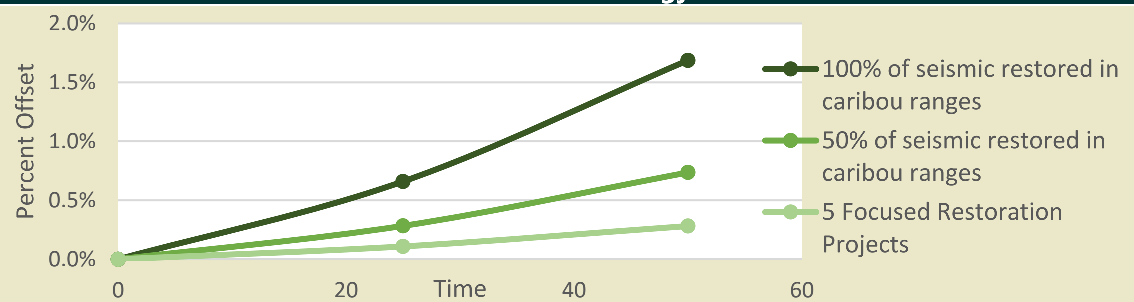
Percent of Development Offset from Linear Restoration
Long-Term Growth Strategy



Percent of Development Offset from Linear Restoration
Short-Term Growth Strategy



Percent of Development Offset from Linear Restoration
Constrained Growth Strategy



4.3.1.2 Water Quality

Water quality was assessed for both the Lower Athabasca watershed and the Southern Athabasca Oil Sands area, however, indicators were slightly different for each region. In the Southern Athabasca Oil Sands Area, the indicator estimated the change in loading potential of nitrogen and phosphorus on the landscape caused by restoring legacy seismic lines. Loading potential was defined as the total possible amount of nitrogen or phosphorus stored on the landscape, indicated by land cover type. It does not account for water flows over the landscape.

In the Lower Athabasca watershed, water flow over the landscape is accounted for, estimating the kg/year of nitrogen and phosphorus supplied to the river.

To assess the value of improvements in water quality, a meta-analysis was conducted to estimate willingness to pay to see an improvement in water quality for the Lower Athabasca watershed. Benefits transfer approaches like this one are completed when there is not enough data within the research site itself to accurately estimate how communities will benefit from a change in water quality.

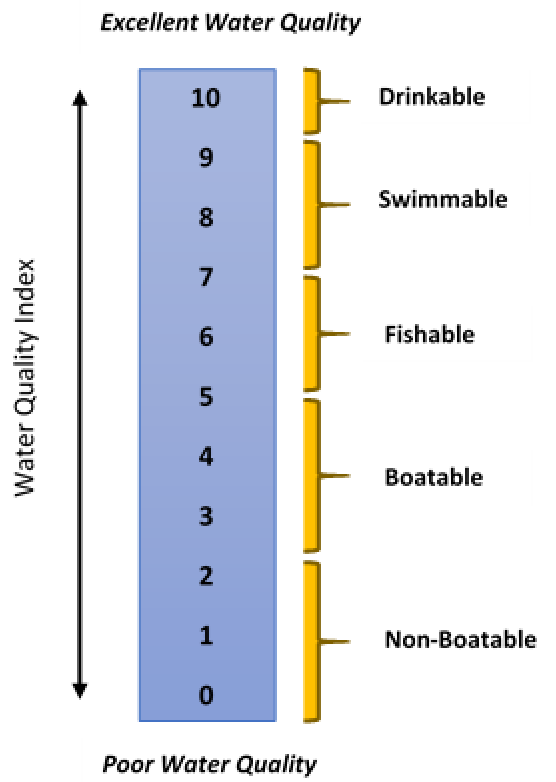


Figure 18 Water Quality Ladder, Taken from Dupont (2016).

Data from 45 case studies was collected, all from research sites in North America. The results from these studies were analyzed, put into a meta-data template and used to estimate a willingness to pay function. Following this, site-specific socioeconomic data from the Lower Athabasca watershed was used for geographic context. [47]

The meta-analysis uses a water quality ladder to estimate what residents are willing to pay for water to be drinkable, swimmable, fishable, boatable, and non-boatable (Figure 18).

Using an assumed baseline that water quality in the watershed currently hovers around a five on the water quality index, results of this analysis show that if linear restoration was to improve water quality from fishable to drinkable (maximum water quality) households are likely willing to pay between $60 and $130

[47] Cutlac (2016). Willingness to pay for water quality improvements in the Lower Athabasca watershed. *Unpublished.*

per household. If water quality was slightly improved along the fishable index, households would likely by willing to pay between $60 to $80. [48]

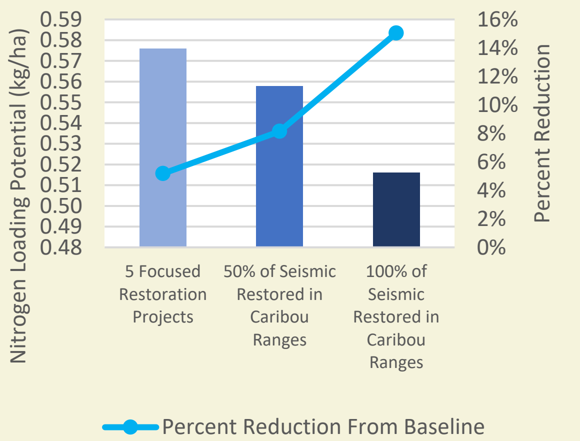
Valuation of water quality improvements was only assessed at the watershed scale. This is because ES need to flow to beneficiaries to be valued. Assessing the benefits of water quality using an administration boundary like the SAOS is therefore not appropriate. The results from the biophysical assessment (e.g. kg/year of pollutants supplied to the river) show that linear restoration does not improve water quality to a level that residents would be willing to pay for. This is likely because the water quality ladder developed to estimate what residents are willing to pay for additional water quality improvements is not sensitive enough to capture the change created from linear restoration. The ladder may be more appropriate in more degraded river systems, where restoration would have a larger impact. There is an opportunity to look at other mechanisms for measuring the change in water quality in the future (e.g. Alberta Water Quality Index).

[48] Cutlac (2016). Willingness to pay for water quality improvements in the Lower Athabasca watershed. *Unpublished.*

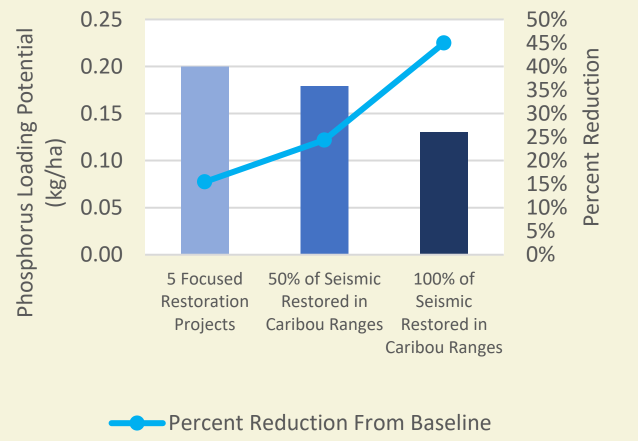
Table 14 Southern Athabasca Oil Sands Area Water Quality Results

Water Quality (Loading Potential) for the SAOS

Nitrogen

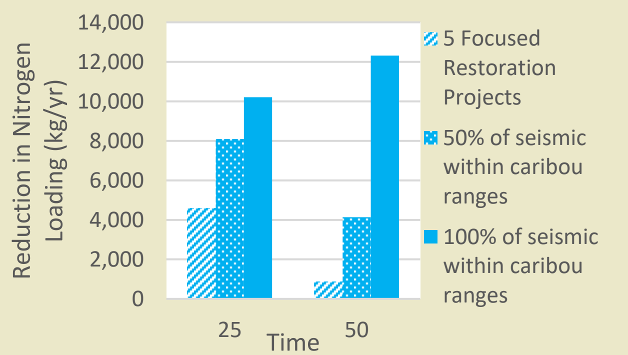


Phosphorus

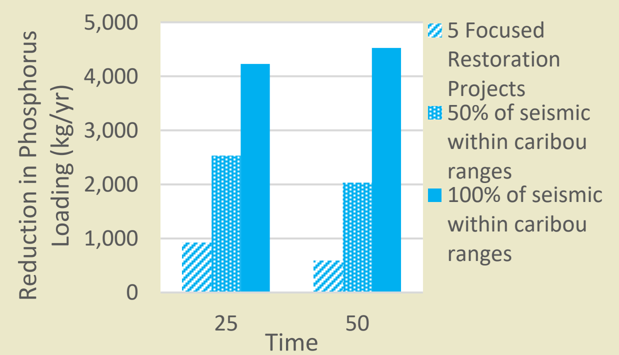


Water Quality (Pollutants Supplied to the River (kg/year)) for the Lower Athabasca Watershed

Nitrogen



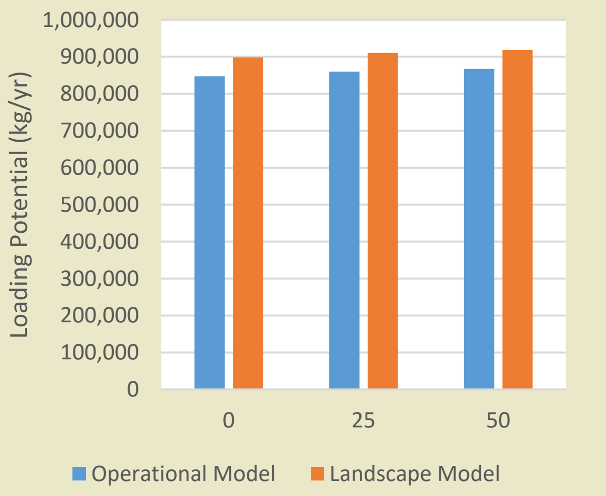
Phosphorus



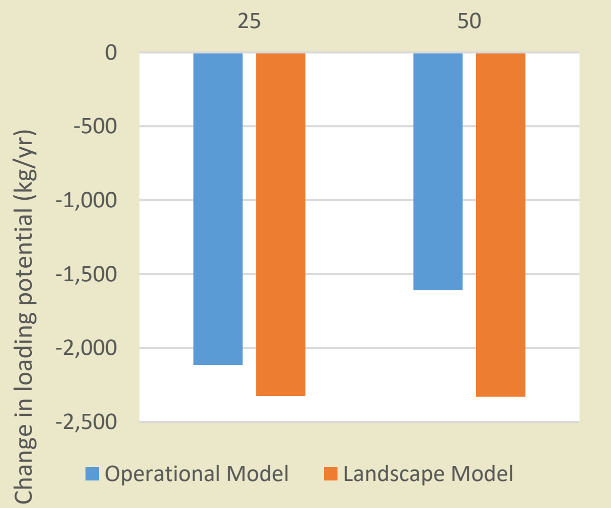
Results Comparison for the SAOS (Loading Potential)

Phosphorus

Baseline (No Restoration)

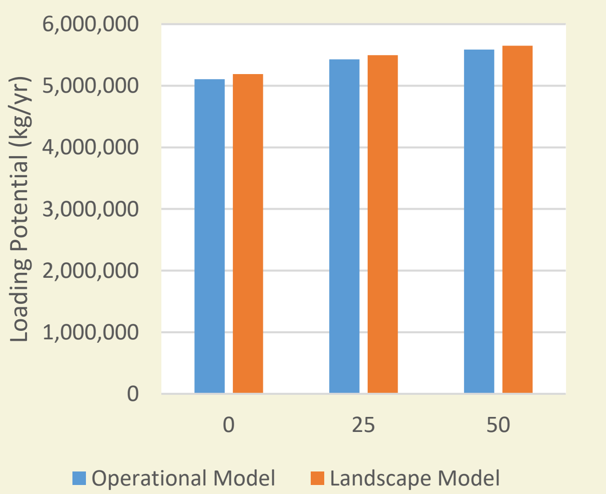


Change from Restoration[49]

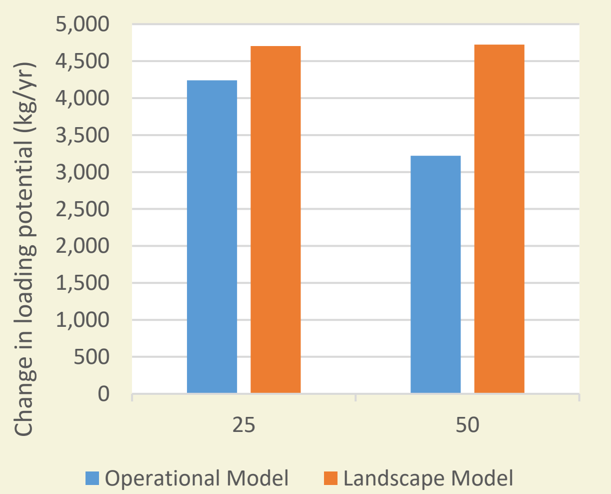


Nitrogen

Baseline (No Restoration)



Change from Restoration[49]



[49] Assuming 100% seismic restoration in caribou ranges

Table 15 Offset Analysis for the SAOS Region

Percent of Development Offset from Linear Restoration Long-Term Growth Strategy	
The effect development has on nitrogen loading potential cannot be significantly offset by linear restoration	The effect development has on phosphorus loading potential cannot be significantly offset by linear restoration
Percent of Development Offset from Linear Restoration Short-Term Growth Strategy	
The effect development has on nitrogen loading potential cannot be significantly offset by linear restoration	The effect development has on phosphorus loading potential cannot be significantly offset by linear restoration
Percent of Development Offset from Linear Restoration Constrained Growth Strategy	
The effect development has on nitrogen loading potential cannot be significantly offset by linear restoration	The effect development has on phosphorus loading potential cannot be significantly offset by linear restoration

4.3.1.3 Carbon Sequestration

The carbon sequestration indicator is measured by the amount of above-ground biomass added to the land base from linear restoration. Both provincial and federal governments released plans in 2016 to put a price on carbon. The Alberta Climate Leadership Plan commits to increasing the carbon levy to $20 per tonne in 2017 and $30 per tonne in 2018. [50] The government of Canada also proposed a Pan-Canadian approach to carbon pricing, where all provinces and territories will be required to have a carbon price in place by 2018. This country-wide plan will set a minimum carbon price of $10 per tonne in 2018 and increase to $50 per tonne by 2022. [51]

The value of additional carbon sequestered from linear restoration will follow the Alberta Climate Leadership Plan and grow with the federal plan to increase the levy to $50 per tonne by 2022 (Figure 19). Changes were valued for the next 50 years.

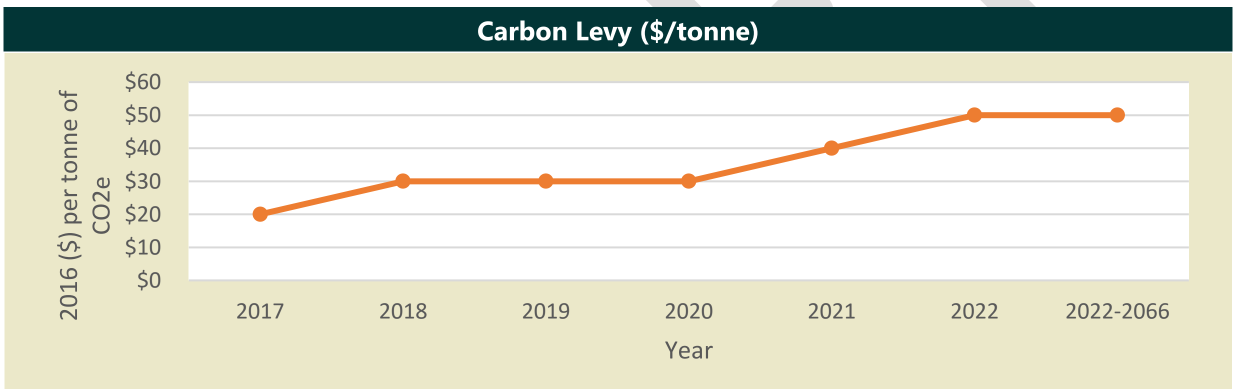
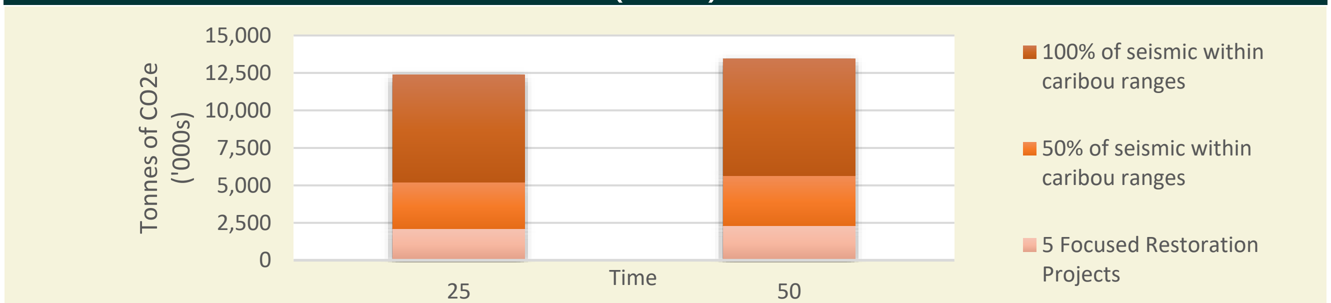


Figure 19 Carbon Levy

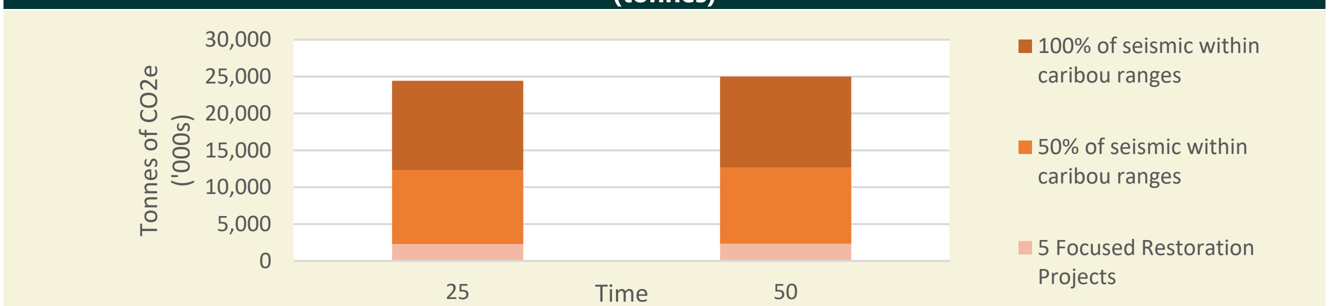
[50] Government of Alberta (2016). Climate Leadership Plan. Carbon Levy and Rebates. Accessed December 19, 2016 from: https://www.alberta.ca/climate-carbon-pricing.aspx#p184s1
[51] Government of Canada (2016). Government of Canada Announces Pan-Canadian Pricing on Carbon Pollution. Accessed December 19, 2016 from: http://news.gc.ca/web/article-en.do?nid=1132149&_ga=1.239953667.1200309308.1480003346

Table 16 Southern Athabasca Oil Sands Area Carbon Sequestration Results

Additional Carbon Sequestration from Restoration in the SAOS (tonnes)

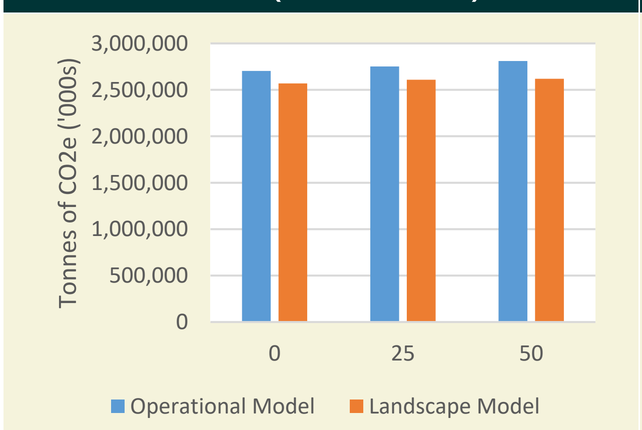


Additional Carbon Sequestration from Restoration in the SAOS (tonnes)

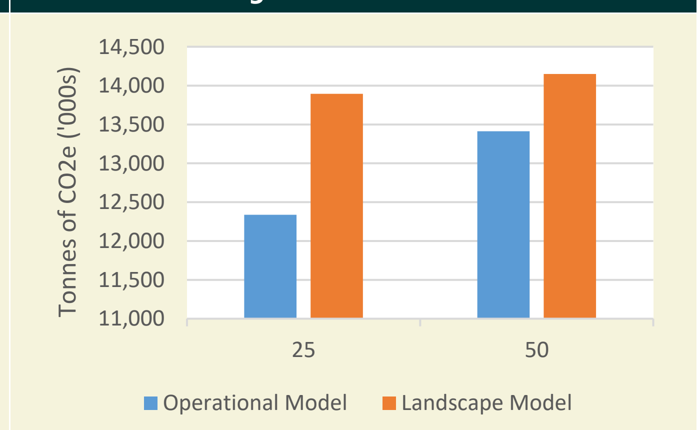


Results Comparison for the SAOS

Baseline (No Restoration)



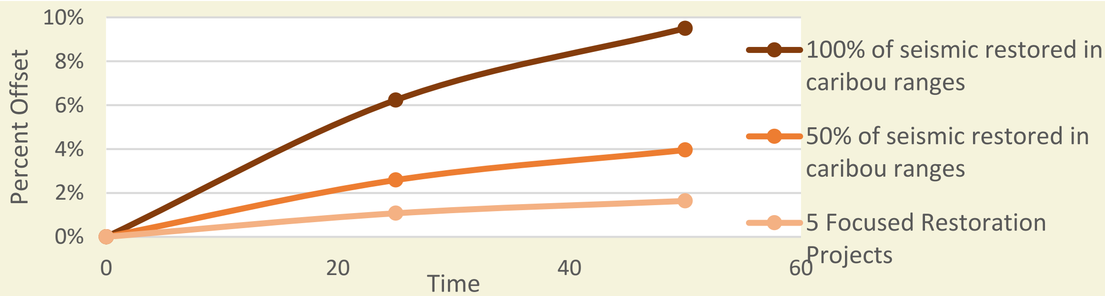
Change from Restoration[52]



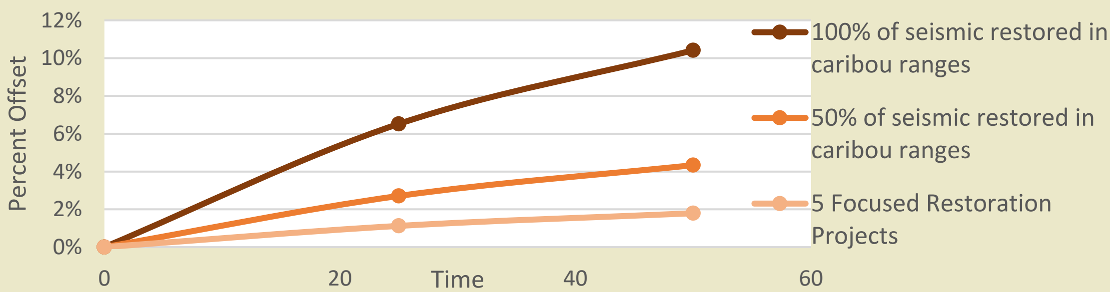
[52] Assuming 100% seismic restoration in caribou ranges

Table 17 Offset Analysis for the SAOS Region

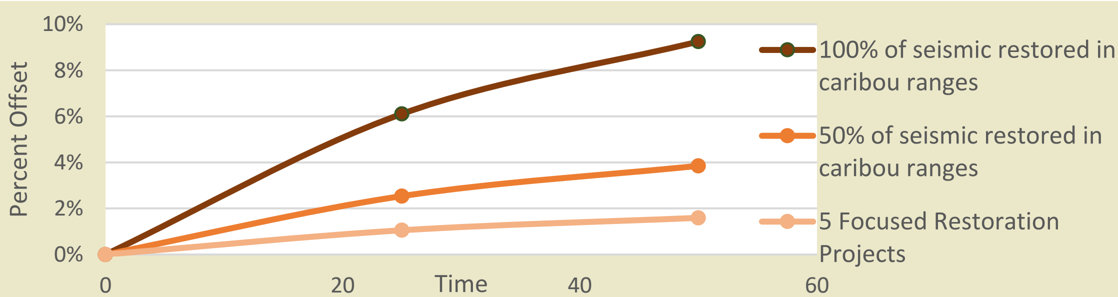
Percent of Development Offset from Linear Restoration
Long-Term Growth Strategy



Percent of Development Offset from Linear Restoration
Short-Term Growth Strategy



Percent of Development Offset from Linear Restoration
Constrained Growth Strategy



4.3.1.4 Moose Hunting

The link of moose population to seismic lines is complex. Fisher and Burton (2016)[53] showed that moose relative abundance increases with seismic density (3D), cutblocks and forested areas, but declines with legacy seismic lines (2D) and other human footprint features. Using their regression model over SAOS area, relative moose abundance is projected to increase from today's baseline from both linear restoration as well as future development (due to future forest harvesting). The relative abundance indicator was defined as an occurrence within the survey period around an observation site, and while it is a proxy for moose population, it cannot directly provide estimates on the moose population or its growth.

It is likely that reforestation of legacy seismic lines will have an impact on populations, with increased forage on restored lines and reduced predator access. As the forest continues to age, eventually the reforested areas will be less suitable for moose habitat, but this is not expected to occur within the 50-year timeframe this analysis is focused on.

Local residents and visitors to Alberta are the beneficiaries of moose hunting, with the impact propagating into the local and provincial economy. For people visiting from outside Alberta, their expenditures translate into new income into Alberta economy, critical in many cases for remote locations with fewer economic opportunities available. Benefit estimates should also consider the non-outfitters, including Aboriginal hunters, where market prices can be applied. Different from visitors from outside Alberta, these expenditures represent a redistribution of income (e.g. using moose meat for an alternative to beef), rather than an additional investment into the economy. Nevertheless, this redistribution of income is still a benefit to local communities. There are also non-use values that should be accounted for, including the existence value of traditional use and bequest values of knowing future generations will be able to hunt as a way of life.

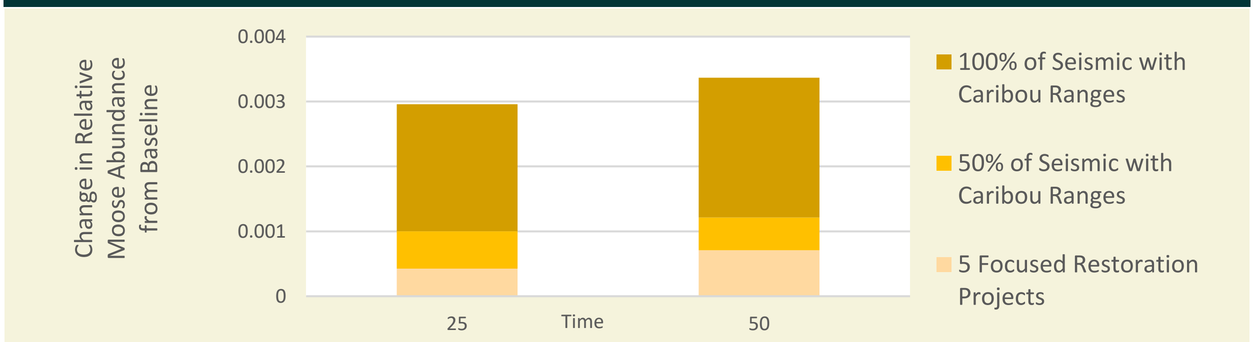
Provincial data shows that there were approximately 1,700 moose allocations held in 2013 by Non-Resident Aliens, about 50% of them being used. Hunters spent approximately 8,500 days moose hunting, province-wide, and their expenditures generated a total economic output $105 million, $47 million representing a contribution to Alberta GDP.[54] Based on the moose population proportion of 21% in the Lower Athabasca watershed, the provincial values are scaled to 357 moose allocations held, 189 used, for 1,785 moose client-days. The contribution to GDP from moose outfitted hunting of the entire watershed is approximately $10 million.

Using ABMI data, approximately 25,000 moose are estimated for Lower Athabasca watershed or about 21% of the total Alberta moose population. Scaling this to the SAOS, it is estimated that approximately 8,700 moose are within the area of interest. [55] Through linear restoration of legacy seismic lines, we are

[53] Fisher and Burton (2016). Moose and Predator Numerical Responses to Anthropogenic Features in the Alberta Oil Sands Region. A final report to the Petroleum Technology Alliance of Canada.
[54] Cutlac and Weber (2014). The Economic Impact of Outfitted Hunting in Alberta. Alberta Innovates, Technology Futures.
[55] ~0.0024 moose/ha * 3.7 million ha = 8,726 moose.

able to increase relative moose abundance between 0.00071 and 0.0022[56], from the baseline, depending on the scale of restoration, for the SAOS area. Translating this to moose added to the land base, it is estimated to be between four and 19 additional moose, depending on the restoration scenario implemented.[57]

Relative Moose Abundance for the SAOS



The value attached to hunting moose (about 2 new licenses to be issued, and 1 to be used) is marginal when comparing to other ES. Clients (both hunters and their non-hunting companions) spend money to purchase a hunting license but also on additional goods and services such as groceries, vehicle rentals, alcohol, and other items not included in the hunting package. They also provided additional income to employees through tips and gratuities. All of these additional expenditures have an impact on the Alberta economy. Clients spent an average of $3,300 on additional goods and services not included in the outfitted hunting package, while a moose hunting package could cost upwards of $10,000 for non-Albertans.[58] Furthermore, Reid (1996) valued hunting moose at $67.50 per day or $540 annually.[59]

Between the price of the hunting package and the additional expenditures as well as downscaling economy-wide impact of this spending, the moose hunting ES due strictly to reforestation of legacy seismic lines is estimated to be approximately $12,500 per year for the SAOS region or $25,000 per year for the entire Lower Athabasca watershed.

As noted above, there are additional benefits derived by local residents not currently being accounted for in the economic valuation. This analysis assumed that new moose added to the land base through the restoration of seismic lines would be harvested by outfitted hunting. This assumption ignores that some may be harvested by local residents as an alternative for meat purchased in the traditional sense (e.g. butcher or grocery store) as well as the existence and bequest values residents may have with hunting

56 At time 50
57 SAOS Estimated Moose Population * Relative Moose Abundance Change from the Baseline (Today)
58 Cutlac and Weber (2014). The Economic Impact of Outfitted Hunting in Alberta. Alberta Innovates, Technology Futures.
59 Reid, R. (1997). The economic value of resident hunting in British Columbia, 1995. Wildl. Branch, BC Minist. Environ., Victoria, BC. 45pp.

moose. This analysis also ignored the impact wolves can have on moose populations. Courtois and Ouellet (2007) modeled moose population being regulated by predation; if moose abundance increase, wolves also increase, independent of the caribou population. The increased wolf population leads to more frequent encounters, leading to an increased predation rate. [60]

An alternative to using the new licenses issued as a result of increasing moose populations, a 2006 Alaskan study broke down the value of increased moose populations into consumptive and non-consumptive values.[61] Consumptive values considered included hunting for sport or food, subsistence food, and considered moose-vehicle accidents. Non-consumptive values included tourism for wildlife viewing and Alaska moose appreciation.

Table 18 Estimated Moose Value, modified from The Value of Alaska Moose (2006) Study.

Consumptive Use	$USD, 2005	$CDN, 2005[62]	$CDN, 2016[63]
Hunting value, food	$15,158,000	$13,519,000	$16,280,000
Hunting experience	$13,418,000	$11,967,000	$14,411,000
Subsistence value	$9,020,000	$8,045,000	$9,688,000
Meat salvage	$726,000	$647,000	$780,000
Total	***$38,322,000***	***$34,178,000***	***$41,159,000***
$/Moose Hunted[64]	**$5,600**	**$5,000**	**$6,000**

If it assumed moose populations in the SAOS are expected to increase by roughly 4 to 19 moose depending on the level of restoration with the landscape expected in 50 years, the value of these additional moose, accounting for both consumptive and non-consumptive values is estimated to be approximately $15,800 at time 50 (using a 4% discount rate, with 100% of seismic lines being restored in caribou ranges).

While both approaches to moose valuation are correct, estimating the additional economic impact to the Alberta economy does not measure the change in human well-being, which is the purpose of this analysis. Nevertheless, because both approaches lead to similar results, it does speak to the robustness of the analysis.

[60] Courtois and Ouellet (2007). Modeling the Impact of Moose and Wolf Management on Persistence of Woodland Caribou. ALCES Vol. 43: 13-27.
[61] The Value of Alaska Moose (2006). Northern Economics Inc. Prepared for Anchorage Soil and Water Conservation district and the Alaska Soil and Water Conservation District.
[62] Exchange rate 0.8919 CDN (Bank of Canada)
[63] Inflation rate from 2005-2016 was estimated to be 20.24% (Bank of Canada)
[64] Average number of moose harvested between 2000 and 2004 in Alaska was 6900 moose.

4.3.1.5 Caribou Habitat

The caribou habitat indicator was assessed for the Southern Athabasca Oil Sands region; East Side Athabasca River caribou range, as this is the only range that falls entirely within the watershed that can be significantly affected by linear restoration. The Richardson range also falls entirely within the watershed, but much of this range was burned in a 2011 fire.

A study was completed in 2012 to estimate Albertan's willingness to pay to move from two to three self-sustaining caribou herds in the province. [65] With large-scale linear restoration, it may be possible to improve the intactness of the range to a more self-sustaining level. Environment Canada suggests a maximum disturbance level of 35% within the range to have a 60% probability that the herd will be self-sustaining.

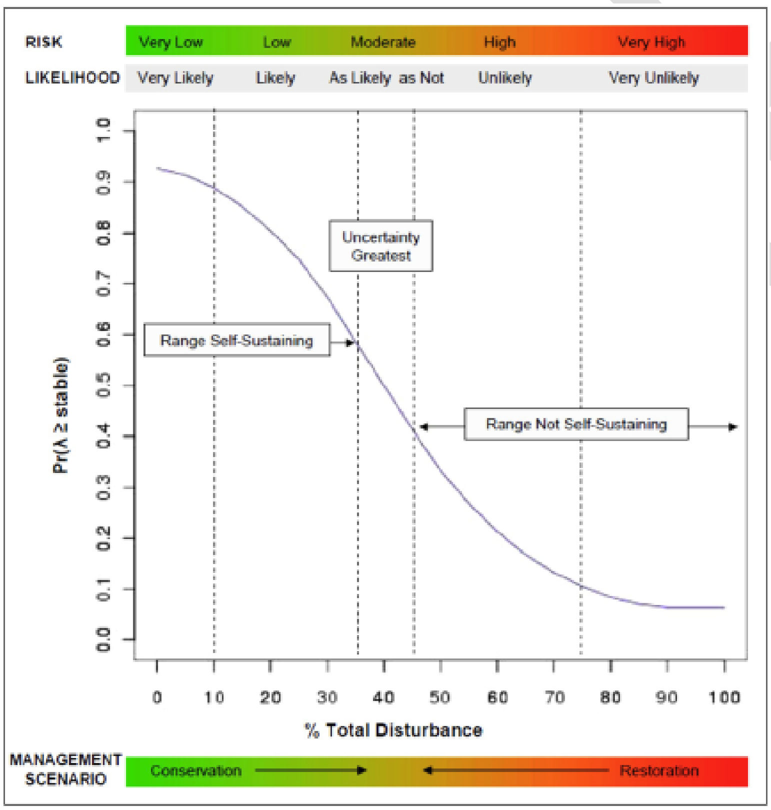


Figure 20 The probability of observing stable or positive growth of caribou populations over a 20-year period at varying levels of total range disturbance. Taken from Environment Canada (2011)).[66]

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[65] Harper, Dana (2012). Analyzing the economic benefits of woodland caribou conservation in Alberta. MSc Thesis. University of Alberta.

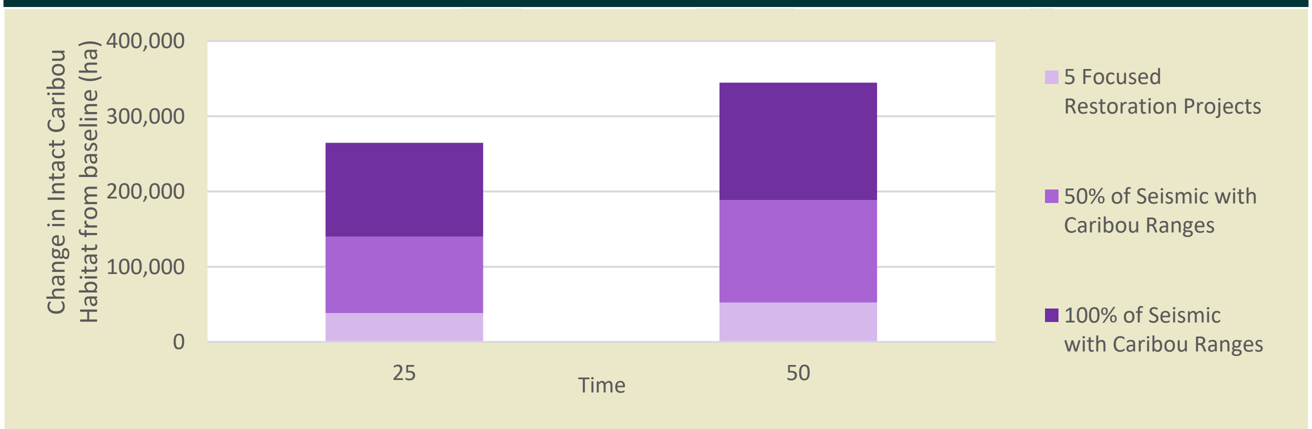
[66] Environment Canada (2011). Scientific Assessment to Inform the Identification of Critical Caribou Habitat for Woodland Caribou (Rangifer tarandus caribou), Boreal Population, in Canada: 2011 update. Ottawa, Ontario, Canada. 102 pp. plus appendices.

Legacy seismic lines also have a large impact on habitat intactness because, as per Environment Canada's recommendations, all disturbance features are buffered 500m. So even though seismic lines by themselves have a smaller footprint than most disturbance features in the Southern Athabasca Oil Sands region, once buffered 500m, they have a much larger influence on the amount of disturbance on the landscape. Using this information, along with the 2012 study, we can estimate the benefit of linear restoration for the caribou indicator.

A number of assumptions were developed to apply this approach. First, it was assumed that all Albertan's value all caribou herds equally and are willing to pay the same amount to see this improvement, no matter where they live in relation to the range or their socioeconomic status. Second, because it takes time for the planted trees to reach a height of 1.2m, at which they are considered restored and likely to influence predator movement, payments will not begin until year 30. The risk-free rate (4%) was used to estimate the net present value of linear restoration at time 50. Probability of herd survival was also accounted for in the calculations.

Table 19 Caribou Habitat Results for the East Side Athabasca River Range

Additional Caribou Habitat from Restoration for the SAOS



Undisturbed Caribou Habitat for the SAOS

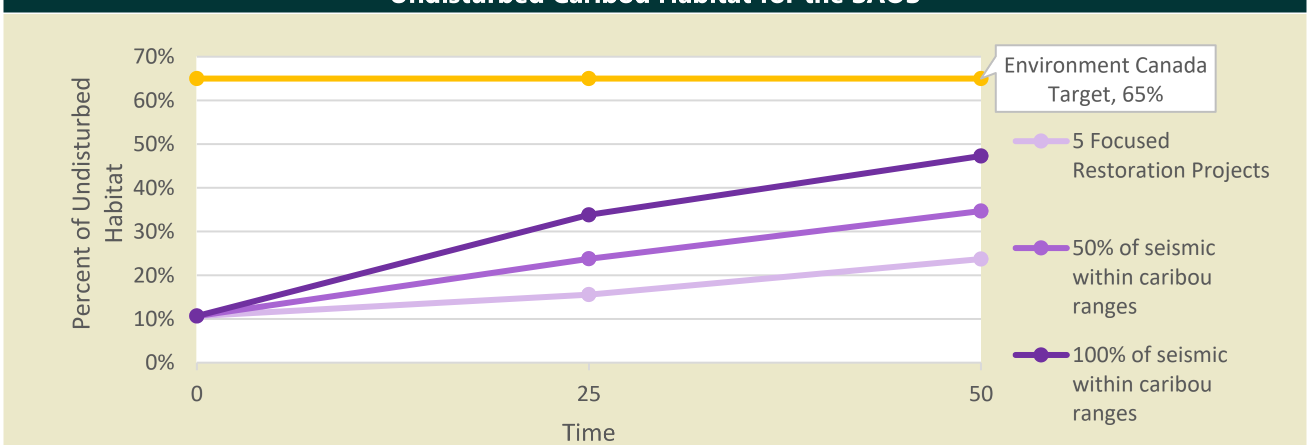
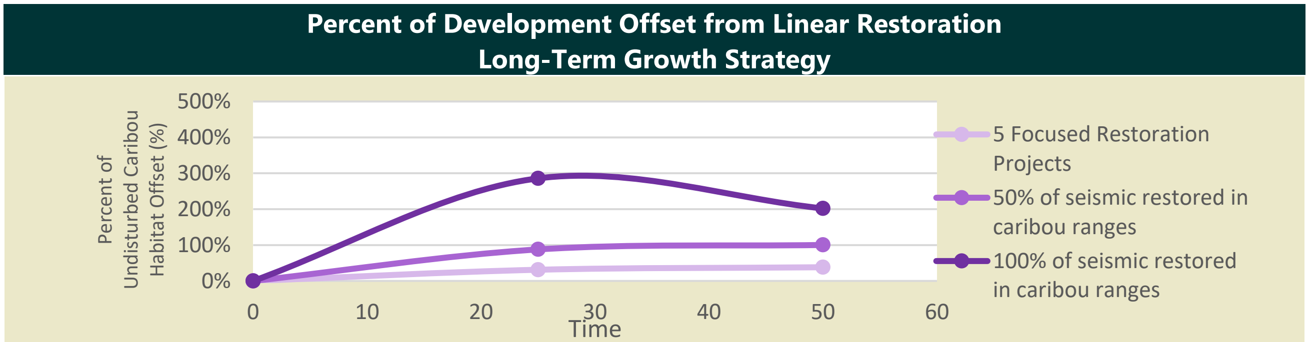
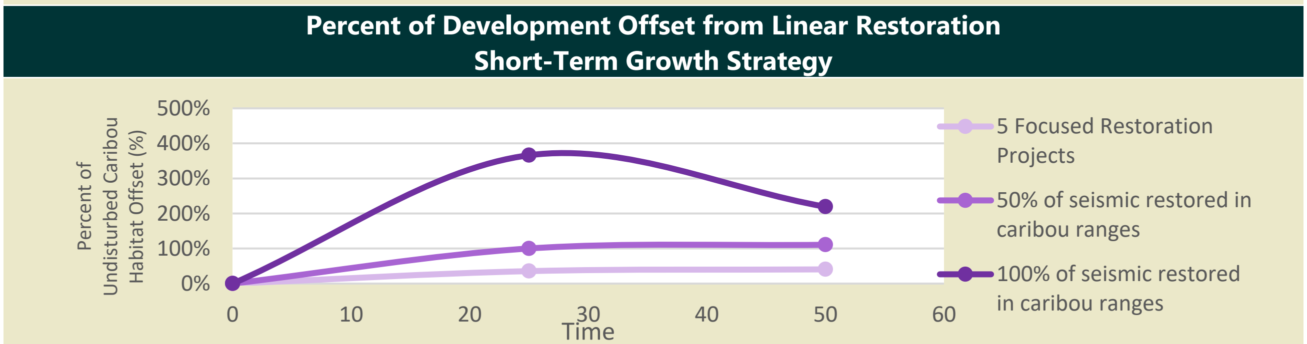
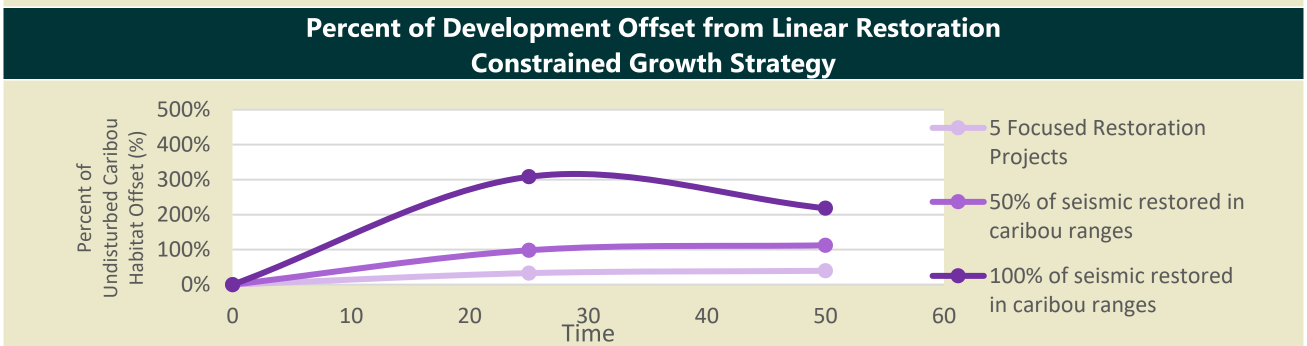


Table 20 Offset Analysis for the SAOS region







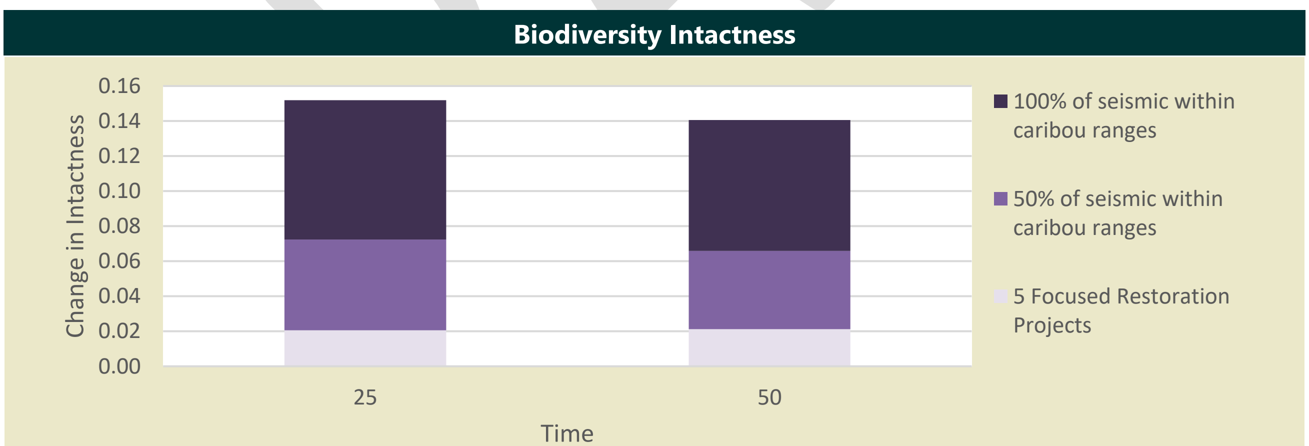
4.3.1.6 Biodiversity Intactness (Genetic Diversity)

Genetic diversity was estimated for the Lower Athabasca watershed by applying ABMI's Biodiversity Intactness model. The intactness index is used to report on the health of a species in a region. The index ranges from 0% to 100%, where 100% represents the abundance of a species we would expect to see if the landscape had remained undisturbed over time. [67]

In the Phase 1 proof of concept, the change in genetic diversity from linear restoration was valued by assuming the opportunity cost of development is a benefit of restoration. However, recent research has argued that this type of approach is not an accurate reflection of economic valuation estimates for ecosystem service analyses. [68] Furthermore, it can be argued that biodiversity is not a final ecosystem service that should be valued because it provides a number of services that feed into more concrete goods and services people benefit from (e.g. improved biodiversity can make an ecosystem more resilient, improving overall wildlife abundance, water storage ability, etc.; see Figure 2).

Nevertheless, improved biodiversity intactness and/or genetic diversity is something that should be tracked and assessed, but for the purposes of this assessment, it will not be assigned an economic value. Furthermore, due to data availability and scale of the model biodiversity intactness was only estimated for the Lower Athabasca Watershed.

Table 21 Biodiversity Intactness Results for the Lower Athabasca Watershed



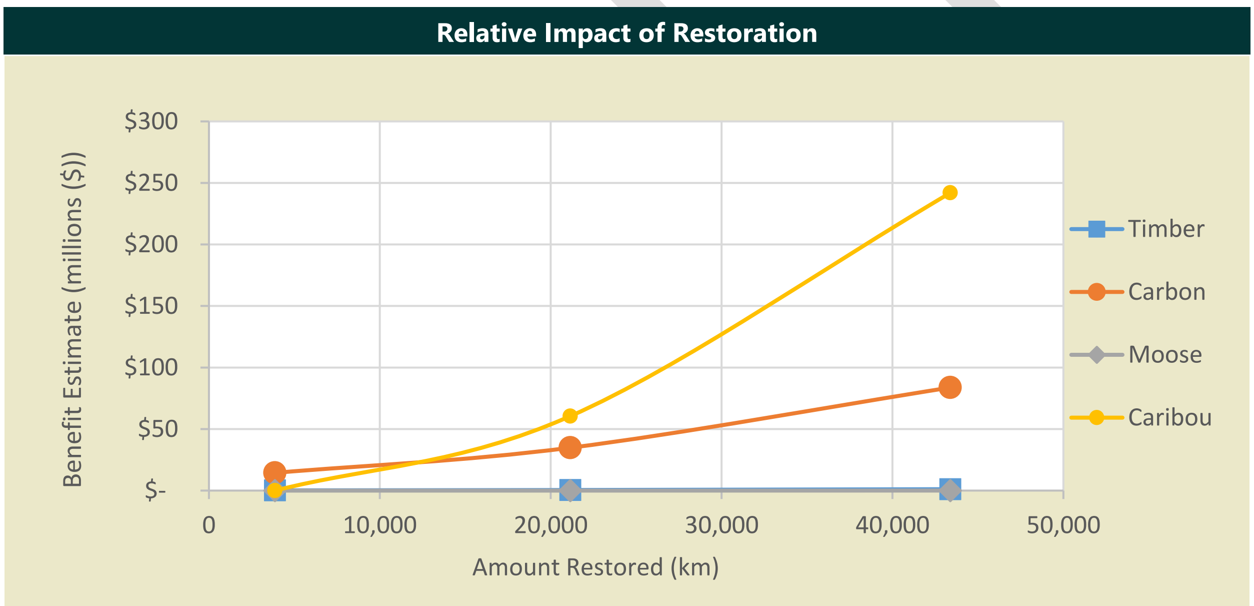
[67] ABMI (2014). ABMI's Intactness Index. Measuring Biodiversity. Accessed December 21, 2016 from: http://www.abmi.ca/home/about-us/intactness-index
[68] National Ecosystem Services Partnership (2016). Federal Resource Management and Ecosystem Services Guidebook. Benefit Assessment: Monetary Valuation. Accessed December 21, 2016 from: https://nespguidebook.com/assessment-framework/monetary-valuation/

4.4 Benefit Estimates for the Southern Athabasca Oil Sands Area

As mentioned in Section 4.3.1, we can assess the changes to human well-being through economic valuation. By translating the benefits of linear restoration into comparable units, it is easier to understand the tradeoffs between indicators identified by stakeholders as important. It also highlights where some benefits have linear (one-to-one) returns per kilometer restored, where others have increasing marginal returns per kilometer restored (Table 22). All benefit estimates were calculated using the valuation techniques outlined in Table 11.

It is important to note that this analysis does not account for the cost of restoration in the benefit estimate. As the amount of restoration is increased, it is possible that restoration will become more costly (e.g. areas available for restoration become less accessible, etc.).

Table 22 Benefit Estimates from Linear Restoration for the SAOS [69]



[69] Water quality improvements were not assessed at this scale

4.5 Employment Effects

The Little Smoky/A La Peche (LSALP) Caribou Range Plan has noted that large-scale linear restoration of legacy seismic lines, along with many other habitat management approaches will be necessary to bring herd populations to a self-sustainable level.[70] It is expected that this approach is likely to occur in other areas of the province as more range plans are released in the coming year. Furthermore, some oil and gas companies have already committed to spending millions of dollars to jump-start linear restoration in other parts of the province, before government intervention.[71]

A successful linear restoration program has many phases, where there are a number of opportunities for future employment, including but not limited to field personnel (Figure 21).

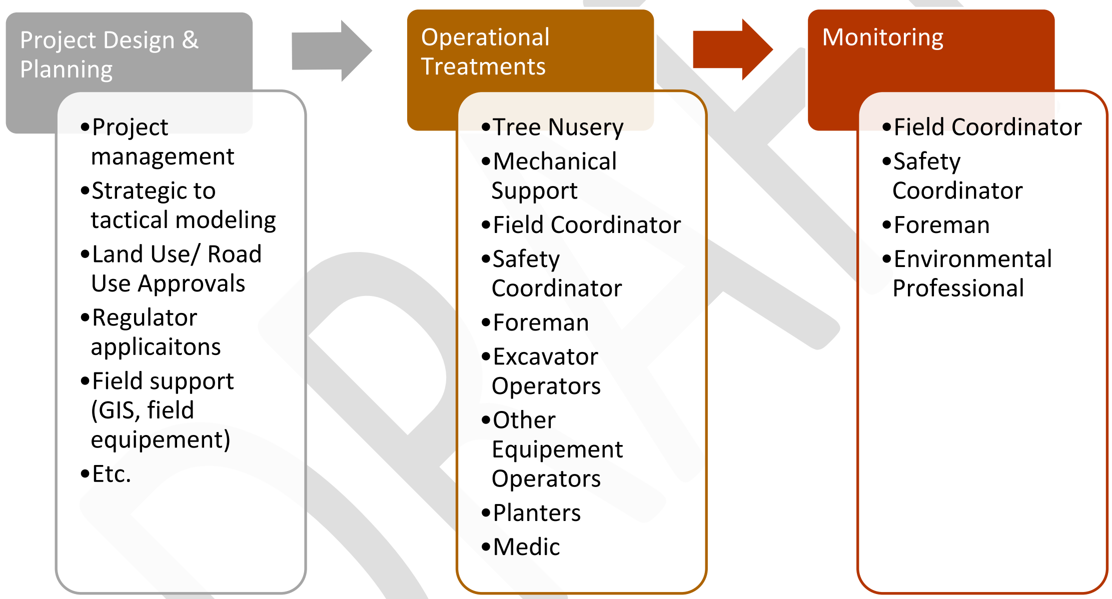


Figure 21 Example of employment opportunities

The amount of people required for a successful linear restoration program is dependent on regional infrastructure, access, lowland conditions, among other things. These programs include project design and planning, operational treatments, remote camp facilities, and so on. Furthermore, winter planting programs offer an opportunity to extend tree planter's seasonal work into months they typically would be unemployed. It is important to note, however, that scaling up programs may create some economies of scale to reduce the amount of personnel required per km in the future.

[70] Government of Alberta (2016). Little Smoky and A La Peche Caribou Range Plan (DRAFT).
[71] Cenovus (2016). Cenovus announces $32 million caribou habitat initiative. Largest single restoration project of its kind ever undertaken. *New Releases.* Retrieved from: https://www.cenovus.com/news/news-releases/2016/06-14-16-Cenovus-announces-$32-million-caribou-habitat-initiative.html

5 Discussion & Next Steps

This interim report addressed Goal 2 of this 3-year project: Test compatibility and transferability of methodologies to other areas in the province. To meet this goal, we leveraged the 7-Step Selection Criteria Process to assess scalability of the work completed in 2015 and used lessons learned from the pilot project, feedback from advisory members, and new research to develop a rigorous framework to complete ecosystem service assessments across the province.

Four questions were set out in the beginning of the year to answer in this report. These included:

1. What are the ecosystem service benefits of large-scale linear restoration?
2. How can ecosystem service concepts be used to prioritize areas for restoration?
3. Do different modeling platforms provide similar, repeatable results?
4. How can ecosystem services be used to assess the value of restoration in conservation offset planning?

The work completed to-date has shown that large-scale linear restoration can generate ecosystem service benefits including timber supply, carbon sequestration, and caribou habitat. Other measured ecosystems services including water quality, biodiversity intactness, and moose habitat showed little to no change from large scale restoration. As such, mapping potential benefits and costs indicators from linear restoration programs can help prioritize areas for restoration across large landscapes. This will focus restoration efforts and investments in high-value areas that are important to stakeholders in the region.

Furthermore, the Government of Alberta has sent many signals with the release of the draft LSALP caribou range plan that large-scale linear restoration will occur imminently and over a short time-span (e.g. 5 years). This will affect how local communities benefit from restoration in terms of ecosystem services, while also creating a number of jobs. If restoration is postponed in the Lower Athabasca watershed or completed over a longer timeframe than the LSALP region, benefit estimates will be reduced appropriately due to the time value of money. All valuation estimates currently assume restoration will begin today and occur over five years. They also applied a risk-free rate of 4%, but this may be changed based on the risk of the linear restoration program and community and/or industry needs.

Linking what communities care about is essential to have meaningful results that can speak to decision makers. The 7-Step Selection Criteria Process developed in 2015 was tested on the Southern Athabasca Oil Sands region and Lower Athabasca watershed to see if it can be scaled up and down to meet project needs. Results indicate that the framework is transparent, transferable and repeatable, and should be applicable to the entire province. It is important to note, however, that scale will affect what indicators are available to measure, due to data availability and biophysical constraints.

Large-scale restoration will also impact multiple ES differently. This will be important to address if conservation offsets are widely adopted in the province. For example, water quality improvements are nominal until a threshold is reached and typically only applicable at the watershed or sub basin scale. Other ES benefits may plateau after a threshold is reached (e.g. caribou habitat improves to support self-sustaining herds). Others will continue to increase as restoration is increased (e.g. timber supply). In addition, the amount linear restoration can offset development varies significantly between indicators. Water quality impacts from future oil and gas development cannot be offset at all according to the modeling results, where impacts to caribou habitat can be offset upwards of 400% (4:1). Lastly, more research needed to address how benefits derived from multiple linear restoration programs should be aggregated. This analysis assumed all linear restoration in the watershed was completed by one project sponsor, where, realistically, the landscape is managed under multiple forms of tenure. Benefits may overlap or interact with adjoining tenures.

The 2016 work followed a number of improvements recommended by advisory members, the project team, and newly available research. This included looking at historical timber damage assessment (TDA) tables to understand how the values may fluctuate in the future, assessing the carbon flux from linear restoration (i.e. the annual change in carbon), rather than the total amount of carbon stored at one period, and creating a market demand curve for water quality improvements, rather than relying on cost-avoidance methodologies to measure changes in human well-being. It was also discussed that water quality improvements should be assessed at the watershed scale, where ecologically they make the most sense and have the largest impact on local communities. Furthermore, the caribou habitat model directly linked the level of disturbance in the East Side Athabasca River range to an increase in the probability that the herd will survive, instead of focusing on a per hectare benefit estimate. Lastly, new research shows that not all ES should be valued using monetary terms. This should not take away from the importance placed on the indicator from local communities, nor that its change should not be assessed is some way. This line of thinking also suggests cost-avoidance methodologies (e.g. opportunity cost of development) should not be employed to measure changes in human well-being. As such, it was decided to assess the change in biodiversity intactness as a proxy for genetic diversity, but not to monetize the benefit estimate, as it can be argued that biodiversity is a supporting service that leads to many changes in final services already being accounted for. These learnings should be enforced for any ecosystem service assessment applied in the province in the future.

Data availability remains a large gap in scaling up analysis. Typically, as the analysis sought to assess the benefits at increasingly larger scales (e.g. from Algar, to the SAOS, to the Lower Athabasca watershed), a number of assumptions were needed to continue the analysis. A significant amount of time was spent building a land base from multiple sources (see Appendix A) to ensure this analysis could be completed at the watershed scale. Because multiple sources were necessary to build the land base, the resolution of the data was not the same between scales. Future investment in open data and/or automated land inventories would greatly benefit this type of analysis.

In addition to data availability, it is important that the appropriate models are selected for the scale of the project to ensure ES benefits are not over or understated. Results from the landscape modeling approach using NetLogo and the operational modeling approach using Remsoft were not comparable for age-dependent ecosystem services due to differences in model construct assumptions. When using ES models conservation offset planning, it will be extremely important that model inputs, the model itself, and the results are well understood to reduce bias and untended errors.

Moving into 2017, the project will shift its focus to the impending release of the conservation offset framework. The hope is to use the lessons learned through the pilot project and the first two years of this deeper dive to understand how ecosystem services will fit into future conservation offset policy. This may include, but is not limited to, alternative funding models, including green bonds as outlined in the Denhoff (2016) report.

Using the results from the past two years of research, we will meet the last goal of the project by identifying policy implications and key conditions to use an ES approach to linear restoration in the province. These conditions may include:

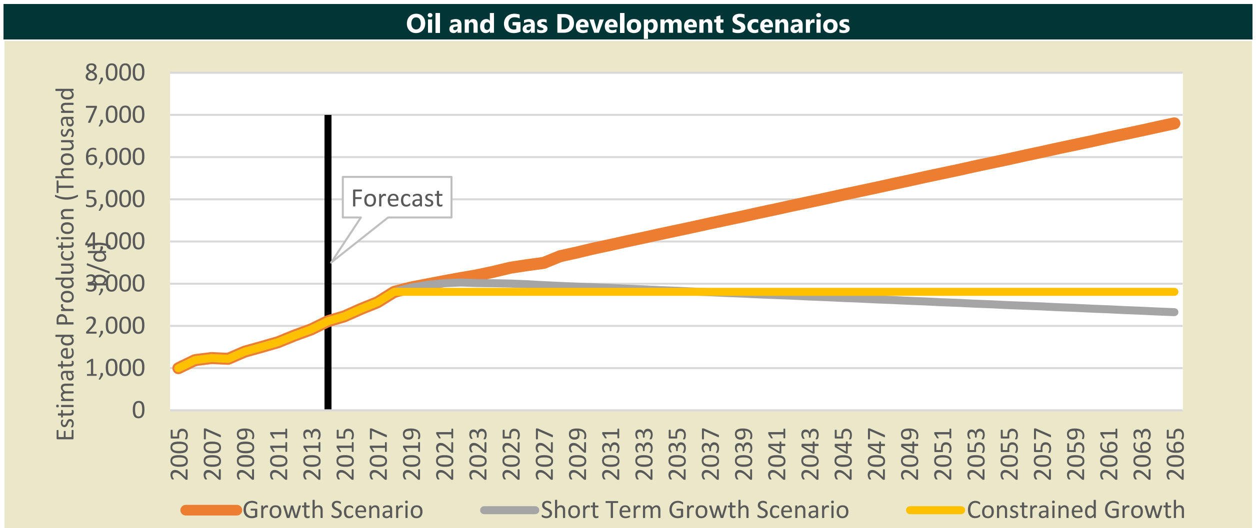
- Technical modeling conditions (taken from 2016 work)
- Challenges moving from local to regional restoration benefit measurements
- Amount of restoration required to see a meaningful change in different ES (taken from 2016 modeling results)
- How to interpret modeling results so the benefits are not misrepresented (over or understated) (taken from 2015 work)
- Additional conditions to be determined.

The project team will continue to work with the Government of Alberta to identify current and upcoming policy relevant to this project. Periodic public release of status updates, interim results, among others, will also continue to be posted through project partner websites, the Ecosystem Service and Biodiversity Network (ESBN), and conference presentations.

Appendix A Hypothetical Future Footprint Modeling

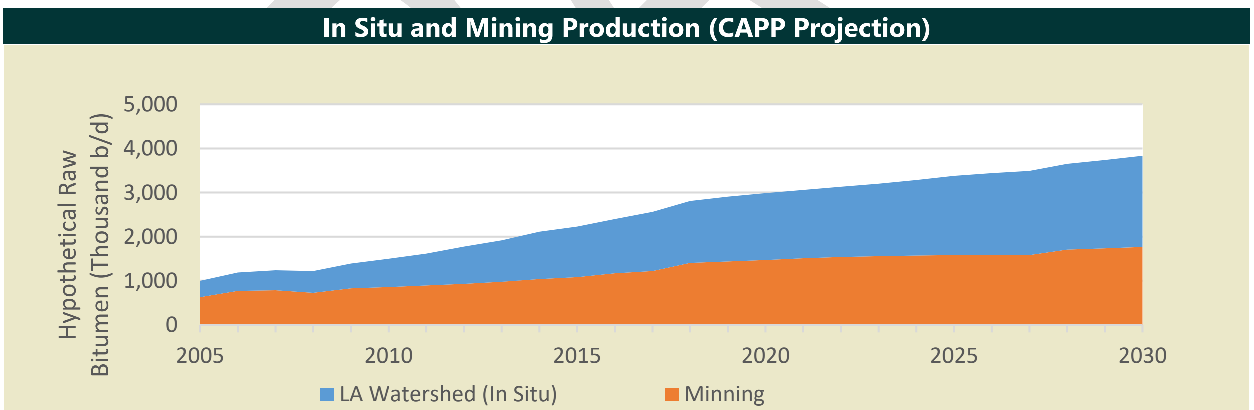
This appendix outlines how the future footprint was determined for oil and gas production scenarios as well as the future forest harvest sequence. The first step was to determine the current and projected bitumen production, based on the three development scenarios chosen for analysis. Three production scenarios were developed to illustrate various potential futures in the oil sands market over the next 50 years.

- Growth Scenario
  - The growth scenario follows the CAPP outlook (June 2015), which uses operating and in construction oil sands projects, as well as projected growth based on market conditions to forecast the amount of production to 2030. Following 2030, the rate of change from 2020 to 2030 was used to estimate the amount of production to 2065.
- Short Term Growth Scenario
  - Oil prices began to fall in late 2014 due to an oversupply in the global markets. To ensure these market forces were captured in the 2015 outlook, CAPP also released a conservative forecast which only accounted for operating and in construction oil sands projects.
  - The short-term growth scenario follows this same forecast for the area of interest and following 2030, the rate of change from 2020 to 2030 was used to estimate the amount of production to 2065.
- Constrained Growth Scenario
  - The constrained growth scenario takes into account additional market constraints including current and future pipeline capacity. According to CAPP, the development of infrastructure will be critical to getting oil sands product to market. With current pipeline projects expected to come on-line in the coming years, if they are continued to be delayed through the regulatory process, transport by rail will become increasingly more important. That said, the constrained growth scenario looks at the amount of pipeline and rail capacity currently available and keeps production rates to match the current infrastructure in place. By 2018, oil sands production for the area of interest will be held constant under this scenario.



Determining Current and Projected Bitumen Production

Production estimates were completed for two areas of interest: the larger Lower Athabasca watershed the Southern Athabasca Oil Sands Area (SAOS). The Lower Athabasca watershed covers in situ production as well as the mineable oil sands region. Furthermore, the watershed covers multiple oil sands regions, including the Athabasca Oil Sands Region and The Cold Lake Oil Sands Region.

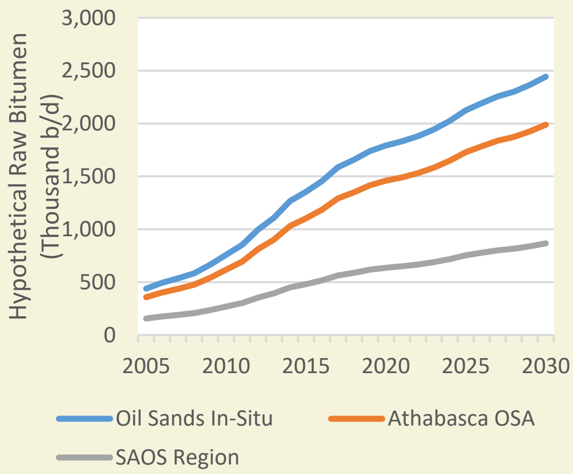


In Situ Production Estimates

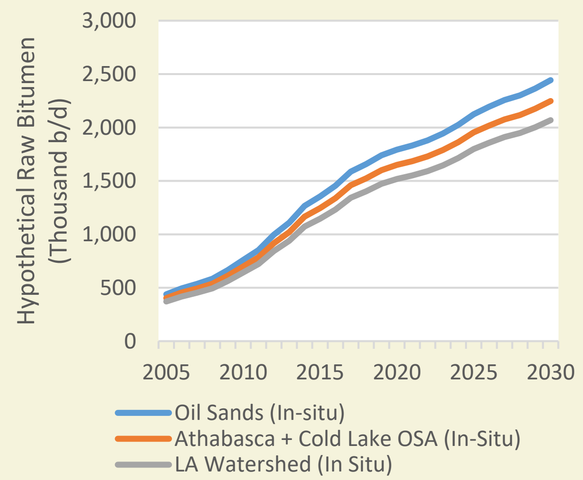
Production estimates were established using estimated bitumen pay thickness for the Wabiskaw-McMurray Formation and Clearwater Cold Lake Formation as well as estimated in-place volume provided by AER. It was projected that 44% of Athabasca Oil Sands production is coming from the SAOS and 92% of Athabasca and Cold Lake Oil Sands production from the LAW.

In Situ Production (CAPP)

Southern Athabasca Oil Sands Area



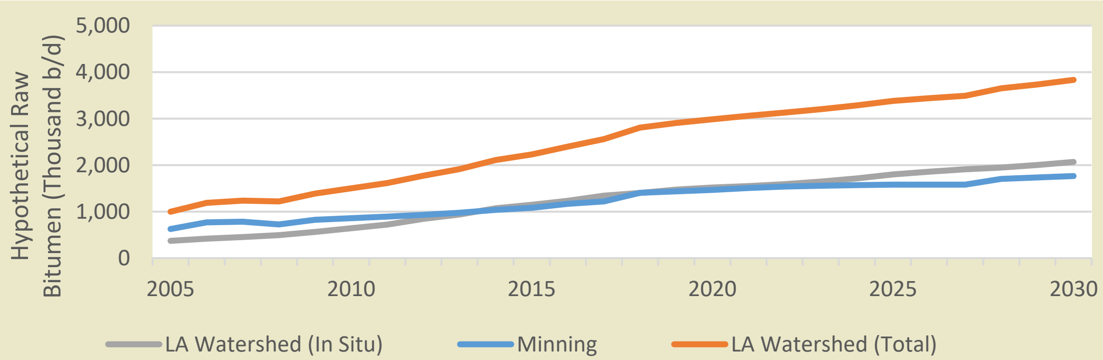
Lower Athabasca Watershed



Oil Sands Mining Production Estimates

The Southern Athabasca Oil Sands region does not fall within the mineable oil sands area so production estimates were only completed for the larger Lower Athabasca watershed. The estimates follow CAPP projections.

Oil Sands Mining Projections



Future Forest Harvest Sequence

Landbase Assembly

The Lower Athabasca Watershed covers approximately 10.6 million hectares, falls within a portion of the Wood Buffalo National Park, over half of Alberta-Pacific's (Alpac) FMA, and a small part of the white zone, surrounding Cold Lake. Two land cover attributes were necessary to project the forest harvest sequence for the watershed:

- Forest cover types (Strata)
- Age of forested types

Because the watershed covers a wide range of landscape types including a national park, an FMA, and white zone, a number of sources were required to compile a complete vegetation inventory.

- Phase 3 Vegetation Data
- Alberta Vegetation Inventory (AVI)
- National Forest Inventory (NFI)
- ABMI Wall to Wall Land Cover Inventory (2010)

AVI provides the most detail for determining age and forest cover types, however, the extent of AVI available for this project only covers the SAOS area. Areas outside of AVI coverage relied on the ABMI Land cover (2010) as the spatial dataset to attribute forest cover types and age. Unfortunately, the ABMI Land cover (2010) does not have detailed information regarding forest cover types and age, rather it outlines if the forested stand is conifer leading, broadleaf or mixed. To estimate a more detailed cover type and age, the species and age distribution in Phase 3 data localized to a township was used, and where this was unavailable, the National Forest Inventory was employed.

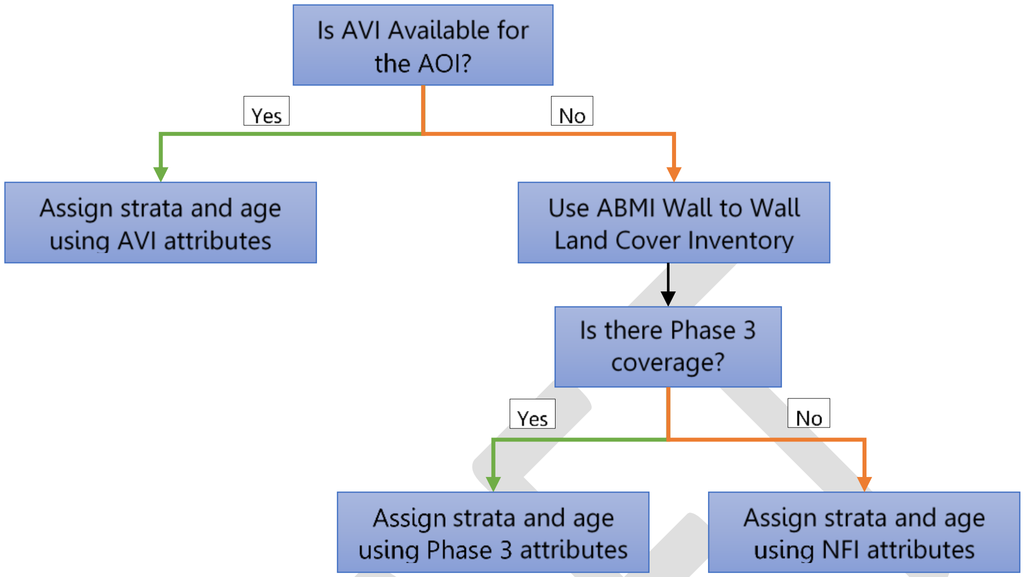


Figure 22 Process for assigning forest strata and age class to the LAW land base

Both Phase 3 and the National Forest Inventory (NFI) are a-spatial datasets. In the Phase 3 data, species and age distribution can be estimated by township. The NFI has a lower resolution, using the ecozones to define species and age distributions. Following a Bernoulli distribution approach, the distribution in each township (or ecozone) was used to randomly assign polygons in the ABMI Land cover (2010), based on the high-level conifer, broadleaf and mixed forested types outlined in the ABMI Land cover.

A Bernoulli distribution approach is a type of binomial probability, where it estimates the probability of assigning a success or failure (e.g. yes or no to a forest cover type). When the species distribution is applied as the probability of success, one can estimate if a forested stand will be assigned that cover group. This analysis was repeated for each forest cover type and age class that did not have AVI coverage. Forest cover types included:

- Pure Coniferous – White Spruce Leading (C-SW)
- Pure Coniferous – Black Spruce Leading (C-SB)
- Pure Coniferous – Pine Leading (C-P)
- Conifer Dominated Mixed Wood – Spruce Leading (CDS)
- Conifer Dominated Mixed Wood – Pine Leading (CDP)
- Deciduous Dominated Mixed Wood – Spruce Leading (DCS)
- Deciduous Dominated Mixed Wood – Pine Leading (DCP)
- Pure Deciduous (D)

The ABMI Human Footprint layer (2012) was used to augment the forested land base by identifying any cut blocks on the landscape. Cut blocks were classified into three categories:

1. Within both the ABMI Human Footprint Layer and AVI for the SAOS area
2. Within the ABMI Human Footprint Layer, and not identified in the AVI (harvested post-AVI)
3. Outside AVI coverage

For cut blocks, without an age (outside AVI coverage or harvested post-AVI) the same binomial approach was used to randomly assign a harvest age to the block.

Finally, forest fires were also used to augment the land base.

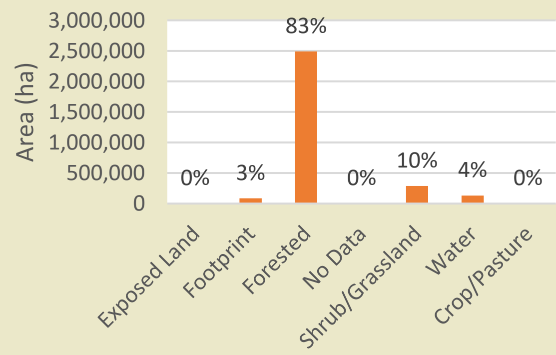
Landbase Benchmarking

Southern Athabasca Oil Sands Region

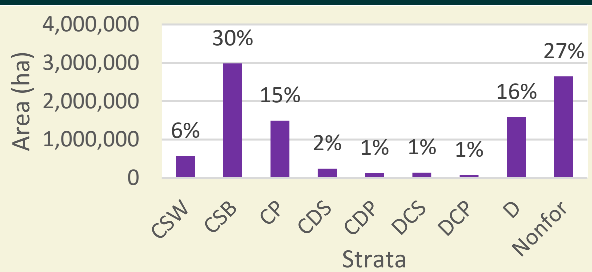
Netdown

Category	Area (ha)	Percent
No Inventory	0	0%
Water	130,486	4%
Parks & Other Deletions	207,540	7%
Anthropogenic	65,033	2%
Naturally Non Forested	291,912	10%
Non-Productive Forested	1,020,607	34%
Riparian Buffers	24,368	1%
Productive Forest Area	1,260,362	42%
Total Area	**3,000,308**	**100%**

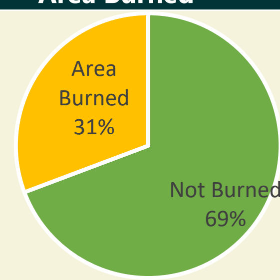
Land Cover



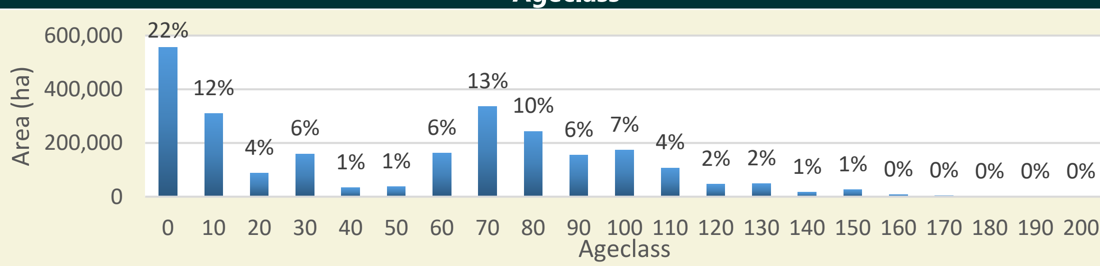
Strata



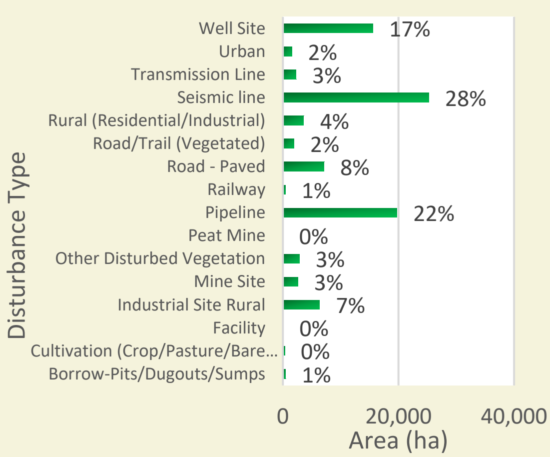
Area Burned



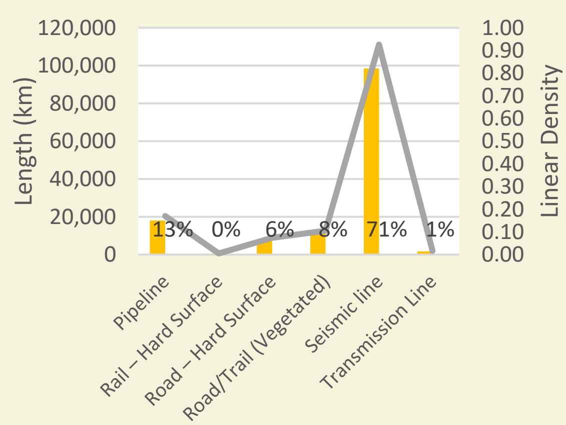
Ageclass



Disturbance



Linear Density

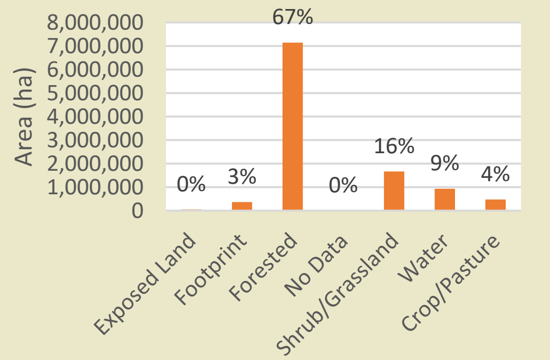


Lower Athabasca Watershed

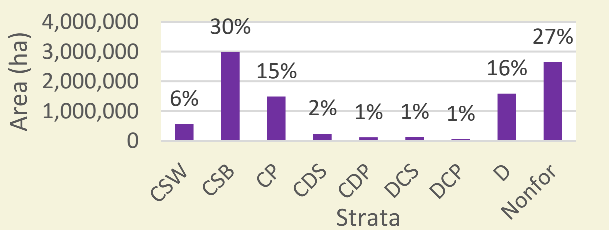
Netdown

Category	Area (ha)	Percent
No Inventory	96	0%
Water	931,363	9%
Parks & Other Deletions	503,459	5%
Anthropogenic	792,536	7%
Naturally Non Forested	1,716,032	16%
Non-Productive Forested	1,328,769	12%
Riparian Buffers	205,013	2%
Productive Forest Area	5,156,697	48%
Total Area	**10,633,965**	**100%**

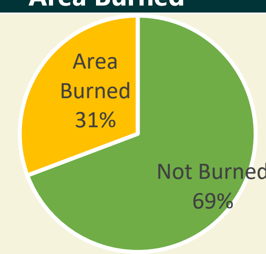
Land Cover



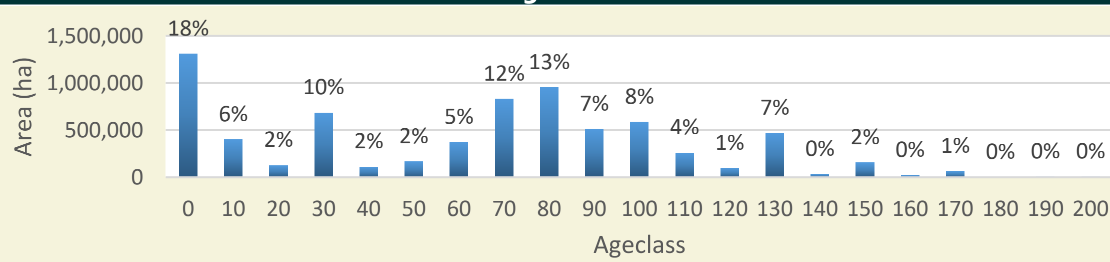
Strata



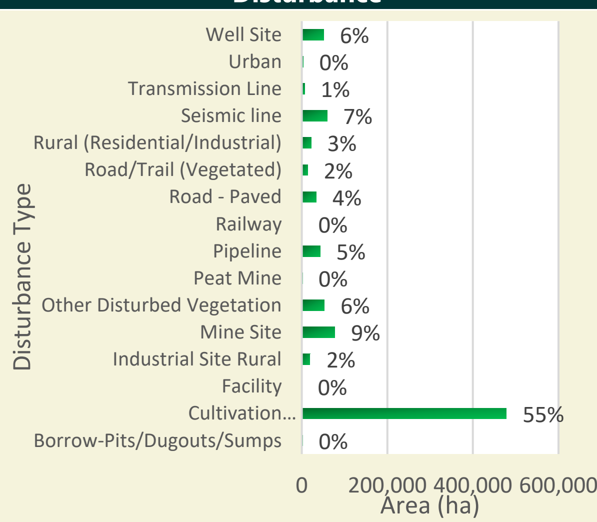
Area Burned



Ageclass



Disturbance



Linear Density