ASSESSING THE ECOSYSTEM SERVICE BENEFITS OF THE COSIA LEAP PROGRAM

Phase 2: Interim Report 1 of 3

Silvacom Ltd.
Head Office
3912 - 91 Street NW
Edmonton, Alberta
Canada T6E 5K7
Tel: 780-462-3238
Fax: 780-462-4726
Email: silvacom@silvacom.com

www.silvacom.com

silvacom™ Alberta Innovates

CONTENTS

Executive Summary

The COSIA LEAP (Landscape Ecological Assessment and Planning) program was launched in 2011, with a goal to restore approximately 350 km of legacy seismic lines in a remote area in the boreal forest of northeast Alberta. Over the following four years, over 161,700 trees were planted, existing natural vegetation was protected, and coarse woody debris scattered to improve microsites and create access barriers.

The COSIA LEAP program was aimed at restoring functional caribou habitat in the East Side Athabasca River range. By restoring previously disturbed areas, programs like LEAP are contributing to the improvement of many ecological functions (e.g. wildlife habitat, water quality regulation and carbon sequestration). When these improvements benefit people, they are considered ecosystem services (ES). ES can include, but are not limited to, the provision of food and fiber, pollution control and water purification, aesthetic and recreational benefits, and wildlife habitat, among others.

ES valuation attempts to translate the benefits we receive from nature into economic terms so we can better understand trade-offs using one common denominator. Leveraging ES valuation in sustainable development supports the maintenance of a healthy economy while also protecting the ecological process for future generations.

This project is the second phase of a multi-phase study to assess the changes in ES gained from linear restoration projects similar to the COSIA LEAP program.

Phase 1 assessed the change in ES resulting from the linear restoration program, along with a preliminary cost-benefit analysis based on market prices and available secondary data. Because restoration of legacy seismic lines is not a regulated requirement, the findings revealed the potential use of linear restoration in a conservation offset scheme in Alberta.

Phase 1 provided a critical perspective on how projects that seek to derive ES and biodiversity benefits are able to perform under rigorous environmental and economic assessment frameworks. The findings revealed there are potential gains to ES from restoration activities conducted in the COSIA LEAP program, and those gains may justify the cost of restoration if the restoration program was scaled up to a larger region. If conservation offsets are pursued in Alberta, it is expected frameworks like LEAP will be of benefit.

Moving into Phase 2, three goals were set out to bring further precision to the LEAP ES assessment in a way that is meaningful and transparent for decision-makers in the private and public sectors.

1. Develop a repeatable process to identify the appropriate ES to evaluate a management plan and it's 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.

This discussion paper reflects the results of the first goal of Phase 2. To meet Goal 1, we have developed criteria for selecting ES and indicators for assessment, making the process repeatable and transparent through selection criteria templates. We have also refined the ES chosen for assessment for the COSIA

LEAP program, and evaluated the underlying model assumptions (from Phase 1) to ensure the benefits are not overstated.

During Phase 1, ES and ES indicators were chosen based on the best available data appropriate for the region in which the COSIA LEAP program was launched. The process for identifying, evaluating and selecting ES lacked rigor, leaving questions about if the correct ES were measured and if any additional ES were missed.

As part of Phase 2, a 7-Step Selection Criteria Process was developed to identify the appropriate ES for assessment. The process revealed that the ES identified in Phase 1 were suitable ES to be assessed for the area of interest. It also revealed that stakeholders in the region highly value moose for the provision of wild foods and hunting opportunities. Moose was added to the ES assessment, however, the results of the assessment revealed that the benefits from linear restoration to the provision of wild foods is negligible.

This approach is a repeatable, transparent process to identify the appropriate ES for an area of interest that involves linking plain-language stakeholder values to the biophysical changes caused by linear restoration and the benefits people receive from these changes. The intent is for this process to be adapted by decision makers in ES assessments in the future. Lastly, this analysis filled a need for a conceptual framework where the selection of ES, and their respective indicators, follow a transparent and rigorous selection process.

To meet Goal 2, we will leverage the 7-Step Selection Criteria Process to identify any additional high priority values in the larger Southern Athabasca Oil Sands Area (SAOS).

Once a list of high priority values for the SAOS is established, Silvacom will work with project partners to prioritize areas for restoration, maximizing the benefits of linear restoration for a basket of ES, linked to high priority values. The project team will define a number of scenarios to understand trade-offs between ES locally and regionally. Furthermore, the project team will address issues of scaling ES assessments up to larger areas of interest by applying the modelling approach to the Lower Athabasca Regional Planning (LARP) area.

Results of Goal 2 will include the identification of high priority restoration areas in the SAOS region and LARP area, the amount of restoration required to see a change in ES in both scales, and the potential trade-offs between local and regional values. The results of Goal 2 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 modelling conditions (taken from 2016 work)
- Challenges and opportunities moving from local to regional restoration benefits
- Amount of restoration required to see a significant change in the supply of an ES (taken from 2016 modelling results)
- How to interpret modelling results so the benefits are not overstated (taken from 2015 work)
- Additional conditions to be determined

Community engagement will be a key to the success of meeting the upcoming goals. The project team hopes to work with additional partners within the Government of Alberta and the Cumulative Effects Management Association (CEMA) to ensure engagement remains strong.

1 Introduction

As historic and current resource developments leave a footprint across much of Alberta's landscapes, restoration and reclamation efforts help balance economic growth with enhanced environmental quality. Further, as Canadian oil and gas producers seek additional access to global markets, more is being asked of them in meeting society's needs for economic, social and environmental sustainability. In response to increasing local and global pressures, Canadian oil sands companies are using collaboration to drive innovation and address some of the environmental challenges related to oil sands development. An early innovator and leader of successful collaboration is the Canadian Oil Sands Innovation Alliance (COSIA) - COSIA is comprised of thirteen member companies[1] dedicated to step-changes in environmental performance for the oil sands industry. One key focus area for COSIA is land stewardship, including the reduction of land disturbance resulting from oil sands development.

A subgroup of COSIA companies (including Nexen, ConocoPhillips, Shell, Statoil, Suncor and Total) co-developed the Landscape Ecological Assessment and Planning framework, also known as LEAP. LEAP is a four part process involving:

1. The establishment of ecological objectives for the future landscape
2. Modelling and projecting ecosystem change
3. On-the-ground restoration implementation
4. Monitoring to measure changes in ecological conditions

Leveraging LEAP, the companies worked together to restore over 350 km of legacy seismic lines in the Algar area, located in the Lower Athabasca Region of Alberta. By restoring previously disturbed areas, programs like LEAP are contributing to the provisioning of ecological functions (e.g. wildlife habitat, water quality regulation and carbon sequestration), which provide benefits to people in the form of ecosystem services (ES) (e.g. hunting, fishing, and climate regulation).

This project is the second phase of a multi-phase study to assess the changes in ecosystem services gained from linear restoration projects similar to the one completed in the Algar area.

Phase 1 assessed the change in ES resulting from the linear restoration program, along with a preliminary cost-benefit analysis based on market prices and available secondary data. Because restoration of legacy seismic lines is not a regulated requirement, the findings revealed the potential use of linear restoration in a conservation offset scheme in Alberta.

Phase 1 provided a critical perspective on how projects that seek to derive the benefits of ES and biodiversity perform under rigorous environmental and economic assessment frameworks. The findings revealed there are gains to ES from restoration activities conducted in Algar, and those gains may justify the cost of restoration. If conservation offsets are pursued in Alberta, it is expected frameworks like LEAP will be of benefit.

Following the wrap up of phase 1, a number of next steps were identified by project partners to bring further precision to the LEAP ES assessment and cost-benefit analysis results including:

[1] BP Canada, Canadian Natural Resources Limited, Cenovus Energy Inc., ConocoPhillips Canada Resources Corp., Devon Canada Corporation, Imperial Oil, Nexen, Shell Canada Energy, Statoil Canada Ltd., Suncor Energy Inc., Syncrude Canada Ltd., Total E&P Canada Ltd., and Teck Resources Limited.

- Identify other potential ecosystem services to include (or drop) in the Algar LEAP assessment
- Review phase 1 methodologies and highlight key assumptions that may affect interpretation of results
- Test compatibility and transferability of the methodologies in another area(s)
- Undertake socio-economic research to better understand the value that Albertans place on the benefits derived from ecosystem services related to land restoration in LARP
- Evaluate Draft Environmental Offset Principles to be provided by the Government of Alberta.

Phase 2 was established to meet the outlined next steps. It is a three year project that has been split into three distinct goals:

1. Develop a repeatable process to identify the appropriate ES to evaluate a management plan and it's 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.

The discussion paper reflects the results of the first goal of Phase 2, where we have developed criteria for selecting ES and indicators for assessment, making the process repeatable and transparent through selection criteria templates. We have also refined the ES chosen for assessment in the Algar region, and reviewed the underlying assumptions in the models used.

In the follow sections, this report will present the ES and indicator section criteria and process, the results of the ES assessment from phase 1, additional results for ES not included in phase 1, and the findings from the underlying model assumptions review to better understand how these models can be scaled up and down.

1.1 Project Outcomes

The desired outcome of this project is to further the development of a repeatable, transferable, and implementable approach to evaluate the net benefits/losses of management alternatives in the boreal region, and to identify high priority areas for seismic restoration that address multiple ES benefits. As part of the success of this project, a restoration planning and implementation document will be developed that identifies key conditions that are required to be met to allow the transfer of methodologies for the ES and biodiversity assessment to alternate sites.

1.2 Project Approach

To meet project objectives, Silvacom has and will continue to work with project partners, Alberta Biodiversity and Monitoring Institute (ABMI), Alberta Environment and Parks (AEP) and Alberta Innovates, Tech Futures (AITF). 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 it's 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.

Assessing the Ecosystem Service Benefits of the COSIA LEAP Program

Figure 1: Overview of Phase 2 Approach

KEY QUESTIONS

1 In the Phase 1 proof of concept, did we select appropriate ecosystem services, indicators and models for the assessment of ecosystem services (ES) change as a result of the Algar linear restoration project?

2 Can we take the same approach & methodology used for the Algar Restoration Project and conduct a similar ES assessment in another part of the province (real or theoretical project)?

What needs to be altered in the general approach framework to accommodate this?

3 How can the results of ES assessment for linear restoration be used in a conservation offsets scheme?

GOAL 1 (2015)

Enhance the ES Assessment Process for the Algar Restoration Project

Purpose:

Phase 1 was a proof of concept approach to assessing ecosystem services for a linear restoration project. Goal 1 of Phase 2 builds on the lessons learned from Phase 1 to strengthen and enhance the assessment process from ES and indicator selection through to model assessments. This will lay the groundwork to meet Goal 2: testing the transferability of the ES assessment approach to another study site.

Expected Outcomes:

A repeatable process will be developed for selecting appropriate ecosystem services and indicators which will be leveraged to meet Goal 2. The ecological change of newly identified ES for inclusion will be assessed. Model results, assumptions, and interpretation of results will be reported in the interim report 1 of 3.

High Level Activities:

1. Develop an ES Selection Criteria Process
2. Finalize list of ES and indicators for assessment in the Algar region
3. Review Phase 1 assessment models and highlight key assumptions that may affect the interpretation of results. Research and/or develop new methodology and models for additional ES identified in phase 2.
4. Complete ES Assessment for newly identified ES
5. Report of results, model assumptions, and consequences for the Algar restoration project.

GOAL 2 (2016/17)

Test the transferability and scalability of the approach & methodology on another site in Alberta

Purpose:

Goal 2 will take the approach & methodologies developed in the previous year to examine the transferability and scalability of ES assessments on larger landscapes including the Southern Athabasca Oil Sands area and the Lower Athabasca Regional Planning area.

Expected Outcomes:

ES will be assessed using the same approach from Goal 1 and key learnings identified of which processes and methodologies are transferable. Specifically, the differences in the scope of stakeholder values will be addressed (e.g. local, regional, and provincial values) and how these influence trade-offs in ES assessments. This information will help develop a restoration planning and implementation manual that will feed into Goal 3: Conservation Offset Strategies.

High Level Activities:

1. Apply Algar ES methodologies to other area(s)
2. Complete ES scenario modelling to evaluate trade-offs between local, regional, and provincial stakeholder values
3. Evaluate transferability of methodologies
4. Identify key conditions required for successful transferability
5. Develop a restoration planning and implementation manual

GOAL 3 (TBD 2016/17)

Evaluating linear restoration and how it fits with conservation offsets

Purpose:

Goal 3 will build on the lessons learned in Goals 1 & 2 to evaluate how linear restoration can fit into a conservation offset scheme.

Expected Outcomes:

Recommendations for how linear restoration can fit into a conservation offset scheme. Identify how trade-offs between ES will be incorporated.

High Level Activities:

1. Conduct a literature review of conservation offset schemes similar to the one proposed by the GOA
2. Review relevant federal and provincial policy that may affect the offset scheme
3. Develop an overview of the linkages between GOA offset principles and potential criteria to support linear restoration

Throughout the project, team members have and will continue to meet regularly to share information and expertise. Furthermore, an advisory committee was established to share relevant information regarding the project across sectors. A scientific advisory committee was also established to critique methods and provide guidance at specific points throughout the project (Table 1-1). 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, and conference presentations.

Table 1-1 Advisory Committee Members

Advisory Committee		Scientific Committee	
Name	**Affiliation**	**Name**	**Affiliation**
Dave Poulton	AACO	Tim Vinge	AEP
Dan Farr	ABMI	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
Gillian Kerr	AEP		
Kim LaLonde	AEP		
Scott Milligan	AEP/Land Use Secretariat		
Lee Woodham	Alberta Agriculture and Forestry		
Carol Bettac	AI Bio, Project Sponsor		
Marian Weber	AITF		
Bob Nichol	Alpac		
Jeremy Reid	Devon Energy		
Gord Whitmore	DMI		
Anthony Hamilton	Land Use Secretariat		
Carolyn Tralnberg	Land Use Secretariat		
Simon Dyer	Pembina Institute		
Judy Smith	Shell Canada		
Avelyn Nicol	Independent		

1.3 Background

This paper is part of a multi-phase, multi-year project. 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 answer a few important questions regarding land restoration in Alberta, including:

- What are the outcomes for ecosystem services associated with land restoration?
- What are the benefits and costs?
- Will land restoration play a key role in Alberta's conservation offsets markets?

Algar ES Phase 1 provided a critical perspective on how projects that seek to derive ecosystem services and biodiversity benefits perform under rigorous environmental and economic assessment frameworks.

Algar ES Phase 1 benefited COSIA member companies, the network of resource management companies that participate in the ecosystem service roadmap process and the Government of Alberta in designing future conservation offset policies. The project was part of a coordinated collaboration of industry, government, ENGO and academic partners advancing the applied research and implementation of integrated resource management in Alberta.

The findings of Algar ES Phase 1 revealed that there are significant gains to be realized from undertaking land restoration such as those associated with the LEAP framework. The value of ecosystem service gains resulting from restoration and conservation in Algar is likely sufficient to justify the cost of restoration. Should a conservation offset scheme be pursued in Alberta, it is expected that interest in the assessment of ES gains resulting from frameworks such as LEAP would increase significantly.

Results of phase 1 spurred interest in pursuing more research into understanding the selection of ES, underlying model assumptions and scalability of assessment results.

1.4 The Algar Restoration Area

The Algar restoration area is within the Regional Municipality of Wood Buffalo (RMWB) located in northeastern Alberta. In 2011, the population of RMWB was estimated to be 65,565, representing a 27.3% increase from the 2006 census subdivision population estimate.[2] In 2006, 82.3% of the population participated in the labour force. Agriculture and resource based industries are the primary sources of employment in the area.[3]

The Algar restoration area covers 0.8% of RMWB. There are no communities within or immediately adjacent to the Algar region. However, some of the Algar region overlaps with the Athabasca River, which flows through Fort McMurray. Therefore, changes in some ecosystem services (i.e. water purification) may impact downstream recipients in Fort McMurray.

The Algar restoration area is historically a site of relatively low industrial and forestry activity. It is home to the Algar caribou herd within the East Side Athabasca River (ESAR) range. The area is approximately 56,000 ha, spanning six townships, of which 261 ha of human caused linear disturbance were eligible for restoration (Figure 2).

Ecologically, the majority of the Algar area is comprised of wet low lying conditions with scattered upland sites where relief is present and the predominate natural disturbance regime is fire.

[2] Statistics Canada (2015). Population and dwelling counts for Canada and census subdivisions (municipalities), 2011 and 2006 censuses. Retrieved from: http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/hlt-fst/pd-pl/Table-Tableau.cfm?LANG=Eng&TABID=1&T=301&SR=5176&RPP=25&S=82&O=A&CMA=0&PR=0#FootCSDType
[3] Ibid

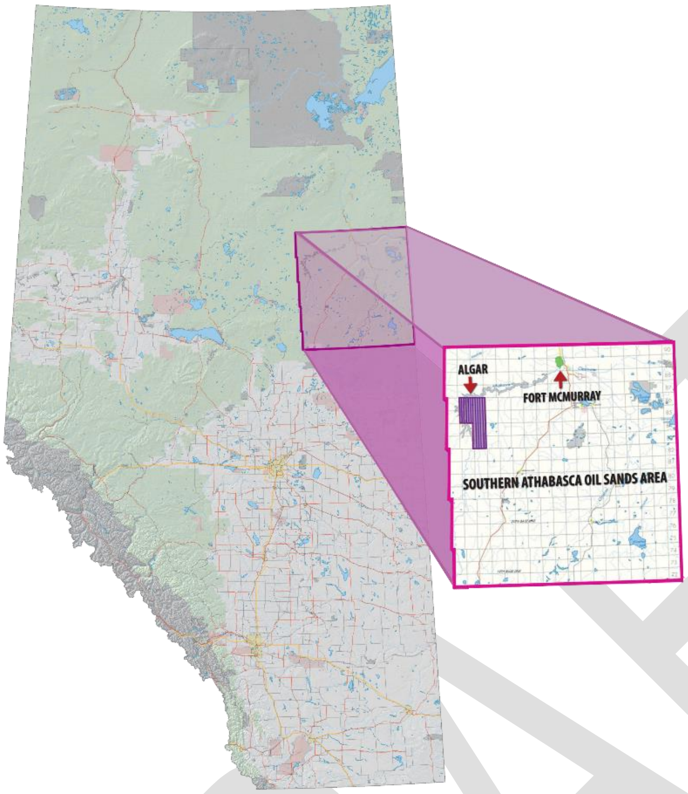

Figure 2: Algar Restoration Area

Using LEAP as the tool to restoration planning, site-specific operational work was initiated during the 2011/2012 winter season. Over the next four years, 340 km of seismic lines were treated during the winter seasons. Treatment activities included:

- Mechanical site preparation for winter tree planting
- Accumulation of coarse woody material (improving microsites and creating access barriers)
- Identification and protection of existing natural vegetation
- Planting of approximately 161,700 trees

2 Ecosystem Service Assessments

2.1 What are Ecosystem Services

Ecosystem services are the benefits people derive from nature. These include, for example, the provision of food and other products, pollution control and water purification, aesthetic and recreational benefits, and wildlife habitat. Ecosystem services are generally characterized into one of four categories: provisioning, regulating, cultural or supporting. Provisioning services are the products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources. Regulating services are the benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification. Cultural services are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. Supporting services are those that are necessary for the production of all other ecosystem services, such as primary production, production of oxygen, and soil formation.[4]

While markets for some ES already exist (the provision of forest products and agricultural crops, air quality through the Specified Gas Emitters Regulation for example), that is not the case for many. By creating economic and regulatory incentives (through the use of offset programs for example) for the conservation and appropriate stewardship of ES, markets can guide people's behaviour in directions that support desired environmental and economic outcomes. Under a market approach for ES, people and businesses that are able to provide ES such as fresh water, erosion control, and wildlife habitat can be economically rewarded for doing so. By valuing ES it can also become evident to policy makers that in some cases nature-based solutions, e.g. using wetlands for water purification, flood protection or carbon storage, may be more cost-effective than technical infrastructure.[5] Establishing markets for ES can also encourage people to limit their use of ecological resources and reduce their environmental impact.

Ecosystem service markets have been implemented around the world. Australia, the United States, and Latin America all have ES markets. Ranchers in Australia can be compensated for conducting management activities that protect and restore ES such as water quality and native vegetation.[6] In the United States, landowners are paid to manage their land for the benefit of endangered species.[7] Farmers in Mexico receive payments in return for preserving forest cover on their property, which provides water filtration and water storage services for downstream users.[8]

Other countries have begun to implement ES into their directives and policies. The EU has launched an initiative to develop a No Net Loss of Biodiversity and Ecosystem Services policy[9], Peru passed a ground-breaking Payments for Ecosystem Services law in 2014[10], and in the fall of 2015, President Barack Obama

[4] Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.
[5] Maes, Joachim, et. al. 2012. "Mapping ecosystem services for policy support and decision making in the European Union" in Journal of Ecosystem Services, Volume 1, Issue 1.
[6] Victoria Department of Natural Resources and Environment. 2002. Victoria's Native Vegetation Management: A Framework for Action. Department of Natural Resources and Environment, East Melbourne.
[7] US Fish and Wildlife Service. 2003. Guidance for the Establishment, Use, and Operation of Conservation Banks. http://www.fws.gov/endangered/pdfs/MemosLetters/conservation-banking.pdf
[8] Alix-Garcia, J., A. de Janvry, E. Sadoulet, and J.M. Torres. 2005. An Assessment of Mexico's Payment for Environmental Services Program. Report prepared for the Comparative Studies Service Agricultural and Development Economics Division, United Nations Food and Agriculture Organization (FAO). Pp. 79.
[9] http://ec.europa.eu/environment/consultations/nnl_en.htm - last updated April 22, 2015.
[10] http://www.ecosystemmarketplace.com/articles/peruvian-congress-passes-historic-ecosystem-services-law/

issued a memorandum advising all federal agencies to begin incorporating ES into their planning processes[11]. The government of Alberta also recently released the draft South Saskatchewan Region Biodiversity Management Framework which highlights the need to implement an ES management approach to encourage landowners to incorporate ES in their land use planning.

2.1.1 Why Assess Ecosystem Services

Ecosystem service assessments characterize, quantify, measure, track and, in some cases, value ES across a range of geographic and temporal scales. Such assessments are increasingly used to evaluate the supply and use (demand) of ES in a region. This type of analysis allows for better understanding of the trade-offs being made between nature and industrial development. Often, the impact development has on the economy and job creation overshadows the cost it will have on the surrounding lakes and forests, keystone species, and so on. These environmental attributes are valued by society, and removing them in the name of economic development has the potential to under estimate the true cost of development. Leveraging ES in sustainable development supports the maintenance of a healthy economy while also protecting the ecological process for future generations.

2.1.2 Ecosystem Service Frameworks

The Millennium Ecosystem Assessment Framework is the most widely accepted framework used in ES assessments, however, there have been a number of ES frameworks developed that link the ecological function to services provided to people and how that translates into human well-being (i.e. value) (MEA, 2005; TEEB, 2010; CICES/MAES 2014).

Ecosystem services changes as a result of a management alternative are difficult to quantify, especially when the ecological function provides more than one service, and even more benefits (value) to people (Figure 3).

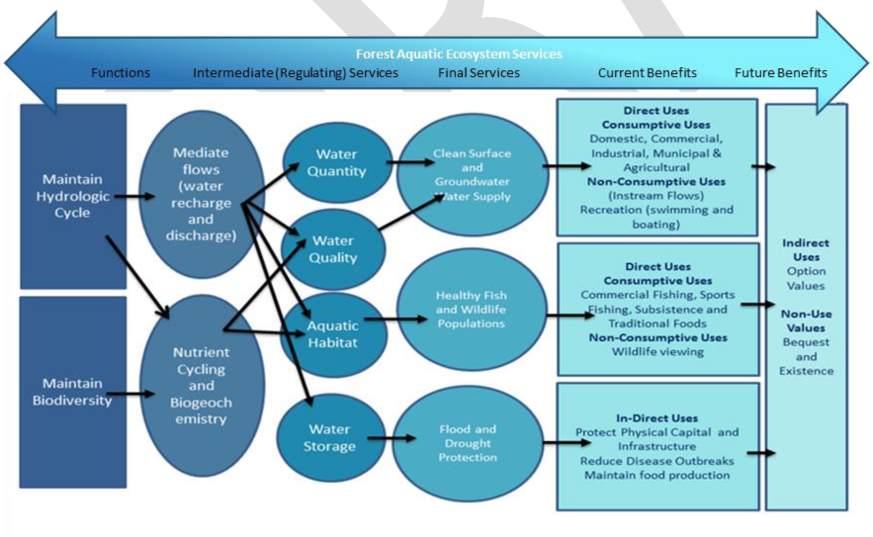

Figure 3: Example of Aquatic Functions, Services, and Benefits (Personal Comm. M. Weber)

[11] https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m-16-01.pdf

It is important to only quantify the changes in the final services of an ecological function in an effort to not double count the value to society.

Furthermore, there is a significant amount of literature surrounding the types of values people derive from ES. People derive a number of values from goods and services, not always accounted for in the market price. Moreover, because many benefits nature provides are freely available, it is often difficult to assess what the true value (i.e. price) should be. The total economic value is the sum of all the values people place on a good or service. These typically include, direct and indirect uses, option values, and non-use values including philanthropic and altruistic values (Figure 4).

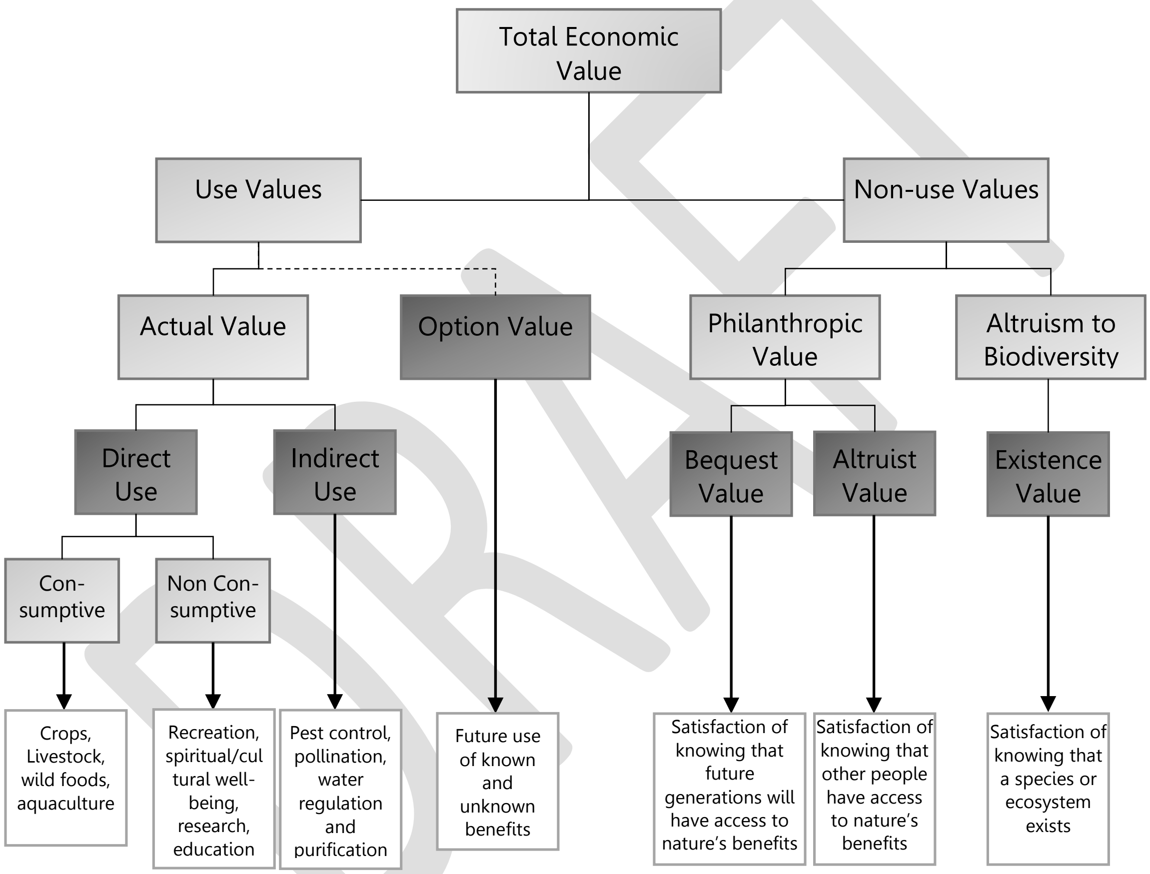

Figure 4: Total Economic Value [12]

While direct use values often have a market price, indirect and non-use values are more difficult to quantify. Economists have developed two main approaches that attempt to capture the total value of ecosystem services: revealed and stated preference techniques.

Revealed preference techniques use a surrogate market that is closely related to the ecosystem service to estimate non-market value. This technique is commonly used because it relies on existing markets that

[12] Pascual, U., Muradian, R., Brander, L., Gómez-Baggethun, E., Martín-López, B., Verma, M., ... & Turner, R. K. (2010). The economics of valuing ecosystem services and biodiversity.

already take into account various individual constraints households face such as income, time, and market imperfections.

Stated preference techniques ask what a person would be willing to pay to enjoy a good or service. These questions are typically asked by surveying the general public either in person or by mail. These techniques are often criticized because they are asking a person to make a decision based on a hypothetical scenario. Because the individual likely will not have to pay their stated price, they may overinflate their response. Nevertheless, this method is essential for valuing goods where no proxy market exists.

The amount of research focused on non-market valuation of ecosystem services is vast. This has sparked a new method for valuation. A benefits transfer approach, relies on previous research in similar areas of interest. Benefits transfer is becoming a popular technique because it is relatively inexpensive and the pool of research to draw upon is continually growing.

3 Selecting the Appropriate Ecosystem Services

3.1 Overview

During phase 1, ES and indicators were chosen based on the best available data that was relevant to the Algar region. The process for identifying, evaluating and selecting ES lacked rigor, leaving questions about if the correct ES were measured and if any additional ES were missed. Phase 2 of the Algar ES Assessment approach looks to refine the methodology for choosing the ES for assessment along with their respective indicators.

A focus on ES requires that all ecological processes and functions are directly related to a community or group of people benefiting from that process (e.g. the beneficiaries). For example, a restoration program focused at improving water quality in a region without beneficiaries downstream to enjoy this improvement, will not be seen by all as relevant and valuable.[13] Identifying the proper stakeholders and beneficiaries for a region is crucial to the success of any initiative.

Furthermore, understanding what the identified stakeholders care about (e.g. their values) is just as important to the success of an initiative. However, there is often a disconnect between stakeholder values and the science behind those values. For example, a stakeholder may value improved water quality, but they do not understand what a meaningful reduction in phosphorus, nitrogen, and total suspended solids is nor how to achieve such a reduction.

This disconnect has revealed a need to develop a repeatable process to identify the proper stakeholders and map their plain-language values to ecological changes and the ecosystem services (ES) they provide. The goal was to develop a repeatable and transparent process that can be used by decision makers in ES assessments in the future.

3.2 Methods

3.2.1 Identifying Potential Ecosystem Services in the Algar Region

As mentioned above, a focus on ES requires that the ecological change is directly related to the benefits provided to people (e.g. the beneficiaries). A number of studies have attempted to translate what people care about into ecosystem services using different approaches over the years.

The Millennium Assessment addressed this by grouping ES into four main categories: regulating, provisioning, supporting, and cultural. They traced these groups of ES into determinates and constituents on well-being, including security, basic material for a good life, health, good social relations and freedoms of choice.[14] The framework shows explicitly how each category of ES fits into what stakeholders would care about (e.g. security, health, etc.). It gives a great starting point for how an ES affects human well-being, and allows researchers to identify any gaps in their assessment. It also links stakeholder values

[13] USDA (2015). Targeting investments to cost effectively restore and protect wetland ecosystems: Some economic insight. Economic Research Report Number 183. Retrieved from: http://www.ers.usda.gov/media/1784721/err183.pdf
[14] Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

explicitly to ES. It has, however, received criticism for being too high level of an analysis, making it difficult to incorporate into decision-making processes.[15] [16]

Other studies have focused on understanding the cultural services and benefits provided by ES.[17] [18] [19] Alberta Environment and Parks (AEP) addressed this by employing a values survey to stakeholders for their pilot study on wetlands. The survey attempted to elicit knowledge of wetlands and associated values and perspectives. The results indicated that people in the region value wetlands for different reasons, whether they were bio-centric focused (e.g. wetlands are valuable in their own right) or anthropogenic focused (e.g. wetlands are valuable based on how they are used by people). Although the values results imply stakeholders are positively inclined towards wetlands, it does not address the ES wetlands provide. To address this gap, researchers also held focus groups, requesting stakeholders to rank ES based on their preferences. The focus group was held with fourteen stakeholders who had significant experience with wetlands. They were asked to rank, based on relative importance to the individual, stakeholder group they were representing, and society, a number of ES identified by the researchers, using this as a guide to what ES to include in an assessment.[20] Although this addresses stakeholder values directly, there is no clear approach outlined if there are conflicting views from stakeholders or if there is a lack of sufficient data to complete an assessment. The study also does not address how the list of ES provided to stakeholders was defined.

AEP has also released an approach focused on operationalizing ES assessment within the Government of Alberta, based on the wetlands pilot.[21] Their recommended approach, which is modelled off the World Resources Institute (WRI) is as follows:

1. Define the issue - what is attempting to be solved through the ES assessment
    a. Identify a case study and the boundaries
2. Identify priority ES to be assessed
    a. Identify ES produced through restoration and determine their ecological processes
    b. Prioritize the ES that will be the focus of further assessment using criteria from decision makers and stakeholders
3. Assess condition and trends of priority ES

---

[15] Kai M. a. Chan, Anne D. Guerry, Patricia Balvanera, Sarah Klain, Terre Satterfield, Xavier Basurto, Ann Bostrom, Ratana Chuenpagdee, Rachelle Gould, Benjamin S. Halpern, Neil Hannahs, Jordan Levine, Bryan Norton, Mary Ruckelshaus, Roly Russell, Jordan Tam, and Ulalia Woodside. (2012) Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement. BioScience, Vol 62, 8.
[16] N. Ash, H. Blanco, C. Brown, K. Garcia, T. Henrichs, N. Lucas, C. Raudsepp-Hearne, R. D. Simpson, R. Scholes, T. P. Tomich, B. Vira, and M. Zurek (2010). Ecosystem Services and Human Well-Being: a manual for assessment practitioners. Retrieved from: http://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/109/original/EcosystemsHumanWellbeing.pdf?1398679213
[17] Martín-López B, Iniesta-Arandia I, García-Llorente M, Palomo I, Casado-Arzuaga I, et al. (2012) Uncovering Ecosystem Service Bundles through Social Preferences. PLoS ONE 7(6): e38970. doi:10.1371/journal.pone.0038970
[18] EU FP7 OpenNESS Project Deliverable 4.1., Gómez-Baggethun, E., B. Martín-López, D. Barton, L. Braat, H. Saarikoski, Kelemen, M. García-Llorente, E., J. van den Bergh, P. Arias, P. Berry, L., M. Potschin, H. Keene, R. Dunford, C. Schröter-Schlaack, P. Harrison (2014). State-of-the-art report on integrated valuation of ecosystem services. European Commission FP7.
[19] Kai M. a. Chan, Anne D. Guerry, Patricia Balvanera, Sarah Klain, Terre Satterfield, Xavier Basurto, Ann Bostrom, Ratana Chuenpagdee, Rachelle Gould, Benjamin S. Halpern, Neil Hannahs, Jordan Levine, Bryan Norton, Mary Ruckelshaus, Roly Russell, Jordan Tam, and Ulalia Woodside. (2012) Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement. BioScience, Vol 62, 8.
[20] Alberta Environment and Sustainable Resource Development (2011). Ecosystem services approach pilot on wetlands. An exploration of approaches to understand cultural services and benefits to ecosystem service assessments. Retrieved from: http://environment.gov.ab.ca/info/library/8685.pdf
[21] Alberta Environmental and Sustainable Resource Development (2011). Ecosystem services approach pilot on wetlands: Operationalizing an ES approach within GoA: Steps and lessons learned. Retrieved from: http://environment.gov.ab.ca/info/library/8683.pdf

    a. Identify indicators linked to ES (e.g. important to stakeholders and relevant to the study area)
    b. Develop and implement methods for assessing the current condition and recent trends
    c. Identify drivers of change (e.g. restoration and development)
4. Evaluate economic and socio-cultural benefits to human well-being
5. Identify risks and opportunities for management
6. Input ES information into decision making

This approach still does not address how a general list of ES are identified or how to prioritize this list, although it is implied that stakeholders should be involved in the process.

The Ecosystem Services and Human Well-Being: a manual for assessment practitioners[22] recommends a user's needs assessment to ensure the credibility, legitimacy and relevancy of an ES assessment to stakeholders. The manual argues that information gathering processes are more likely to see uptake from decision makers and stakeholders if the process is transparent and stakeholders can recognize their contributions to the analysis.

Other studies have attempted to make the link between ecological changes and the services they provide by mapping them using a means-end diagram.[23] [24] A means-ends diagram can be used to help illustrate casual connections between management actions (means) and outcomes to those actions (ends). Using these in the ecological sense forces the researcher to sort out connections between the management alternative (e.g. restoration or development), the ecological change caused by the management alternative, and ultimately the ES provided by the ecological change. It also helps develop a repeatable process where the researcher can go back and distinguish why a specific ES was chosen for analysis.

The Federal Resource Management and Ecosystem Service Guidebook (2015)[25] takes the means-ends diagram a step further by, addressing how to identify the proper stakeholders, offering tools to help communicate with stakeholders and validating the means-ends diagram with the stakeholders.

Lastly, there have been a number of studies published recently that discuss criteria for the selection of ES.[26] [27] [28] [29] These studies all argue that there is a need for a conceptual framework where the selection of ES and their respective indicators follow a transparent and rigorous selection process.

A number of different approaches to ES assessment have been addressed in the literature, a few of which were outlined above. A common theme in the literature is the process to complete an ES assessment (Figure 5). Where the gap remains is in the first step of the process where there is no repeatable method to select ES to include in the assessment. Many studies choose ES based on the best available data, the

[22] N. Ash, H. Blanco, C. Brown, K. Garcia, T. Henrichs, N. Lucas, C. Raudsepp-Hearne, R. D. Simpson, R. Scholes, T. P. Tomich, B. Vira, and M. Zurek (2010). Ecosystem Services and Human Well-Being: a manual for assessment practitioners. Retrieved from: http://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/109/original/EcosystemsHumanWellbeing.pdf?1398679213
[23] R. Gregory and K. Wellman (2001). Bringing stakeholder values into environmental policy choices: a community-based estuary case study. Ecological Economics 39; 37-52.
[24] Duke Nicholas Institute (2015). National Ecosystem Services Partnership. Assessment Framework. Retrieved from: https://nespguidebook.com/assessment-framework/framework-overview/
[25] Ibid
[26] Crossman et al. (2013). A blueprint for mapping and modelling ecosystem services. Ecosystem Services 4; 4-14.
[27] D. Niemeijer and R. de Groot (2008). A conceptual framework for selecting environmental indicator sets. Ecological Indicators 8; 14-25.
[28] Müller, F., and Burkhard, B. (2012). The indicator side of ecosystem services. Ecosystem Services, 1(1): 26-30.
[29] Feld, C. K., Sousa, J. P., Da Silva, P. M., and Dawson, T. P. (2010). Indicators for biodiversity and ecosystem services: towards an improved framework for ecosystems assessment. Biodiversity and Conservation, 19(10): 2895-2919.

ability to develop biophysical and economic models, and what has been measured in the past. However, if data is not available for a specific ES, but the stakeholders in the region highly value this ES, that ES should be represented in some way. This gap is addressed by outlining an ES and Indicator Selection Criteria Process that makes the selection of ES a repeatable, transparent process that can be applied to multiple research sites across Alberta. It also encourages strong stakeholder involvement, increasing the probability of uptake from decision makers and affected groups.

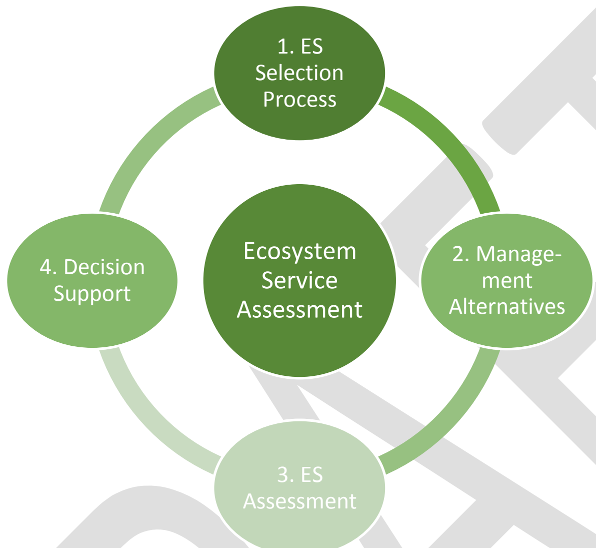

Figure 5: ESA Process

3.2.2 ES and Indicator Selection Criteria Process

The ES and Indicator Selection Criteria Process (Figure 6) was developed to combine multiple approaches in the literature and develop a repeatable process that can be applied in several research sites across Alberta. It is a step-by-step process flowing from site identification through selection of ES indicators for assessment. It brings a new level of transparency to the process and ensures stakeholders feel engaged from the beginning and throughout the entire ES assessment. The goal is to have a transparent process which will increase the likelihood of adoption from decision makers and stakeholders.[30]

[30] N. Ash, H. Blanco, C. Brown, K. Garcia, T. Henrichs, N. Lucas, C. Raudsepp-Hearne, R. D. Simpson, R. Scholes, T. P. Tomich, B. Vira, and M. Zurek (2010). Ecosystem Services and Human Well-Being: a manual for assessment practitioners. Retrieved from: http://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/109/original/EcosystemsHumanWellbeing.pdf ?1398679213

Figure 6: ES and Indicator Selection Criteria Process

ECOSYSTEM SERVICES AND INDICATORS SELECTION PROCESS

The Ecosystem Services and Indicators Selection Process is a repeatable, transferable exercise for the identification and selection of appropriate ecosystem services (ES) and indicators for an ES assessment project. It is a step-by-step process flowing from site identification through selection of ES indicators for assessment. It brings a new level of transparency to the process and ensures stakeholders feel engaged from the beginning and throughout the entire ES assessment.

1 DETERMINE PROJECT OBJECTIVES & IDENTIFY AREA(S) OF INTEREST

Clarify the purpose of the ESA and locate project or study area.

2 IDENTIFY RELEVANT STAKEHOLDERS

Identify relevant stakeholders to the area of interest through a desktop review.

3 ENGAGE STAKEHOLDERS & IDENTIFY HIGH LEVEL STAKEHOLDER VALUES

Consult with stakeholders through a workshop and/or complete a literature review of relevant studies to better identify and understand stakeholder values.

4 CONNECT STAKEHOLDER VALUES TO ECOSYSTEM SERVICES

Complete an extensive literature review of ES and their indicators. Map stakeholder values to the ES.

5 COMPLETE ES & INDICATOR SELECTION CRITERIA

Complete a detailed individual assessment of ES that are linked to stakeholder values. If the ES is relevant to the area of interest, complete the selection criteria for the indicators identified for the respective ES. The ES and Indicator Selection Criteria Template will help examine relevance, scale, and data availability, among others.

6 STAKEHOLDER APPROVAL

Validate selection criteria through stakeholder review.

7 PREPARE LIST OF ES INDICATORS FOR ASSESSMENT

Summarize key learnings from the selection process including reasons for inclusion or exclusion of particular indicators and services. List the ES indicators that have been approved for assessment and continue with the ES Assessment Process.

The next section of this discussion paper walks through the ES and Indicator Selection Process using the Algar case study as an example.

1. Identify the Area of Interest	**Purpose:** Identify possible spatial relationships between supply (restoration area) and demand (communities) of ES	Section 3.2.2.1
2. Identify Stakeholders	**Purpose:** Ensure all land values are accounted for in the ES assessment	Section 3.2.2.2
3. Determine Stakeholder Values	**Purpose:** To identify plain-language values that may link to ecological processes and ecosystem services provided through linear restoation	Section 3.2.2.3 (Table 2)
4. Connect Values to ES	**Purpose:** To gain a comprehensive list of ES that stakeholders in the Algar region have deemed important	Section 3.2.2.4 (Table 3)
5a. Develop an Extensive List of ES Indicators	**Purpose**: To generate an extensive list of potential indicators for ES identified by stakeholders	Section 3.2.2.5 (Table 4)
5b. Complete the ES Portion of the Selection Criteria Template	**Purpose**: To narrow down the amount of ES available for assessment using a repeatable and transparent process	Section 3.2.2.5 (Table 6)
5c. Assess Indicators using Quick Filtering Questions	**Purpose**: To narrow down the amount of indicators applicable to the Algar study area	Section 3.2.2.5 (Table 7)
5d. Complete the Indicator Portion of the Selection Criteria Template	**Purpose:** To identify the appropriate indicators used to assess a change in ES for the Algar region using a repeatable and transparent process	Section 3.3 (Table 8)

Figure 7: ES and Indicator Selection Criteria Process for the Algar Region

3.2.2.1 Identify Area of Interest

ES assessments can be implemented for many reasons. They may be used to assess the amount of ES being added or taken from the landbase, based on a management alternative, they may be used to create a scorecard of the current state of an area, or used in a cost-benefit analysis.

In determining the scope of the assessment the first step is to identify the issue and spatial extent of the analysis. In this case, the issue is restoration of legacy seismic line in the northeast boreal forest, and determining the potential supply and benefits from the ES produced through restoration. Defining the spatial extent is complicated by the fact that for most ES, the supply and demand areas are disjoint. For example, linear restoration at sufficient scale may improve downstream water quality, or increase the value of habitat for species at a broader regional scale that are hunted or culturally significant. Figure 8 shows the possible relationships between where ES are produced (for example restoration on a lease in the forested area (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.

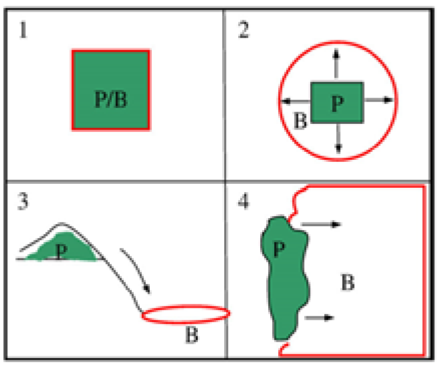

Figure 8: Possible Spatial Relationships between supply (production areas (P)) and demand (service benefit areas modified from (Fisher et al. 2009) (B))[31]

For the Algar case study, the purpose of the ES assessment is to assess the ES added to the landbase through linear restoration. The area of interest, therefore, is the six township region, described in section 1.4, where the management alternative has occurred. Even though the assessment is focused on the supply area, the demand area remains extremely important, as valuation in the change in supply will depend on it. The demand area will vary, depending on the ES being assessed. It may be (Figure 8):

- Identical to the supply area (e.g. timber supply)
- Larger than the supply area (e.g. caribou habitat)
- Downstream from the supply area (e.g. water quality).

3.2.2.2 Identify Stakeholders

Once the area of interest was defined, identification of stakeholders through a desktop review of land management in the area of interest was completed. In the Algar region, stakeholders identified include:

- General public

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

- First Nations communities [32]
- Trappers and outfitters
- Industry
    - Alberta-Pacific Forest Industries Inc. (Al-Pac) Forest Management Agreement holder
    - Millar Western Forest Products Ltd. Coniferous Timber License
    - Canadian Natural Resources Limited (CNRL) (primary road access into the Algar region)
    - Additional disposition holders
    - Restoration project partners: Nexen, ConocoPhillips Canada Resources Corp., Shell Canada Energy, Statoil Canada Ltd., Suncor Energy Inc. and Total E&P Canada Ltd.
- Government of Alberta

3.2.2.3 Engage Stakeholders and Identify High Level Stakeholder Values

Following stakeholder identification, a literature review of relevant studies was completed to gather information on stakeholder values from a number of sources. Sources included:

- Al-Pac Forest Management Plan (FMP)
- Alberta Forest Management Planning Standard, Annex 4
- Algar Linear Restoration Application
- Biodiversity Management Framework
- First Nations consultation from resource development projects in the area
- Terrestrial Ecosystem Management Framework (CEMA, 2008)
- Traditional Knowledge Research Guidelines (CEMA, 2012)
- Water for Life Framework

The majority of the stakeholder values were identified through the TEMF (2008) report, which gives a comprehensive overview of the regional goals the Regional Sustainable Development Strategy (RSDS) for the Regional Municipality of Wood Buffalo, of which the Algar area falls within. The report outlines value-based statements that align with CEMA's vision, the Land-use Framework (LUF) and the RSDS for Wood Buffalo. Additional literature was reviewed to ensure all values are captured for the purpose of this analysis. Two values were identified though a review of First Nations consultations that were not in the TEMF report: air quality and aesthetic values.

[32] Aboriginal Communities in the Regional Municipality of Wood Buffalo today. Downloaded from: http://www.ramp-alberta.org/people/aboriginal/aboriginal+communities+today.aspx

Table 3-1: Identified Stakeholder Values

Stakeholder Value	Reference
Maintain opportunities for oil sands development	CEMA (2008) Government of Alberta (2014)
Sustain a land base for timber harvest	CEMA (2008) Phase 1 Advisory Committee members Government of Alberta (2014) Alpac FMP (2009) Algar Linear Restoration Application Alberta Forest Management Planning Standard Annex 4 (2006)
Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants	CEMA (2008) CEMA (2012) Fort McKay First Nation Consultation (2012) Fort McMurray First Nation Consultation (2012)
Companies maintain their social license to operate	Phase 1 Advisory Committee members Alpac FMP (2009) Alberta Forest Management Planning Standard Annex 4 (2006) Water for Life Progress Report 2008-2011 (2011)
Maintain opportunities for tourism development	CEMA (2008) Government of Alberta (2014)
Sustain recreational capability	CEMA (2008) Algar Linear Restoration Application (Trappers)
Sustain successional patterns and ecological processes	CEMA (2008) Government of Alberta (2014) Fort McKay First Nation Consultation (2012) Alberta Forest Management Planning Standard Annex 4 (2006)
Sustain healthy populations of native wildlife	CEMA (2008) CEMA (2012) Phase 1 Advisory Committee members (Caribou) Government of Alberta (2014) Fort McKay First Nation Consultation (2012) Fort McMurray First Nation Consultation (2012) Alberta Forest Management Planning Standard Annex 4 (2006)
Maintain opportunities for traditional land use	CEMA (2008) CEMA (2012) Government of Alberta (2014) Fort McKay First Nation Consultation (2012) Algar Linear Restoration Application (Trappers) Fort McMurray First Nation Consultation (2012) Alberta Forest Management Planning Standard Annex 4 (2006)
Sustain fish populations	CEMA (2008) CEMA (2012) Fort McKay First Nation Consultation (2012) Fort McMurray First Nation Consultation (2012) Water for Life Progress Report 2008-2011 (2011)
Sustain water quality and quantity	CEMA (2012) Phase 1 Advisory Committee members Fort McKay First Nation Consultation (2012)

Stakeholder Value	Reference
	Fort McMurray First Nation Consultation (2012)
	Alberta Forest Management Planning Standard Annex 4 (2006)
	Water for Life Progress Report 2008-2011 (2011)
Maintain current air quality	Fort McKay First Nation Consultation (2012)
	Fort McMurray First Nation Consultation (2012)
Visual aesthetics[33]	Fort McKay First Nation Consultation (2012)
Global ecological cycles	Alberta Forest Management Planning Standard Annex 4 (2006)
Sustain soil quality	Alberta Forest Management Planning Standard Annex 4 (2006)

3.2.2.4 Connect Stakeholder Values to Ecosystem Services

A comprehensive list of ES from the Millennium Ecosystem Assessment was used (Table 3-2) to link stakeholder values to ES (Table 3-3).

Table 3-2 MEA Ecosystem Services

Category	Sub-class
Provisioning	Food
	Biological raw materials
	Bio-chemicals, natural medicines, and pharmaceuticals
	Water
	Genetic resources
Regulating	Air quality
	Climate
	Water quantity
	Soil
	Water quality
	Biological control
	Pollination
Cultural	Recreation and amenity
	Aesthetic
	Spiritual and cultural
	Scientific and educational
Supporting	Soil formation
	Photosynthesis
	Primary production
	Nutrient cycling
	Water cycling
	Pollination
	Habitat

[33] It was noted in the consultation package that stakeholders in the region are concerned that project development may be visible at nearby sacred sites, trapper cabins, and people living along the Athabasca River. Restoration that changes the view scape may be highly values by these stakeholders.

Table 3-3: Stakeholder values connected to ES

Stakeholder Value	Ecosystem Service	MEA Category	MEA Sub-Class
Maintain opportunities for oil sands development	N/A	N/A	N/A
Sustain a land base for timber harvest	Provision of raw materials: wood as timber	Provisioning	Biological raw materials
	Provision of raw materials: biomass fuels	Provisioning	Biological raw materials
	Provision of raw materials: fiber	Provisioning	Biological raw materials
	Regulation of pest outbreaks	Regulating	Biological control
Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants	Provision of wild foods	Provisioning	Food
	Provision of freshwater	Provisioning	Water
	Maintenance of genetic diversity	Provisioning	Genetic resources
	Regulation of water quality	Regulating	Water quality
	Maintain recreational opportunities	Cultural	Recreation and amenity
Companies maintain their social license to operate	Provision of freshwater	Provisioning	Water
	Regulation of air quality	Regulating	Air quality
	Climate regulation	Regulating	Climate
	Water quality regulation	Regulating	Water quality
	Maintenance of genetic diversity	Provisioning	Genetic resources
	Supporting habitats	Supporting	Habitat
Maintain opportunities for tourism development	Maintenance of genetic diversity	Provisioning	Genetic resources
	Maintain recreational opportunities	Cultural	Recreation and amenity
	Aesthetic	Cultural	Aesthetic
Sustain recreational capability	Maintenance of genetic diversity	Provisioning	Genetic resources
	Maintain recreational opportunities	Cultural	Recreation and amenity
	Aesthetic	Cultural	Aesthetic
	Supporting habitats	Supporting	Habitat
Sustain successional patterns and ecological processes	Maintenance of genetic diversity	Provisioning	Genetic resources
	Regulation of pest outbreaks	Regulating	Biological control
	Regulation of pollination	Regulating/Supporting	Pollination
	Supporting habitats	Supporting	Habitat
	Intrinsic value of biodiversity	Cultural	Spiritual and cultural
Sustain healthy populations of native wildlife	Provision of wild foods	Provisioning	Food
	Maintenance of genetic diversity	Provisioning	Genetic resources
	Supporting habitats	Supporting	Habitat
	Intrinsic value of biodiversity	Cultural	Spiritual and cultural
Maintain opportunities for traditional land use	Provision of wild foods	Provisioning	Food
	Provision of raw materials: fiber	Provisioning	Biological raw materials
	Provision of natural medicines	Provisioning	Bio-chemicals, natural medicines, and pharmaceuticals

Stakeholder Value	Ecosystem Service	MEA Category	MEA Sub-Class
	Supporting habitats	Supporting	Habitat
	Cultural heritage	Cultural	Spiritual and cultural
	Status of traditional knowledge, innovation and practices	Cultural	Scientific and educational
Sustain fish populations	Provision of wild foods	Provisioning	Food
	Provision of fresh water	Provisioning	Water
	Regulation of water quality	Regulating	Water quality
	Maintain recreation opportunities	Cultural	Recreation and amenity
	Intrinsic value of biodiversity	Cultural	Spiritual and cultural
Maintain water quantity and quality	Provision of fresh water	Provisioning	Water
	Regulation of water quality	Regulating	Water quality
	Aesthetic	Cultural	Aesthetic
	Maintain recreational opportunities	Cultural	Spiritual and cultural
Maintain visual aesthetics	Aesthetic	Cultural	Aesthetic
	Supporting habitats	Supporting	Habitat
	Maintenance of genetic diversity	Provisioning	Genetic resources
Maintain current air quality	Regulation of air quality	Regulating	Air quality
Global ecological cycles	Climate regulation	Regulating	Climate
Maintain soil quality	Erosion regulation	Regulating	Soil
	Soil formation	Supporting	Soil formation

This exercise revealed 20 different ES that are important to stakeholders in the region:

- Provision of wild foods
- Provision of fresh water
- Provision of raw materials: wood as timber
- Provision of raw materials: fiber
- Provision of raw materials: biomass fuels
- Provision of natural medicines
- Climate regulation
- Regulation of air quality
- Regulation of pest outbreaks
- Regulation of water quality
- Maintenance of recreational opportunities
- Aesthetic values
- Maintenance of genetic diversity
- Cultural heritage
- Status of traditional knowledge, innovation and practices
- Supporting habitats
- Pollination
- Intrinsic value of biodiversity
- Global ecological cycles

- Soil quality

3.2.2.5 Complete Ecosystem Service and Indicator Selection Criteria

An extensive literature review was conducted to link the ES identified as priorities for the assessment to potential supply and demand indicators that could be modeled. The objective of the indicator review was to:

- To generate an extensive and comprehensive list of ecosystem services (ES) indicators
- To develop a preliminary list of indicators which were feasible to the COSIA LEAP Program in Algar based on data availability and mapping potential

The initial review resulted in an extensive list of ES indicators shown in Table 3-4 below. These were then refined based on several criteria into a preliminary list.

Table 3-4: Extensive List of ES Indicators

Ecosystem Service	ES Indicator	Source
Provision of wild foods	Plant biomass/ha; Animals available/ha; kJ/ha	Burkhard et al., 2012
	Offtake of given species; turnover or gross profit of fisheries or hunting sector	Ash et al., 2010
	Number of wild species used for human food	Layke, 2009
Provision of fresh water	Liters or m3/ ha	Burkhard et al., 2012
	M3 of fit-to-use water (for large flows km3 are used);	Ash et al., 2010
	Evapotranspiration; groundwater; litter containment; population density; precipitation; quick flow; river salinity	Egoh et al., 2012
	Population served by renewable water resource; renewable water supply; renewable water supply accessible to humans; water storage capacity	Layke, 2009
	No of public drinking systems; no of potential point sources;	Cutlac, 2014
Provision of raw materials: wood as timber	Wood/ha; kJ/ha	Burkhard et al., 2012
	Harvest of products, usually as m3, but also in local units such as board-feet or number of poles	Ash et al., 2010
	Employment in forest sector; forest biomass production; roundwood production; value of forest products; value of forest products used for local crafts; wood pulp production	Layke, 2009
Provision of raw materials: fiber	Yield of given products (tons); turnover or gross profit of textile sector or paper-making industries	Ash et al., 2010
	Employment in fibers production; fibers production; production of wildlife-derived skins, wool, and feathers; value of fibers production	Layke, 2009
Provision of raw materials: biomass fuels	Wood or plant biomass/ha; kJ/ha	Burkhard et al., 2012
	Yield (MJ) of given primary or secondary energy product; % of biofuels in energy mix	Ash et al., 2010
	Charcoal production; fuel-wood production; industrial energy production from forest systems; monetary value of fuel production	Layke, 2009
Provision of natural medicines	Amount or number of products; kg/ha	Burkhard et al., 2012
	Reeds cutting	Egoh et al., 2012
	Land cover	Egoh et al., 2012
	Harvest of known medicinal species (tons, or number of organisms) Number of people using natural medicines	Ash et al., 2010
	Biodiversity for food and medicine	Ash et al., 2010
Climate regulation	Temperature, albedo, precipitation, wind; Temperature amplitudes; Evapotranspiration	Burkhard et al., 2012
	Above ground biomass; below ground biomass; forest biomass; land cover; NPP; nutrient flux; soil carbon	Egoh et al., 2012
	Canopy stomatal conductance; cloud formation; evapotranspiration	Layke, 2009
	Source-sink of water vapour, methane, CO2	Burkhard et al., 2012
	Atmospheric gases flux (CO2, CH4, etc); carbon accumulation; carbon uptake; cloud formation; evapotranspiration; carbon sequestration capacity; surface albedo	Layke, 2009

Ecosystem Service	ES Indicator	Source
Regulation of air quality	Leaf area index; Air quality amplitudes	Burkhard et al., 2012
	Flux in atmospheric gases; atmospheric cleansing (tropospheric oxidizing)	Layke, 2009
Regulation of pest outbreaks	Pest density	Egoh et al., 2012
	Intensity, duration and extent of outbreaks of undesirable species; expenditures on biocides, area occupied by alien species, number of alien species	Ash et al., 2010
Regulation of water quality	Human excretory; nutrient deposition; urea price	Egoh et al., 2012
	Denitrification, P fixation, S precipitation; downstream NO3, PO4, and SO4	Ash et al., 2010
	Difference in concentration of toxin in input and output stream; illnesses attributable to toxins, incidence of fish kills	Ash et al., 2010
	Amount of waste processed by ecosystems; capacity of ecosystem to process waste; value of ecosystem waste treatment and water purification	Layke, 2009
	Sediment retention and stabilization; phosphorus retention; nitrate removal and retention; thermoregulation; wetland sensitivity; wetland ecological condition; wetland stress (risk);	Adamus, 2011[34]
	Incidence of human-induced ecosystem failure; health and wellbeing of communities who depend directly on local ecosystem goods and services;	Ash et al., 2010
Maintenance of recreational opportunities	Number of visitors or facilities; Questionnaires on personal preferences	Burkhard et al., 2012
	Accessibility; accommodation; fish abundance; footpaths; urban green space; visitors numbers	Egoh et al., 2012
	Tourism sector turnover or gross profit; number of visitors	Ash et al., 2010
	Nature and/ or rural tourism employment; number of recreational anglers and hunters; spending on nature tourism; total recreation value; visitors to natural areas	Layke, 2009
Aesthetic values	Distance to scenic site	Egoh et al., 2012
	Area of landscape in attractive condition; visitor opinion polls; visits to beauty spots	Ash et al., 2010
	Land cover; land use; landscape values	Egoh et al., 2012
	Comparative value of real estate near cleaner water bodies; comparative value of real estate nearer to nature; number of visitors; willingness to pay for improved water quality in local water bodies	Layke, 2009
	"Visual quality": combination of divers habitat types; impacts of alien species on aesthetic perception of landscape; no of scenic roads, views used for photos; property and house prices	Morcillo et al., 2013

[34] See Adamus (2011) for valuation models.

Ecosystem Service	ES Indicator	Source
Maintenance of genetic diversity	Investment into natural products prospecting; number of species that have been the subject of major investment; value of genetic resources	Layke, 2009
	Land cover	Egoh et al., 2012
	Indicator species representative for a certain phenomenon or sensitive to distinctive changes	Burkhard et al., 2012
	Connectivity/ fragmentation of ecosystems; trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance;	Ash et al., 2010
Cultural heritage	Presence of sites, landscapes, or species of spiritual or cultural significance; number or area of important sites; protection status	Ash et al., 2010
	No. of sites with cultural heritage	Egoh et al., 2012
	Sites of spiritual, religious, or other forms of exceptional personal meaning; Sites relevant to local history and culture	Plieninger et al., 2013
	Riparian forest composition in sacred sites; no. of intact ecosystems providing sacred grounds; no. of people participating in sacred activities; Benefits in production of folklore; Tangible objects contributing to sense of place; % of authentic land use/ cover in cultural heritage landscape; no. of lyrics purporting sustainable use	Morcillo et al., 2013
	Threats: Sites that are neglected, abused, damaged or unpleasant; sites that feel dangerous or threatening; sites that are disturbingly noisy	Plieninger et al., 2013
Status of traditional knowledge, innovation and practices	Status and trends of linguistic diversity and numbers of speakers of indigenous languages; other indicator of the status of indigenous and traditional knowledge	Ash et al., 2010
Supporting habitats	Fragmentation indices; connectivity; heterogeneity indices; number/ area of habitats	Burkhard et al., 2012
	Area of suitable habitat for a given species, Coverage of protected area; Change in status of threatened species; Trends in representative or key species; Number and status of endemic species; Number and status of migratory species; Trends in genetic diversity of selected species; Trends in abundance and distribution of selected species; Trends in invasive alien species	Ash et al., 2010
Pollination	Amount of plant products; Distribution of plants; Availability of pollinators	Burkhard et al., 2012
Intrinsic value of biodiversity	Number of endangered, protected or rare species or habitats	Burkhard et al., 2012
Erosion regulation	Loss of soil particles by wind or water; vegetation cover	Burkhard et al., 2012
	Erodibility; Land use; slope; soil characteristics; soil retention; vegetation map	Egoh et al., 2012
Soil formation	Leaching of nutrients, e.g. N,P	Burkhard et al., 2012
	Sediment retention and stabilization; carbon sequestration; organic matter export	Adamus, 2011

Ecosystem Service	ES Indicator	Source
	Soil fauna: Micro-arthropods; earthworms; total macrofauna; myriapods; Microbial parameters: bacterial and fungal biomass	Pulleman et al.,2012
	Earthworm; land cover; litter; nutrient retention; soil characteristics	Egoh et al., 2012

Once the indicators were identified for the 20 ES linked to stakeholder values, the Selection Criteria Template was employed to identify the most suitable ES to be measured following restoration in the Algar region. The Selection Criteria Template is separated into two parts: The Ecosystem Service Selection Criteria and the Indicator Selection Criteria (Table 3-5).

The Selection Criteria Template is the most technical step in the selection process. The template itself was developed with project partners and input from the project's advisory groups to assess the applicability of an identified ES to measure a quantifiable change following a management alternative (e.g. restoration or project development) in an area of interest. It links stakeholder values to ES in a repeatable and transparent way, making it defendable for decision makers to employ. It also provides an opportunity to address data gaps and limitations through the selection of ES and indicators.

For the Algar case study, the purpose of the Selection Criteria Template was to assess the applicability of identified ES to linear restoration and the Algar region. The purpose of this step is to ensure the repeatability and transparency of the selection of ES.

Table 3-5: Selection Criteria Template

Ecosystem Service Characteristics	
Ecosystem Service:	The ecosystem service as defined within the Millennium Ecosystem Assessment (2005)[35].
Stakeholder Value:	Defined as what is important to stakeholders in the region. Completed through a literature review of current studies within the region of interest or direct stakeholder consultation.
Description:	Description of the ES

Stakeholders			
Are there stakeholders within the defined region?	☒Yes	☐ No ☐ Unconfirmed	• Any group or individual who can affect or is affected by the ecosystem's services

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:	Estimate time required (years) for benefits to reach beneficiaries	**In-situ** ☐	**Larger than Area of Interest** ☐	**Downstream** ☐

Ecosystem Service Selection Criteria			
How many times the stakeholder value was identified (literature review or consultation)		**Can we model a change in defined indicators for the ES?**	☒ Yes ☐ No
Does the ES clearly link to a 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:		**Is the model transparent and easy to understand?**	☒ Yes ☐ No
Does the ES related to a species at risk?	☒ Yes ☐ No	**Additional comments:**	

Approvals			
Include on Final ES List:	☐Yes	☐ **No**	**If yes, continue to next section**
Reason for in/exclusion:			

[35] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Indicator Characteristics					
Ecological Indicator:	The measurable service or function of a particular ES (e.g. Timber Supply)				
Description	Description of the ecological indicator	**Units:** Measurable units for the ecological indicator (e.g. m³/ha)			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** model used for the ecological assessment	
Owner: Who the established owner of the model is					
Model Use Agreement: Is the model available free of charge?					
Is there available input data?	☐Yes	☐ No	**Required Inputs:**		
Name: Name of required input data	**Version:** Version of the input data and effective date		**Coverage:** Geographic coverage of the data inputs	**Acquired from:** Who the data was acquired from	
Name: Name of required input data	**Version:** Version of the input data and effective date		**Coverage:** Geographic coverage of the data inputs	**Acquired from:** Who the data was acquired from;	
Is there an ABMI ESA model available?	☒Yes ☐ No ☐ N/A		**Is the ABMI ESA model being used?**	☒Yes ☐ No ☐ N/A	**If no, why?**

Model Output Scale			
The scale in which you model outputs are summarized			
Smaller than the area of interest ☐	**In-situ** ☐	**Larger than the area of interest** ☐	**Downstream** ☐
Comments: *Additional details on the scale of the model (e.g. time-dependency, input scale, is it rasterized? etc.)*			

Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☐Yes	☐ No	**Is there a valuation indicator available?**	☒Yes	☐ No
				List (units): List any available indicators (include the units the indicator is measured in (e.g. $/m³)	
Is the indicator sensitive to change?	☐Yes	☐ No	**Does the valuation indicator link to the ES?**	☐Yes	☐ No
Is the indicator transparent to calculate?	☐Yes	☐ No	**Is there a market price for the indicator?**	☐Yes	☐ No
Can the indicator be scaled up/down?	☐Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☐Yes	☐ No	**Additional Comments:**		

Approvals		
Internal recommendation to include in analysis:	☐Include	☐Exclude
Reason for In/exclusion: List of main points for why the indicator will be included or excluded from the assessment		
Stakeholder Approval:	☐Yes	☐No
Include as final indictor for the ES?	☐Yes	☐No

The first section of the template looks specifically at the ES identified through stakeholder engagement. It asks a number of filtering questions regarding the applicability of the ES to the management alternative, how important it is to stakeholders in the region, if it is measuring a use or non-use value, and if there are available indicators to measure a quantifiable change. Here, a number of ES were dropped from the selection process due to lack of available indicators, data, or models. While these ES were eventually dropped from the assessment, having stakeholders highlight their importance, and having a sound process for documenting why or why not they were included improves the overall transparency of the process. A total of six ES moved onto the second portion of the selection criteria template (Table 3-6). The completed templates for the 20 ES can be found in Appendix A.

Table 3-6: ES in the Selection Process

Ecosystem Service	Potential Indicators	Source
Provision of wild foods	Plant biomass/ha; Animals available/ha; kJ/ha	Burkhard et al., 2012
	Offtake of given species; turnover or gross profit of fisheries or hunting sector	Ash et al., 2010
	Number of wild species used for human food	Layke, 2009
Provision of raw materials – timber supply	Wood/ha; kJ/ha	Burkhard et al., 2012
	Harvest of products, usually as m3, but also in local units such as board-feet or number of poles	Ash et al., 2010
	Employment in forest sector; forest biomass production; roundwood production; value of forest products; value of forest products used for local crafts; wood pulp production	Layke, 2009
Climate regulation	Temperature, albedo, precipitation, wind; Temperature amplitudes; Evapotranspiration	Burkhard et al., 2012
	Above ground biomass; below ground biomass; forest biomass; land cover; NPP; nutrient flux; soil carbon	Egoh et al., 2012
	Canopy stomatal conductance; cloud formation; evapotranspiration	Layke, 2009
	Source-sink of water vapour, methane, CO2	Burkhard et al., 2012
	Atmospheric gases flux (CO2, CH4, etc); carbon accumulation; carbon uptake; cloud formation; evapotranspiration; carbon sequestration capacity; surface albedo	Layke, 2009
Regulation of water quality	Human excretory; nutrient deposition; urea price	Egoh et al., 2012
	Denitrification, P fixation, S precipitation; downstream NO3, PO4, and SO4	Ash et al., 2010
	Difference in concentration of toxin in input and output stream; illnesses attributable to toxins, incidence of fish kills	Ash et al., 2010

Ecosystem Service	Potential Indicators	Source
	Amount of waste processed by ecosystems; capacity of ecosystem to process waste; value of ecosystem waste treatment and water purification	Layke, 2009
	Sediment retention and stabilization; phosphorus retention; nitrate removal and retention; thermoregulation; wetland sensitivity; wetland ecological condition; wetland stress (risk);	Adamus, 2011[36]
	Incidence of human-induced ecosystem failure; health and wellbeing of communities who depend directly on local ecosystem goods and services;	Ash et al., 2010
Maintenance of genetic diversity	Investment into natural products prospecting; number of species that have been the subject of major investment; value of genetic resources	Layke, 2009
	Land cover	Egoh et al., 2012
	Indicator species representative for a certain phenomenon or sensitive to distinctive changes	Burkhard et al., 2012
	Connectivity/ fragmentation of ecosystems; trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance;	Ash et al., 2010
Supporting habitats	Fragmentation indices; connectivity; heterogeneity indices; number/ area of habitats	No Source
	Area of suitable habitat for a given species, Coverage of protected area; Change in status of threatened species; Trends in representative or key species; Number and status of endemic species; Number and status of migratory species; Trends in genetic diversity of selected species; Trends in abundance and distribution of selected species; Trends in invasive alien species	No Source

With the narrowed down list of ES to include, there still remained a significant amount of possible indicators to quantify a change in the ES. Before completing the second portion of the selection template, the indicators first had to meet two quick filtering questions:

1. Is the indicator applicable to the Algar region?

[36] See Adamus (2011) for valuation models.

2. Is the indicator sensitive to change?

The International Petroleum Industry Environmental Conservation Association (IPIECA) has developed a checklist that covers the five stages of the oil and gas lifecycle for six habitat types that highlights the industry's dependence on ES. [37] This checklist may help narrow down the list of indicators sensitive to change through development and restoration.

Following the quick filtering questions, a number of indicators were dropped from the analysis (Table 3-7).

Table 3-7: List of indicators meeting quick filtering questions

Ecosystem Service	Potential Indicators	Indicators meeting quick filtering questions
Provision of wild foods	Plant biomass/ha; Animals available/ha; kJ/ha	Plant biomass/ha
	Offtake of given species; turnover or gross profit of fisheries or hunting sector	Offtake of a given species
	Number of wild species used for human food	Animals available for hunting
Provision of raw materials – timber supply	Wood/ha; kJ/ha	Forest Biomass
	Harvest of products, usually as m3, but also in local units such as board-feet or number of poles	Wood used for production (timber supply)
	Employment in forest sector; forest biomass production; roundwood production; value of forest products; value of forest products used for local crafts; wood pulp production	Pulp and paper (fiber production)
Climate regulation	Temperature, albedo, precipitation, wind; Temperature amplitudes; Evapotranspiration	Forest Biomass
	Above ground biomass; below ground biomass; forest biomass; land cover; NPP; nutrient flux; soil carbon	
	Canopy stomatal conductance; cloud formation; evapotranspiration	
	Source-sink of water vapour, methane, CO2	Carbon Sequestration
	Atmospheric gases flux (CO2, CH4, etc); carbon accumulation; carbon uptake; cloud formation; evapotranspiration; carbon sequestration capacity; surface albedo	
Regulation of water quality	Human excretory; nutrient deposition; urea price	Downstream N, P, TSS

[37] IPIECA (2011). Ecosystem services checklists. Downloaded from: http://www.ipieca.org/publication/ecosystem-services-guidance-biodiversity-and-ecosystem-services-checklists

Ecosystem Service	Potential Indicators	Indicators meeting quick filtering questions
	Denitrification, P fixation, S precipitation; downstream NO_3, PO_4, and SO_4	
	Difference in concentration of toxin in input and output stream; illnesses attributable to toxins, incidence of fish kills	
	Amount of waste processed by ecosystems; capacity of ecosystem to process waste; value of ecosystem waste treatment and water purification	
	Sediment retention and stabilization; phosphorus retention; nitrate removal and retention; thermoregulation; wetland sensitivity; wetland ecological condition; wetland stress (risk);	Water quality ladder
	Incidence of human-induced ecosystem failure; health and wellbeing of communities who depend directly on local ecosystem goods and services;	
Maintenance of genetic diversity	Investment into natural products prospecting; number of species that have been the subject of major investment; value of genetic resources	Species subject to a major investment (Caribou)
	Land cover	Indicator species representative for a certain phenomenon or sensitive to distinctive changes (Caribou)
	Indicator species representative for a certain phenomenon or sensitive to distinctive changes	
	Connectivity/ fragmentation of ecosystems; trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance;	Connectivity/ fragmentation indices (ABMI Index)
Supporting habitats	Fragmentation indices; connectivity; heterogeneity indices; number/ area of habitats	Connectivity/ fragmentation indices (ABMI Index)
	Area of suitable habitat for a given species, Coverage of protected area; Change in status of threatened species; Trends in representative or key species; Number and status of endemic species; Number and status of migratory species; Trends in genetic diversity of selected species; Trends in abundance and distribution of selected species; Trends in invasive alien species	Area of suitable habitat for a given species
		Trends in a representative or key species

The second portion of the template was completed for all the indicators that met quick filtering questions that are linked to the six ES identified in section one of the template. The focus of this portion of the template is to address the applicability of indicators identified for the specific ES and to choose the most appropriate measure. All selection criteria templates can be found in Appendix A.

3.3 Results

The results of this analysis left six ES to measure with six quantifiable indicators.

Table 3-8: ES and Indicator Selection Criteria

Ecosystem Service	Ecological Indicator
Provision of wild foods	Available moose for hunting
Provision of raw materials – timber supply	Timber Supply
Climate regulation	Carbon Sequestration
Regulation of water quality	Downstream N, P, TSS
Maintenance of genetic diversity	ABMI Biodiversity Index
Supporting habitats	Caribou Habitat

The 7-step process for selecting ES and indicators for assessment was developed to be transferable across regions. If this process was employed elsewhere, the results of the analysis may reveal different ES and indicators, depending on the stakeholder values in the area of interest.

3.3.1 Linking Ecosystem Services to Stakeholder Values

The analysis began with stakeholder values to identify the appropriate ES to assess for the region, therefore, it is also important to link the final list of ES back to those values to ensure they are all being captured in some way throughout the assessment. The results of this analysis show that two values identified in the literature review are not being captured in the ES assessment. These include opportunities for oil sands development and maintenance of current air quality (Table 3-9). These two values are not captured in the assessment because they are insensitive to restoration efforts. It is important to note however, that should restoration occur on a larger scale, it may affect air quality in the future. Furthermore, there are a number of ES that were identified through this analysis that are not sensitive to restoration, but are highly valued by stakeholder in the region (e.g. provision of natural medicines, maintenance of recreational capability, and regulation of pest outbreaks, among others). Because this assessment is focused on quantifying the change in ES from linear restoration, these ES cannot be measured, as they are likely insensitive to restoration efforts. It is not to take away from the value stakeholders hold in these ES, and should the project objective change, the ES included in the assessment may also change.

Table 3-9: Linking stakeholder values back to the final list of ES

Stakeholder Value	Final List of ES
Maintain opportunities for oil sands development	Not sensitive to restoration efforts

Stakeholder Value	Final List of ES
Sustain a land base for timber harvest	Provision of raw materials: wood as timber
Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants	Provision of wild foods
	Maintenance of genetic diversity
Companies maintain their social license to operate	Climate regulation
	Water quality regulation
	Maintenance of genetic diversity
	Supporting habitats
Maintain opportunities for tourism development	Maintenance of genetic diversity
Sustain recreational capability	Maintenance of genetic diversity
	Supporting habitats
Sustain successional patterns and ecological processes	Maintenance of genetic diversity
	Supporting habitats
Sustain healthy populations of native wildlife	Provision of wild foods
	Maintenance of genetic diversity
	Supporting habitats
Maintain opportunities for traditional land use	Provision of wild foods
	Supporting habitats
Sustain fish populations	Regulation of water quality
Water quality	Regulation of water quality
Maintain current air quality	Not sensitive to restoration efforts
Visual aesthetics[38]	Supporting habitats
	Maintenance of genetic diversity

3.4 Discussion

The Selection Criteria Process revealed that the ES identified in phase 1 were defendable as ES to be assessed in the area of interest. It also revealed that stakeholders in the region also highly value moose for the provision of wild foods and hunting opportunities. Should the linear restoration program be scaled up to a larger region, or moved to a different research site, these values may change, along with the associated ES and indicators.

Including moose as an indicator species for the provision of wild foods will allow the ES assessment for the Algar region to show the tradeoffs 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 their ability to provide recreational opportunities. However, improving caribou habitat in the region has the potential to reduce the habitat available for moose, and vice versa.

[38] It was noted in the consultation package that stakeholders in the region are concerned that project development may be visible at nearby sacred sites, trapper cabins, and people living along the Athabasca River. Restoration that changes the view scape may be highly values by these stakeholders.

Identifying these tradeoffs will be important in the ES assessment as the benefits received will not be additive.

This analysis developed a repeatable, transparent process to identify the appropriate ES for an area of interest that involves linking plain-language stakeholder values to the biophysical changes caused by linear restoration and the benefits people receive from these changes. Because of the strong stakeholder engagement used to develop an appropriate list, this process is more likely to be used by decision makers in ES assessments in the future. Lastly, this analysis fills a need for a conceptual framework where the selection of ES and their respective indicators follow a transparent and rigorous selection process.

4 Analysis of Future States

4.1 Overview

During phase 1, the future state of five ES' were assessed. One additional ES was identified during phase 2 through the ES and Indicator Selection Criteria Process. Below provides a review of phase 1 results and the methodologies used to assess the additional ES added to the analysis in phase 2. The technical details and assumptions of the models that were employed during both phases can be found in Appendix B.

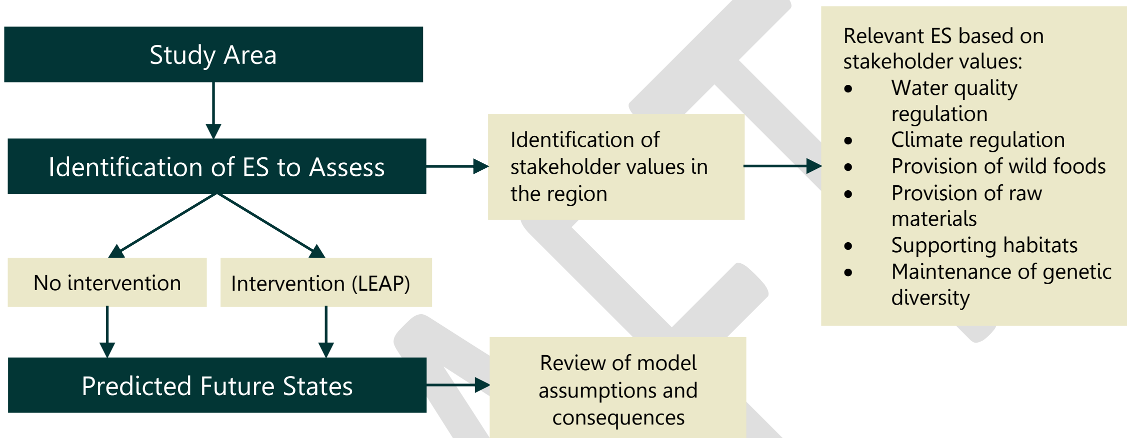

Figure 9: Workflow of the benefits assessment for the COSIA LEAP program

4.2 Methods

A number of models were used in phase 1 to assess the biophysical response to linear restoration for the ES identified, and different economic valuation approaches were used to translate the response to economic benefits for the population. Each model looked at two scenarios: no intervention and intervention using LEAP. From that, a predicted future state was estimated, and using a number of assumptions, the benefits of intervention were also estimated.

4.2.1 Estimating the Biophysical Response to Linear Restoration

4.2.1.1 Timber Supply

The timber supply model was developed to estimate the total amount of merchantable timber added to the land base following restoration. Without intervening, the natural trajectory of the seismic lines that were restored would have taken a significantly longer time to regenerate on their own. By intervening, the benefit of restoration occurs as merchantable timber is added back to the land base *faster* than it would have taken without action.

The model leveraged work completed in the *LEAP Algar Caribou Restoration Project.* In that project, a series of forest growth metrics (yield (m^3/ha) and height (m)) were developed for different forest types through a detailed literature review and modelling using GYPSY (Growth and Yield Projection System), which was developed by Alberta Environment and Parks. Detailed descriptions of the methods and analysis used to prepare the growth and yield projections can be found in the *Algar Caribou Habitat Restoration Program: Strategic to Tactical Plan.*[39]

The timber supply model used Remsoft's Woodstock modelling platform to estimate a predicted future state of conifer growing stock (m^3) and deciduous growing stock (m^3) as well as area by timber damage assessment (TDA) strata (ha).

Remsoft's modelling platform is widely accepted in the forest industry as a scientifically sound method for determining the future state of a forested land base and is heavily used by the industry in timber supply analyses. Woodstock also has the ability to use vector inputs, improving how the model represents the landscape. Many other modelling platforms use raster data inputs which are grids of pixels at a predefined scale (Figure 10). While this allows for models to run faster and are more efficient to use on large landscapes (e.g. provincial scale), they are difficult to operationalize at the tactical level as resolution may be too coarse to be meaningful. Because the Algar region is relatively small, a modelling platform that uses vector based inputs allowed the results to be presented at the treatment line scale as well as at the Algar region as a whole.

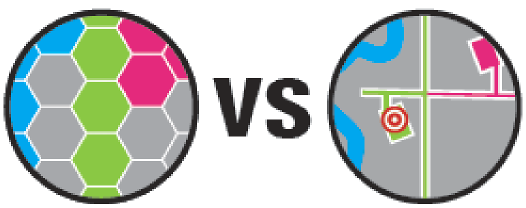

Figure 10: Raster versus Vector Inputs

4.2.1.2 Carbon Sequestration

The carbon model was developed to estimate the total ecosystem carbon sequestered through restoration efforts. The model was run under both scenarios: no intervention and intervention using LEAP. Similar to the timber supply model, with no intervention, the trajectory of the seismic lines would have been much slower to regenerate, reducing the amount of carbon sequestered through vegetation on the lines.

The model leveraged work completed in the *LEAP Algar Caribou Restoration Project.* In that project, a series of carbon stock curves (tonnes/ha) were developed for different forest types through simulation modelling using the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3).[40] Base forest growth and yield curves for the area of interest were obtained from the publicly available Detailed Forest Management Plan which Alberta-Pacific Forest Products Inc. submitted to Alberta Environment and Parks

[39] Oil Sands Leadership Initiative (OSLI) (2011). Algar Caribou Habitat Restoration Program: Strategic to Tactical Plan.
[40] Information on the CBM-CFS3 model itself including how it was developed and what it can be used for can be found on the NRCan website: Natural Resources Canada. Climate Change: Carbon Budget Model. http://www.nrcan.gc.ca/forests/climate-change/13107

in 2006.[41] From this document, local empirical yield curves were used as a base input into the CBM-CFS3 model. Detailed descriptions of the methods and analysis employed to prepare the carbon stock projections can be found in the Algar Caribou Habitat *Restoration Program: Strategic to Tactical Plan.*[42]

The CBM-CFS3 model complies with the Intergovernmental Panel on Climate Change (IPCC) carbon estimation methods. It is a widely accepted model used to estimate carbon storage that can be integrated into spatial models similar to Remsoft's Woodstock modelling platform. It will however, underestimate the amount of carbon in organic soils, including soils with thick peat layers (up to 40 cm thick).

4.2.1.3 Caribou Habitat

The caribou intactness model was developed to estimate the amount of improved functional habitat of a highly valued species by stakeholders. The model looked at the future state of caribou habitat if no restoration was to occur on the landscape as well as what occurs once lines are treated using LEAP.

The model leveraged the *Environment Canada Recovery Strategy for the Woodland Caribou,*[43] which considers disturbed caribou habitat areas within a 500 meter zone of influence of all anthropogenic features that are visible on 1:50,000 Landsat imagery and fires that are less than 40 years old.

The model used forest growth curves and treatment response height curves in Remsoft's Woodstock modelling platform to remove linear features from the landscape through restoration efforts. Linear features were considered restored once a target height of 1.2 meters was reached in the simulation. For post-restoration intact caribou habitat, restored seismic lines and their respective 500m buffer, are removed from the disturbed area where that area is also outside the zone of influence of remaining active footprint features on the landbase (e.g. active LOCs).

4.2.1.4 Biodiversity Intactness

The biodiversity intactness model was created by ABMI to measure the change in biodiversity from preindustrial conditions (i.e. if no industrial footprint were present). To apply this model to the Algar region, two scenarios were modelled: no intervention and intervention using LEAP. Both scenarios were compared to preindustrial conditions, then compared to each other to estimate the change in biodiversity intactness gained from using LEAP for linear restoration.

The model leverages work completed by ABMI to report on the health of a species in a region. The Biodiversity Intactness Index changes for "decreaser" species, such as the boreal chickadee that is likely to see a decrease in population sizes with industrial development, and "increaser" species, such as the coyote, where population sizes increase as industrial development also increases. The index ranges from 0% and 100% intact. When 100% intactness is reached, this implies the abundance of the species is the same as expected to preindustrial conditions. [44] This calculation is completed individually for species, and

[41] Alberta-Pacific Forest Industries Inc. 2006. Alberta-Pacific FMA Area Forest Management Plan. Alberta-Pacific Forest Industries Inc. Boyle, Alberta.
[42] Oil Sands Leadership Initiative (OSLI) (2011). Algar Caribou Habitat Restoration Program: Strategic to Tactical Plan.
[43] Environment Canada (2012). Recovery strategy for the woodland caribou *(Rangifer tarandus caribou)*, Boreal population, in Canada. Species at Risk Act: Recovery Strategy Series.
[44] ABMI (2014). ABMI's Intactness Index. Meausring Biodiversity. Retrieved from: http://www.abmi.ca/home/about-us/intactness-index

then averaged and aggregated across all species present in the area of interest to obtain an overall intactness value. [45]

A comparison of the two scenarios: no intervention and intervention using LEAP predicted the change in biodiversity following linear restoration, assuming the seismic lines treated during restoration are eliminated from the landbase 30 years into the future.

4.2.1.5 Water Purification

The water model was developed by ABMI to assess the source and sink areas of a landscape for non-point source pollution, including nitrogen, phosphorus, and total suspended solids. The model was run under both scenarios: no intervention and intervention using LEAP.

The spatially explicit model uses the net-logo modelling platform to estimate changes in annual loading of pollutants to waterbodies of interest. The model rasterizes data to a 64 ha resolution, making it most appropriate for large landscapes. It also uses a digital elevation model (DEM) to derive a stream network, along with a number of nutrient export and retention coefficients for land cover types and annual precipitation data. The amount of each pollutant (kg/year) exported and retained by each landscape cell is then estimated. These cells follow the elevation flow of water until reaching a waterbody, where the pollutant is carried downstream.

4.2.1.6 Moose Habitat

Moose occupy a large variety of habitats and exhibit seasonal patterns of use. Moose are mobile animals with ranges typically encompassing a mix of habitats.[46] High quality browse is particularly critical in winter, as well as shelter areas that allow access to food, aquatic feeding areas and isolated sites for calving. Young forested stands with deciduous shrubs and forbs are primarily associated with summer feeding, whereas mature forests provide shelter from both snow and heat, as well as mineral licks.[47]

Habitat selection by moose is primarily driven by forage availability; shrub fields are the most critical community in moose habitat. Moose are commonly associated with aquatic habitats, such as lakes, streams, or ponds and observations suggest that aquatic vegetation is highly palatable to them. [48] Edges are also used by moose as they offer an interspersion of browse species and coniferous forest; this allows for the maximum quantity and quality of browse with adjacent escape cover available. [49,50]

Two habitat suitability models were reviewed to assess the changes in moose habitat following linear restoration: *Mistik FMA Area Moose Winter Habitat Determination Model* and the *Tolko Habitat Requirements for Moose.*

---

[45] Habib, T. & Farr, D. 2013. "Current and Future Biodiversity Intactness Assessment of the OSLI LEAP Project". ABMI: Ecosystem Services Assessment.

[46] Peek, J. M. 1997. Habitat Relationships in Ecology and Management of the North American Moose. Smithsonian Institution Press. pp. 351-376.

[47] Thompson, I. D. and R. W. Stewart. 1997. Management of Moose Habitat in Ecology and Management of the North American Moose. Smithsonian Institution Press. pp. 377-402

[48] Peek, J. M. 1997. Habitat Relationships in Ecology and Management of the North American Moose. Smithsonian Institution Press. pp. 351-376.

[49] McNicol, J. G. and F. F. Gilbert. 1980. Late Winter Use of Upland Cutovers by Moose. J. Wild. Mange. 44(2): 363-371.

[50] Brusnyk, L. M. and F. F. Gilbert. 1983. Use of Shoreline Timber Reserves by Moose. J. Wildl. Manage. 47(3): 673-685.

Mistik is dedicated to sustainably managing 1.9 million hectares of boreal forest in northwestern Saskatchewan. [51] The Mistik FMA Area Moose Winter Habitat Determination Model was developed for mid and late winter environments, where animals may have less access to forage. Winter habitat suitability was chosen because forage is not a limiting factor for moose in the summer months. The model weights a number of factors including stand type, vertical structure, canopy closure, and adjacency to early seral stages, aquatic vegetation and rivers/streams. [52]

The model leveraged work completed in the *LEAP Algar Caribou Restoration Project*. In that project, using a series of forest growth curves for different forest types, the Alberta Vegetation Inventory (AVI), and the linear restoration inventory, the landbase was benchmarked and a future landbase was estimated. From that, two scenarios were modelled to estimate the impact of restoration on moose habitat: no intervention and intervention using LEAP.

The Tolko Habitat Requirements for Moose were developed for the natural sub regions of Alberta: Central Mixedwood, Dry Mixedwood, Wetland Mixedwood, Subartic, Peace River Lowlands, and the Boreal Highlands. The model looks at two main factors affecting suitable moose habitat, including age and cover type of the forest, with mixedwood cover types between 50 and 100 years being the optimal habitat for moose.[53]

This model also leveraged work completed in the *LEAP Algar Caribou Restoration Project*. Using a series of forest growth curves for different forest types, the Alberta Vegetation Inventory (AVI), and the linear restoration inventory, the landbase was benchmarked and a future landbase was estimated. From that, two scenarios were modelled to estimate the impact of restoration on moose habitat: no intervention and intervention using LEAP.

4.2.2 Translating the Biophysical Response to Economic Benefits

4.2.2.1 Timber Supply

TDA strata was used to estimate the *value* of the growing stock added to the land base through linear restoration (Figure 11). The predicted future state is 30 years into the future, with the baseline year being 2010, before restoration began.

[51] http://www.mistik.ca/index.htm
[52] Proulx, G. (2006). Development of queries and predictive distribution maps for wildlife indicator species, species of concern, and species at risk for the current (2006) forest condition in the Mistik FMA area.
[53] Tolko Industries Ltd. (2011.). Advancing non-fibre value forecasting through application of forest growth models.

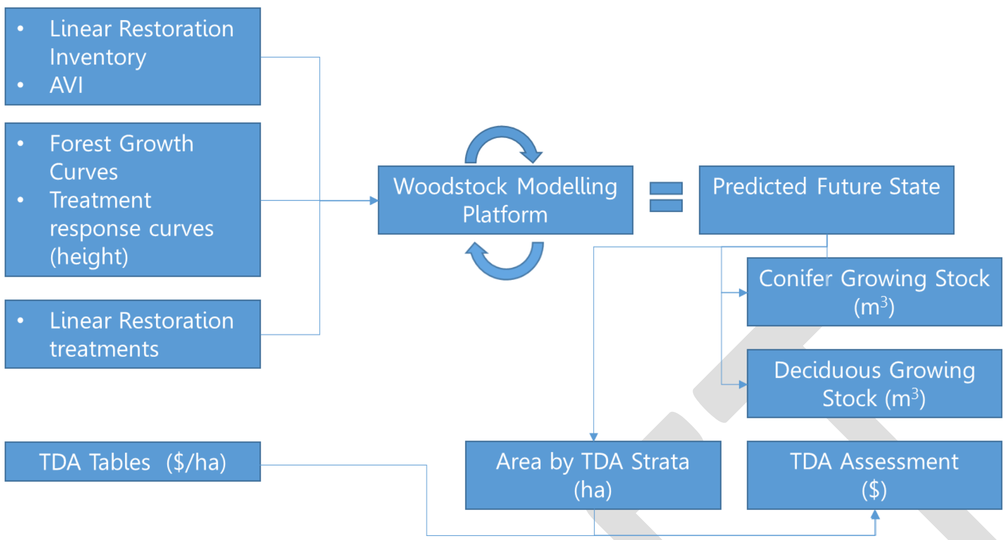

Figure 11: Timber Supply inputs and outputs

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.[54] 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.

4.2.2.2 Carbon Sequestration

The carbon model used the CBM-CFS3 model and Remsoft's Woodstock modelling platform to estimate a predicted future state of total ecosystem carbon. A set carbon price ($/tonne of CO_2) was then used to estimate the total benefit of linear restoration to carbon sequestration as an ecosystem service (Figure 12). The predicted future state is 30 years into the future, with the baseline year being 2010, before restoration began.

[54] Alberta Forest Products Association. https://www.albertaforestproducts.ca/our-industry/forestry/timber-damage-assessments

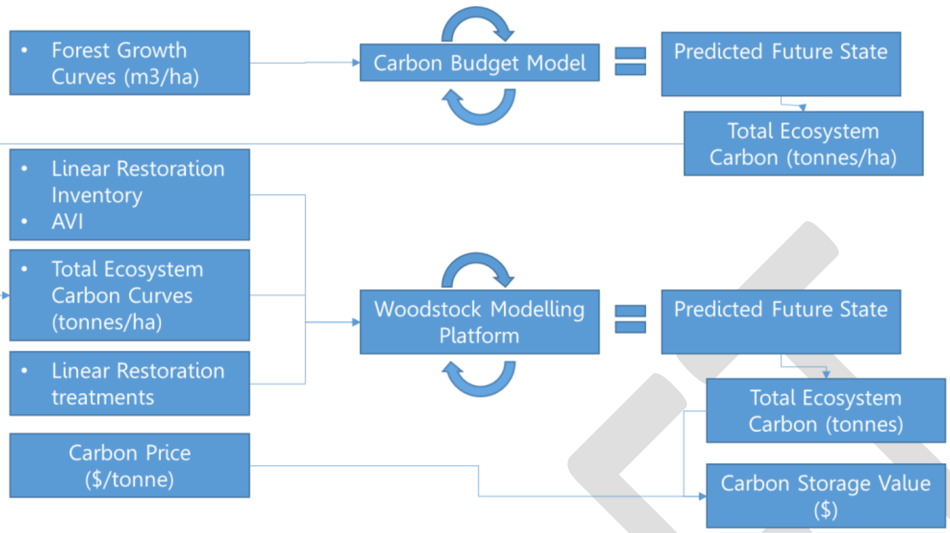

Figure 12: Carbon model inputs and outputs

Carbon prices have been defined by Alberta's government Emission Reduction Regulations as well as Environment Canada. Both were used to estimate the benefit of carbon sequestration as lower and upper values, respectively.

4.2.2.3 Caribou Habitat

To assign a monetary value to the benefits of habitat improvements, two methods were used (Figure 13). The first approach used 2012 study which estimated the amount, per year, Albertan's were willing to pay to move from two to three self-sustaining caribou herds in Alberta. [55] The second approach applied the opportunity cost of development to the restored area. In this analysis, the net present value (NPV) of resources on the land represents the opportunity cost of conserving habitat. This approach leveraged a study by Hauer et al., where the NPV per township was calculated taking into consideration the total value of all resources (gas, oil, bitumen, and forestry).[56]

[55] Harper, Dana (2012). Analyzing the economic benefits of woodland caribou conservation in Alberta. MSc Thesis. University of Alberta.
[56] Hauer, G. et al. (2010). A net present value model of natural gas exploitation in northern Alberta: An analysis of land values in woodland caribou ranges. Rural Economy: Project Report. University of Alberta.

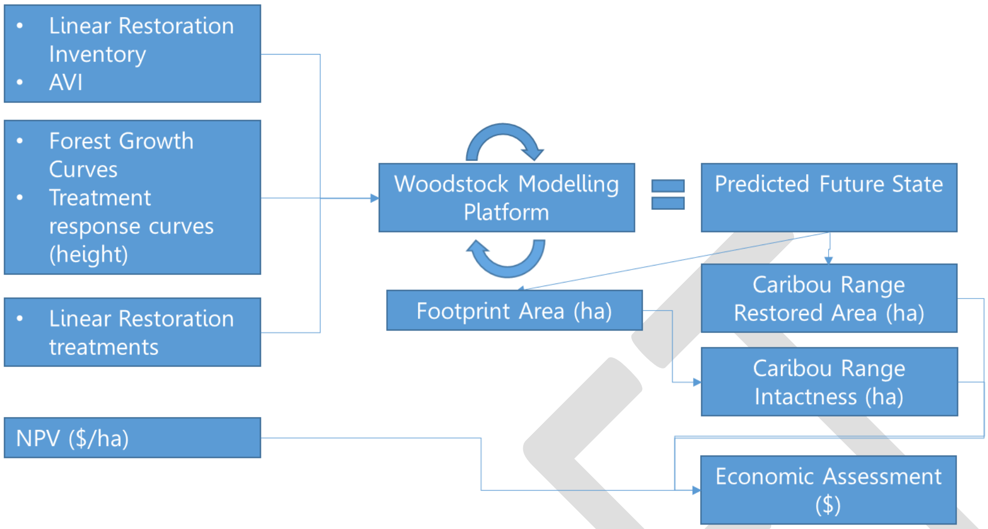

Figure 13: Caribou Intactness Inputs and Outputs

4.2.2.4 Biodiversity Intactness

To estimate the economic benefits from increased biodiversity intactness through linear restoration, the opportunity cost of development was used by assuming the value of biodiversity was the same value to Albertan's as taking land out of production indefinitely (e.g. a conservation area). This was calculated using the study by Hauer et al. [57] that estimated the net present value of resource extraction per township in northern Alberta.

4.2.2.5 Water Purification

A replacement cost approach was used to estimate the impact of linear restoration on beneficiaries downstream. Both avoided dredging costs and avoiding drinking water treatment costs were calculated based on a review of the literature across North American studies.

Replacement cost approaches are often employed when no direct market price is available. With this type of approach, the services provided by the ecosystem are valued based the cost that would have to be incurred to replace the service artificially (e.g. a water treatment plant). [58] This type of approach is known as *direct market valuation* because the economic model relies on concrete production or cost data. This approach is generally more accepted among industry than revealed or stated preference techniques that rely heavily on hypothetical scenarios and assumptions.

4.2.2.6 Moose Habitat

[57] Hauer, G. et. al. 2010. "A Net Present Value Model of Natural Gas Exploitation in Northern Alberta: An Analysis of Land Values in Woodland Caribou Ranges". Rural Economy: Project Report. University of Alberta.
[58] TEEB (2010). The economics of valuing ecosystem services and biodiversity. Chapter 5. Retrieved from: http://www.teebweb.org/wp-content/uploads/2013/04/D0-Chapter-5-The-economics-of-valuing-ecosystem-services-and-biodiversity.pdf

A benefits transfer approach was used to assess the value of improved moose habitat in the Algar region. The valuation metrics followed a 2006 study conducted in Alaska, which measured the consumptive and non-consumptive values of the Alaskan moose population.[59]

The study used a replacement cost approach to estimate the consumptive value of moose, assuming moose meat would be a replacement for beef. Furthermore, hunting experience was also included in the consumptive value calculation, accounting for sport hunters in the area who do not depend on moose for subsistence, but still partake in hunting. To estimate this value, a travel cost method was employed, which surveyed hunters and asked their total costs of a recent overnight hunting trip.

Non-consumptive values identified included wildlife viewing, wildlife appreciation (existence value from residents and non-residents), and traditional knowledge. However, because Alaska's tourism industry depends heavily on wildlife viewing, the study focused on the effect the presence of moose has on the industry as a method to estimate non-consumptive values.

To estimate the value of moose habitat improvements for the Algar region, population changes were estimated based on the current density of moose in the region and the assumption that density would improve as habitat suitability improves. Furthermore, only consumptive values were applied, as moose was used as an indicator to measure the provision of wild foods.

[59] Northern Economics Inc. 2006, The Value of Alaska Moose, Prepared for Anchorage Soil and Water Conservation District and the Alaska Soil and Water Conservation District.

4.3 Algar Ecosystem Service Assessment Results

The results of the phase 1 ES assessment are summarized in Table 4-1, with the exception of the provision of wild foods (moose habitat) as this was added to the assessment in phase 2. For a discussion regarding the interpretation of these results, please see Appendix B.

Table 4-1: Ecosystem Service Assessment Summary

Ecosystem Service [Indicator]	Future State Assessment		Biophysical Response	Economic Response [60]	
	Control	Restoration		Lower Limit	Upper Limit
Provision of Raw Materials (m^3) [Timber Supply]	6,695,000	6,703,000	8,100	$6,600	$6,600
Climate Regulation (tonnes) [Carbon Sequestration]	15,700,000	15,718,000	18,200	$309,000	$515,000
Supporting Habitats (ha) [Intact Caribou Habitat]	9,900	22,700	12,800	$278,000	$775,102,000
Water Purification (kg/year) [Phosphorus]	6,700	5,300	-1,400	$16,800[61]	$1,051,000
[Nitrogen]	23,000	21,700	-1,300	$20[62]	$2,100
[Total Suspended Solids]	3,993,000	3,862,000	-131,000	$4[63]	$400
Genetic Diversity (%) [Biodiversity Intactness]	95.96%	96.73%	0.77%	$26,663,000	$26,663,000
Provision of Wild Foods (ha) [Moose Habitat: Mistik Model]	46,471[64]	46,469	-2	Negligible	Negligible
Provision of Wild Foods (ha) [Moose Habitat: Tolko Model]	43,537	43,558	21		

4.4 Discussion

The models used to assess the ES benefits obtained through the COSIA LEAP program depend on a number of assumptions. The assumptions, model parameters, and recommendations for interpreting results can be found in Appendix B.

There remain opportunities to improve the analysis of the ES assessed in Phase 1. Should the same (or some of the same) ES be assessed in a different region, some of these improvements may be beneficial.

The timber supply analysis uses historical TDA values to estimate the benefit of additional growing stock in the future. TDA tables are updated annually, and their values can vary significantly between years (Table 4-2).[65]

---

[60] Summarized using a 4% discount rate to reflect the risk free rate.
[61] Avoided treatment costs for phosphorus
[62] Avoided dredging costs
[63] Avoided treatment costs for sediment
[64] High and medium habitat quality estimates, assuming linear restoration improves low quality habitat faster than without intervention
[65] Alberta Environment and Parks. http://aep.alberta.ca/lands-forests/forest-management/timber-damage-assessment/default.aspx

Table 4-2: TDA Table Inputs

Alpac TDA Table	Coniferous Standing Timber Value ($/m^3)	Deciduous Standing Timber Value ($/m^3)
2014/15	6.67	2.72
2015/16	7.11	2.02
Difference	***+0.44***	***-0.70***

Completing a sensitivity analysis on historical TDA values may improve the understanding on how values can fluctuate in the future. While imperfect, this type of analysis may improve benefits estimates by reducing the uncertainty surrounding TDA fluctuations.

The Carbon Budget Model currently underestimates the amount of carbon in organic soils, including soils with thick peat layers (up to 40 cm thick). While this model update is in development, it was recommended to complete a literature review to confirm the likelihood of additional soil carbon in peatlands. Furthermore, updating the valuation approach to account for yearly carbon flux would more accurately reflect the market price of carbon.

Furthermore, the current assessment of caribou habitat does not account for the probability of increasing a self-sustaining herd through linear restoration. The assessment could be refined to account for the probability of increasing a self-sustainable herd, leveraging work already completed by the federal government's recovery strategy team. Furthermore, not all linear footprint was restored in the Algar region, due to active dispositions and active trap lines, causing some of the seismic lines that were restored to be unaccounted for in the intactness analysis as they were still within the 500 meter zone of influence of an active disturbance. This analysis could be leveraged when choosing another site for restoration, accounting for existing footprint density and active footprint visible using 1:50,000 Landsat imagery.

The biodiversity intactness model could be improved to include temporal parameters, including the ability to assess partially recovered footprint. This would however, require significant field data from areas in intermediate stages of ecological recovery. In terms of the economic valuation, the NPV of resource extraction could be considered a cost of restoration rather than a benefit to biodiversity. To address this at alternative sites, it has been recommended that biodiversity intactness be recognized for its implicit value, and no dollar value be assigned. Rather, define biodiversity as a supporting ecosystem service, where other services would decline without its existence.

Additionally, the water purification model parameters could be refined for non-agricultural regions. Currently data sources are being pulled from the white zone of Alberta, which could be significantly different when looking at the boreal forest. Furthermore, the model could also be refined to produce hourly or daily loading outputs (rather than annual) as this would help address the linear assumption used for the economic valuation. At this time there is not enough information to calculate if the pollutant concentration reductions are crossing a threshold to reduce water treatment costs. It has also been recommended that there may be more appropriate pollutants to measure that are easier to understand by stakeholders (e.g. water turbidity) or can measure other ecosystem services such as fish population improvements or recreational values.

Lastly, moose was included as an indicator for the provision of wild foods. Moose is a keystone species in the boreal forest and are a distinct part of aboriginal culture. Not surprisingly, the 7-step process revealed moose to be an important indicator to stakeholders in the Algar region. However, linear restoration has a minimal effect on improving moose habitat and some argue linear restoration may have a negative effect on moose populations in the future. Nevertheless, these tradeoffs must be accounted for to estimate the total economic value of linear restoration to stakeholders in the region. Moreover, the economic valuation depends on increasing moose populations. Because linear restoration has a minimal effect on moose habitat improvements, it is unlikely moose populations will increase through linear restoration alone.

Other recommendations included updating linear restoration trajectories with monitoring data, however, this is contingent on the continuation of the monitoring program in the Algar region. To-date three years of data has been collected. Lastly, there is the opportunity to incorporate risk from future natural and anthropogenic disturbances into the modelling platform.

5 Next Steps

Phase 2 is a three year project that has been split to meet three goals:

1) Goal 1: Identify the appropriate ES for the Algar Region
2) Goal 2: Test compatibility and transferability of methodologies to other areas in the province
3) Goal 3: Evaluate how this assessment fits into GoA policy (current and proposed)

This discussion paper reflects the results of the first goal of phase 2, where we have developed a repeatable, transferable and transparent process for the selection of ES and ES indicators. We have also refined the ES chosen for assessment, and looked to understand the underlying assumptions in the models used.

To meet Goal 2, we will leverage the 7-step process for the selection of ES in the Algar region to identify any additional high priority values in the larger Southern Athabasca Oil Sands Area (SAOS).

Once a list of high priority values for the SAOS is established, Silvacom will work with project partners to prioritize areas for restoration, maximizing the benefits of linear restoration for a basket of ES, linked to high priority values. The project team will also define a number of scenarios that will address trade-offs between ES locally and regionally. Furthermore, the project team will address issues of scaling ES assessments up to larger areas of interest by applying the modelling approach to the Lower Athabasca Regional Planning (LARP) area.

Results of Goal 2 will include the identification of high priority restoration areas in the SAOS region and LARP area, the amount of restoration required to see a change in ES in both scales, and the potential trade-offs between local and regional values. The results of Goal 2 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 modelling conditions (taken from 2016 work)
- Challenges moving from local to regional restoration benefits
- Amount of restoration required to use an ES approach (taken from 2016 modelling results)
- How to interpret modelling results so the benefits are not overstated (taken from 2015 work)
- Additional conditions to be determined

Community engagement will be a key to the success of meeting the upcoming goals. The project team hopes to work with additional partners including the government of Alberta and CEMA to ensure engagement remains strong.

Appendix A

The selection criteria template was created to assess the applicability of the ecosystem service (ES) and the indicator chosen for the case study area (e.g. Algar region). The template links stakeholder values to ES, and those ES are in turn linked to indicators that can show a measurable change over time. The template addresses whether or not the chosen indicators are relevant to the study area, if there are stakeholders and beneficiaries in the area, and if there is accessible data to measure a change. Final approval of the ES and indicators for assessment will go through the relevant stakeholders.

Table A-0-1. Ecosystem Service Selection Criteria – Aesthetic Values

Ecosystem Service Characteristics					
Ecosystem Service:	Aesthetic values				
Stakeholder Value:	Maintain opportunities for tourism development[66]; Sustain recreational capability;[67] Water quality for communities[68]				
Description:	Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing location[69]				
Stakeholders					
Are there stakeholders within the defined region?	☐**Yes**	☐ **No** ☒**Unconfirmed**	• First Nations • General Public		
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:	Unknown – trees at 1.2 m at 15-20 years.		**In-situ** ☒	**Larger than Area of Interest** ☐	**Downstream** ☐
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)		**1**	**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:			**Is the model transparent and easy to understand?**		☒ **Yes** ☐ **No**
Additional comments:					
Approvals					
Include on Final ES List:	☐**Yes**	☒ **No**	**If yes, continue to next section**		
Reason for in/exclusion:	Not enough stakeholders in the region to make this a meaningful measurement of an ES; no indicators identified that are sensitive to restoration				

[66] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[67] Ibid
[68] Stakeholder engagement from the advisory committee in phase 1
[69] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Table A-0-2. Ecosystem Service Selection Criteria – Climate Regulation

<table>
<tr><th colspan="6">Ecosystem Service Characteristics</th></tr>
<tr><td>Ecosystem Service:</td><td colspan="5">Climate regulation</td></tr>
<tr><td>Stakeholder Value:</td><td colspan="5">Companies maintain their social license to operate[70]</td></tr>
<tr><td>Description:</td><td colspan="5">Locally, changes in land cover can affect both temperature and precipitation. Globally, ecosystems play a role in sequestering or emitting greenhouse gases, which can have an effect on severe weather events associated with climate change.</td></tr>
<tr><th colspan="6">Stakeholders</th></tr>
<tr><td>Are there stakeholders within the defined region?</td><td>☒Yes</td><td>☐ No
☐Unconfirmed</td><td colspan="3">• General public
• Oil and gas
• Forestry
• Government</td></tr>
<tr><th colspan="3">Ecosystem Service Type</th><th colspan="3">Market Prices</th></tr>
<tr><td>☐ Provisioning</td><td colspan="2">☒ Regulating</td><td>Is there a market price available?</td><td>☒Yes</td><td>☐ No
☐Unknown</td></tr>
<tr><td>☐ Cultural</td><td colspan="2">☐ Supporting</td><td>If no, can a market price be created?</td><td>☐Yes</td><td>☐ No
☐Unknown</td></tr>
<tr><th colspan="3">Timeline</th><th colspan="3">Scale of Benefits</th></tr>
<tr><td>Estimated time until benefits are received:</td><td colspan="2">1+ years</td><td>In-situ
☐</td><td>Larger than Area of Interest
☒</td><td>Downstream
☐</td></tr>
<tr><th colspan="6">Ecosystem Service Selection Criteria</th></tr>
<tr><td colspan="2">How many times the stakeholder value was identified (literature review or consultation)</td><td>2</td><td colspan="2">Can we model a change in defined indicators for the ES?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="2">Does the ES clearly link to the stakeholder value?</td><td>☒ Yes
☐ No</td><td colspan="2">Is there available input data for the model?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="2">Is the ES currently relevant to policy (current or upcoming)</td><td>☒ Yes
☐ No</td><td colspan="2">If yes, is the data freely available?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="3">If yes, specify which policy: Alberta carbon offset system, Industrial emissions management, etc.</td><td colspan="2">Is the model transparent and easy to understand?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="6">Additional comments:</td></tr>
<tr><th colspan="6">Approvals</th></tr>
<tr><td>Include on Final ES List:</td><td>☒Yes</td><td>☐ No</td><td colspan="3">If yes, continue to next section</td></tr>
<tr><td>Reason for in/exclusion:</td><td colspan="5">Relevant to stakeholders and policy. Globally accepted ES, important to industry</td></tr>
</table>

[70] Phase 1 Advisory Committee Members

Table A-0-3. Ecological Indicator Selection Criteria – Carbon Sequestration Capacity

Indicator Characteristics					
Ecological Indicator:	Carbon sequestration capacity				
Description	Capacity of the area to sequester carbon	**Units:** CO_2e (tonnes)			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** CBM-CFS3, Woodstock	
Owner: Canadian Forest Service, Remsoft					
Model Use Agreement: Open, purchased					
Is there available input data?	☒Yes ☐ No	**Required Inputs:** Forest growth curves			
Name: Linear Restoration Inventory, AVI	**Version:** RLI 2015, AVI 2.1.1	**Coverage:** Algar, Alberta	**Acquired from:** AltaLIS		
Is there an ABMI ESA model available?	☒Yes ☐ No ☐ N/A	**Is the ABMI ESA model being used?**	☐Yes ☒ No ☐ N/A	**If no, why?** Model developed in house, higher resolution with internal linear restoration inventory data	
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒	**Larger than the area of interest** ☐	**Downstream** ☐		
Comments: Measures change in capacity to sequester carbon on the seismic line restored and for the Algar region as the forest changes.					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes	☐ No
				List (units): $/tonne/year	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☒Yes	☐ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:	☒Include	☐Exclude			
Reason for In/exclusion: Widely accepted as an indicator for climate regulation, clear accounting scheme established, important measure for industry					
Stakeholder Approval:	☒Yes	☐No			
Include as final indictor for the ES?	☒Yes	☐No			

Table A-0-4. Ecological Indicator Selection Criteria – Forest biomass Production

Indicator Characteristics			
Ecological Indicator:	Forest Biomass		
Description	Amount of biomass added to the landbase through restoration activities	**Units:** ODT	

Scientific Foundation				
Is the indicator measured or modelled?	☐**Measured** ☒**Modelled**	**Is there an available model:**	☒**Yes** ☐ **No** ☐ **N/A**	**Name:** BRIMS Methodology
Owner: N/A				
Model Use Agreement: N/A				
Is there available input data?	☒**Yes** ☐ **No**	**Required Inputs:** Forest growth curves		
Name: Linear Restoration Inventory, AVI	**Version:** RLI 2015, AVI 2.1.1	**Coverage:** Algar, Alberta	**Acquired from:** AltaLIS	
Is there an ABMI ESA model available?	☒**Yes** ☐ **No** ☐ **N/A**	**Is the ABMI ESA model being used?**	☐**Yes** ☒ **No** ☐ **N/A**	**If no, why?** Model developed in house, higher resolution with internal linear restoration inventory data

Model Output Scale			
The scale in which you model outputs are summarized			
Smaller than the area of interest ☐	**In-situ** ☒	**Larger than the area of interest** ☐	**Downstream** ☐
Comments: Measures change in capacity to sequester carbon on the seismic line restored and for the Algar region as the forest changes			

Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒**Yes**	☐ **No**	**Is there a valuation indicator available?**	☒**Yes**	☐ **No**
				List (units): $/tonne/year	
Is the indicator sensitive to change?	☒**Yes**	☐ **No**	**Does the valuation indicator link to the ES?**	☒**Yes**	☐ **No**
Is the indicator transparent to calculate?	☒**Yes**	☐ **No**	**Is there a market price for the indicator?**	☒**Yes**	☐ **No**
Can the indicator be scaled up/down?	☒**Yes**	☐ **No**	**If no, can a market price be created?**	☐**Yes**	☐ **No**
Is the indicator a species at risk?	☐**Yes**	☒ **No**	**Additional Comments:**		

Approvals		
Internal recommendation to include in analysis:	☐**Include**	☒**Exclude**
Reason for In/exclusion: The change in biomass will also be captured in the measurement of timber supply (m^3) as this would be an input for the biomass calculation; biomass increases do not directly link to climate regulation; no valuation scheme available		
Stakeholder Approval:	☐**Yes**	☒**No**
Include as final indictor for the ES?	☐**Yes**	☒**No**

Table A-0-5. Ecosystem Service Selection Criteria – Cultural Heritage

Ecosystem Service Characteristics				
Ecosystem Service:	Cultural Heritage			
Stakeholder Value:	Maintain opportunities for traditional land use [71,72]			
Description:	Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species [73]			
Stakeholders				
Are there stakeholders within the defined region?	☒**Yes**	☐ **No** ☐**Unconfirmed**	• First Nations	
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:	Unknown	**In-situ** ☒	**Larger than Area of Interest** ☐	**Downstream** ☐
Ecosystem Service Selection Criteria				
How many times the stakeholder value was identified (literature review or consultation)	**6**	**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: Land Use Framework		**Is the model transparent and easy to understand?**	☐ **Yes** ☒ **No**	
Additional comments:				
Approvals				
Include on Final ES List:	☐**Yes**	☒ **No**	**If yes, continue to next section**	
Reason for in/exclusion:	Cannot be modelled, no market price available.			

[71] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[72] Government of Alberta (2014). Biodiversity Management Framework, Version 1.0. Draft
[73] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Table A-0-6. Ecosystem Service Selection Criteria – Erosion Regulation

Ecosystem Service Characteristics					
Ecosystem Service:	Erosion regulation				
Stakeholder Value:	Maintain soil quality				
Description:	Locally, changes in land cover can affect erosion. Forested cover reduces erosion of soils.				
Stakeholders					
Are there stakeholders within the defined region?	☒**Yes**	☐ **No** ☐**Unconfirmed**	• General public • Oil and gas • Forestry • Government		
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** ☐	**Downstream** ☒	
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)	**1**	**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: FMP process		**Is the model transparent and easy to understand?**	☒ **Yes** ☐ **No**		
Additional comments:					
Approvals					
Include on Final ES List:	☐**Yes**	☒ **No**	**If yes, continue to next section**		
Reason for in/exclusion:	Not sensitive to linear restoration in the Algar region. Value only identified once in the stakeholder literature review (Alberta Forest Management Planning Standard Annex 4).				

Table A-0-7. Ecosystem Service Selection Criteria – Intrinsic Values of Biodiversity

Ecosystem Service Characteristics					
Ecosystem Service:	Intrinsic value of biodiversity				
Stakeholder Value:	Sustain successional patterns and ecological processes[74]; Sustain healthy populations of native wildlife[75], Sustain fish populations[76]				
Description:	Nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.[77]				
Stakeholders					
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• General Public • First Nations		
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** ☒	**Downstream** ☐
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)		9	**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: Biodiversity Management Framework			**Is the model transparent and easy to understand?**		☐ Yes ☐ No
Additional comments:					
Approvals					
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**		
Reason for in/exclusion:	No available economic model to complete the valuation assessment. The change in biodiversity will be captured through the genetic diversity ES assessment.				

[74] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[75] Ibid
[76] Ibid
[77] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis.
Island Press, Washington, DC.

Table A-0-8. Ecosystem Service Selection Criteria – Maintain Recreational Opportunities

Ecosystem Service Characteristics					
Ecosystem Service:	Maintain recreational opportunities				
Stakeholder Value:	Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants; [78] Maintain opportunities for tourism development;[79] Sustain recreational capability;[80] Sustain fish populations;[81] Water quality for communities[82]				
Description:	Healthy ecosystems provide a place for people to enjoy recreationally (e.g. hunting, wildlife viewing, etc.) [83]				
Stakeholders					
Are there stakeholders within the defined region?	☐Yes	☐ No ☒Unconfirmed	• General Public • First Nations		
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:	Unknown		**In-situ** ☐	**Larger than Area of Interest** ☒	**Downstream** ☐
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)		**16**	**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: Regional Plans			**Is the model transparent and easy to understand?**		☒ Yes ☐ No
Additional comments:					
Approvals					
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**		
Reason for in/exclusion:	Lack of defined recreational users in the area of interest (Algar region)				

[78] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[79] Ibid
[80] Ibid
[81] Ibid
[82] Feedback from Phase 1 Advisory Committee Members
[83] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Table A-0-9. Ecosystem Service Selection Criteria – Maintenance of Genetic Diversity

Ecosystem Service Characteristics					
Ecosystem Service:	Maintenance of Genetic Diversity				
Stakeholder Value:	Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants;[84] Maintain opportunities for tourism development[85]; Sustain recreational capability[86]; Sustain successional patterns and ecological processes;[87] Sustain healthy populations of native wildlife[88]				
Description:	Genetic diversity of native wildlife populations				
Stakeholders					
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• General Public • First Nations • Hunters • Wildlife Viewers		
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** ☒	**Downstream** ☐	
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)	17	**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: Biodiversity Management Framework		**Is the model transparent and easy to understand?**		☒ Yes ☐ No	
Additional comments:					
Approvals					
Include on Final ES List:	☒Yes	☐ No	**If yes, continue to next section**		
Reason for in/exclusion:	Significant stakeholder value, models available, market prices potentially available.				

[84] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[85] Ibid
[86] Ibid
[87] Ibid
[88] Ibid

Table A-0-10. Indicator Selection Criteria – Biodiversity Intactness

Indicator Characteristics					
Ecological Indicator:	Biodiversity intactness				
Description	Represents the difference in species abundances between current landscape conditions and reference conditions (i.e. if no footprint were present)			**Units:** % intact	
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** ABMI Biodiversity Intactness model	
Owner: ABMI					
Model Use Agreement: Free, open					
Is there available input data?	☒Yes	☐ No	**Required Inputs:** Landcover, abundance index		
Name: Landbase	**Version:** N/A		**Coverage:** Southern Athabasca Oil Sands Area	**Acquired from:** COSIA landbase, developed by Silvacom	
Is there an ABMI ESA model available?	☒Yes ☐ No ☐ N/A		**Is the ABMI ESA model being used?**	☒Yes ☐ No ☐ N/A	**If no, why?**
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒		**Larger than the area of interest** ☐	**Downstream** ☐	
Comments: *The model is run for the Algar region, however it is capable of modelling changes provincially*					

Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☐Yes	☒ No
				List (units):	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☐Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☐Yes	☒ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☒Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		

Approvals		
Internal recommendation to include in analysis:	☒Include	☐Exclude
Reason for In/exclusion: Identified stakeholder value, model available, sensitive to restoration, likely to be a part of GoA offset policy		
Stakeholder Approval:	☒Yes	☐No
Include as final indictor for the ES?	☒Yes	☐No

Table A-0-11. Ecosystem Service Selection Criteria - Pollination

Ecosystem Service Characteristics					
Ecosystem Service:	Pollination (supporting function)				
Stakeholder Value:	Sustain successional patterns and ecological processes [89]				
Description:	Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators[90]				
Stakeholders					
Are there stakeholders within the defined region?	☐Yes	☒ No ☐Unconfirmed	• N/A		
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:	Unknown		**In-situ** ☐	**Larger than Area of Interest** ☒	**Downstream** ☐
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)	**3**		**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:			**Is the model transparent and easy to understand?**		☒ Yes ☐ No
Additional comments:					
Approvals					
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**		
Reason for in/exclusion:	No defined stakeholders in the region. The model is designed for canola pollination, not relevant to the Algar area.				

[89] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[90] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Table A-0-12. Ecosystem Service Selection Criteria – Provision of Fresh Water

Ecosystem Service Characteristics	
Ecosystem Service:	Provision of fresh water
Stakeholder Value:	Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants[91]; Sustain fish populations[92]; Companies maintain their social license to operate[93]; Water quality for communities[94]
Description:	People obtain fresh water from ecosystems and thus the supply of fresh water can be considered a provisioning service.

Stakeholders			
Are there stakeholders within the defined region?	☒**Yes**	☐ **No** ☐**Unconfirmed**	• General Public • First Nations

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:	Unknown	**In-situ** ☐	**Larger than Area of Interest** ☐	**Downstream** ☒

Ecosystem Service Selection Criteria			
How many times the stakeholder value was identified (literature review or consultation)	**14**	**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: Water Act, Water for Life, etc.		**Is the model transparent and easy to understand?**	☒ **Yes** ☐ **No**
Additional comments:			

Approvals			
Include on Final ES List:	☐**Yes**	☒ **No**	**If yes, continue to next section**
Reason for in/exclusion:	Not sensitive to restoration – river salinity may be sensitive to change, however, it is likely this will be captured by a water quality ladder for the measurement of the regulation of water quality		

[91] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework Prepared for the Regional Municipality of Wood Buffalo.
[92] Ibid
[93] Phase 1 Advisory Committee members
[94] Ibid

Table A-0-13. Ecosystem Service Selection Criteria – Provision of Natural Medicines

Ecosystem Service Characteristics			
Ecosystem Service:	Provision of Natural Medicines		
Stakeholder Value:	Maintain opportunities for traditional land use[95]		
Description:	The provision of naturally provided sources of health products		
Stakeholders			
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• First Nations

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:	Unknown	**In-situ** ☒	**Larger than Area of Interest** ☐	**Downstream** ☐

Ecosystem Service Selection Criteria			
How many times the stakeholder value was identified (literature review or consultation)	6	**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: Land Use Framework		**Is the model transparent and easy to understand?**	☐ Yes ☒ No
Additional comments: Model could be run to simulate growth and availability of traditional use plants, but would not be transparent or easy to understand.			

Approvals			
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**
Reason for in/exclusion:	Not transparent to calculate, too much uncertainty surrounding likelihood of use by local stakeholders		

[95] Alberta Government (2014). Lower Athabasca Region, Biodiversity Management Framework, Version 1.0, Draft

Table A-0-14.Ecosystem Service Selection Criteria – Provision of Biomass Fuels

Ecosystem Service Characteristics			
Ecosystem Service:	Provision of Raw Materials – Biomass Fuels		
Stakeholder Value:	Sustain a land base for timber harvest [96]		
Description:	Provision of wood for the use of biomass		
Stakeholders			
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• General Public • Forestry

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:	1-100 years	**In-situ** ☒	**Larger than Area of Interest** ☐	**Downstream** ☐

Ecosystem Service Selection Criteria			
How many times the stakeholder value was identified (literature review or consultation)	5	**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: Bioenergy Producer Credit Program		**Is the model transparent and easy to understand?**	☒ Yes ☐ No
Additional comments:			

Approvals			
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**
Reason for in/exclusion:	With the inclusion of biomass fuels, we would be double counting the timber supply available for harvest. Timber supply is included on the final list.		

[96] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo

Table A-0-15. Ecosystem Service Selection Criteria– Provision of Raw Materials – Fiber

<table>
<tr><th colspan="6">Ecosystem Service Characteristics</th></tr>
<tr><td>Ecosystem Service:</td><td colspan="5">Provision of Raw Materials – Fiber</td></tr>
<tr><td>Stakeholder Value:</td><td colspan="5">Sustain a land base for timber harvest[97], Maintain opportunities for traditional land use [98]</td></tr>
<tr><td>Description:</td><td colspan="5">Provision of fibers available for harvest in the forest (e.g. pulp and paper)</td></tr>
<tr><th colspan="6">Stakeholders</th></tr>
<tr><td>Are there stakeholders within the defined region?</td><td>☒Yes</td><td>☐ No
☐Unconfirmed</td><td colspan="3">• General Public
• Forestry
• First Nations</td></tr>
<tr><th colspan="2">Ecosystem Service Type</th><th colspan="4">Market Prices</th></tr>
<tr><td>☒ Provisioning</td><td>☐ Regulating</td><td colspan="2">Is there a market price available?</td><td>☒Yes</td><td>☐ No
☐Unknown</td></tr>
<tr><td>☐ Cultural</td><td>☐ Supporting</td><td colspan="2">If no, can a market price be created?</td><td>☐Yes</td><td>☐ No
☐Unknown</td></tr>
<tr><th colspan="2">Timeline</th><th colspan="4">Scale of Benefits</th></tr>
<tr><td>Estimated time until benefits are received:</td><td>30+ years</td><td>In-situ
☒</td><td colspan="2">Larger than Area of Interest
☐</td><td>Downstream
☐</td></tr>
<tr><th colspan="6">Ecosystem Service Selection Criteria</th></tr>
<tr><td>How many times the stakeholder value was identified (literature review or consultation)</td><td>11</td><td colspan="3">Can we model a change in defined indicators for the ES?</td><td>☒ Yes
☐ No</td></tr>
<tr><td>Does the ES clearly link to the stakeholder value?</td><td>☒ Yes
☐ No</td><td colspan="3">Is there available input data for the model?</td><td>☒ Yes
☐ No</td></tr>
<tr><td>Is the ES currently relevant to policy (current or upcoming)</td><td>☒ Yes
☐ No</td><td colspan="3">If yes, is the data freely available?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="2">If yes, specify which policy: Forestry Act, Alberta Land Stewardship, Land Use Framework</td><td colspan="3">Is the model transparent and easy to understand?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="6">Additional comments:</td></tr>
<tr><th colspan="6">Approvals</th></tr>
<tr><td>Include on Final ES List:</td><td>☐Yes</td><td>☒ No</td><td colspan="3">If yes, continue to next section</td></tr>
<tr><td>Reason for in/exclusion:</td><td colspan="5">Although Alpac is a pulp and paper producer, we are capturing that value in the measurement of timber supply (the provision of raw materials – timber supply). Wildlife derived products was the other potential indicator identified in the literature review, however, it is assumed restoration will not have a large impact on the amount of animals trapped in the area of interest – there will not likely be more trap lines established once restoration occurs (e.g. not sensitive to restoration).</td></tr>
</table>

[97] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[98] Alberta Government (2014). Lower Athabasca Region, Biodiversity Management Framework, Version 1.0, Draft

Table A-0-16 Ecosystem Service Selection Criteria – Wood as Timber

Ecosystem Service Characteristics				
Ecosystem Service:	Provision of Raw Materials – Wood as Timber			
Stakeholder Value:	Sustain a land base for timber harvest [99]			
Description:	Provision of wood for the use of timber			
Stakeholders				
Are there stakeholders within the defined region?	☒**Yes**	☐ **No** ☐**Unconfirmed**	• General Public • First Nations	
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:	30 years	**In-situ** ☒	**Larger than Area of Interest** ☐	**Downstream** ☐
Ecosystem Service Selection Criteria				
How many times the stakeholder value was identified (literature review or consultation)	**5**	**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: Forest Act, Alberta Land Stewardship Act, Land Use Framework		**Is the model transparent and easy to understand?**	☒ **Yes** ☐ **No**	
Additional comments:				
Approvals				
Include on Final ES List:	☒**Yes** ☐ **No**	**If yes, continue to next section**		
Reason for in/exclusion:	Important ES, globally accepted, transparent and intuitive. Direct relationship between value and service			

[99] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo

Table A-0-17. Indicator Selection Criteria – Wood Available for Production

Indicator Characteristics					
Ecological Indicator:	Wood available for production (timber supply)				
Description	Wood available for harvest by forestry companies at time 30		**Units:** m^3/ha		
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** Timber Supply Analysis	
Owner: Silvacom (COSIA)					
Model Use Agreement: Restricted (owned)					
Is there available input data?	☒Yes	☐ No	**Required Inputs:** Growth and Yield, Landbase (developed by Silavcom)		
Name: Name of required input data	**Version:** Version of the input data and effective date		**Coverage:** Geographic coverage of the data inputs		**Acquired from:** Who the data was acquired from
Name: Name of required input data	**Version:** Version of the input data and effective date		**Coverage:** Geographic coverage of the data inputs		**Acquired from:** Who the data was acquired from;
Is there an ABMI ESA model available?	☒Yes ☐ No ☐ N/A		**Is the ABMI ESA model being used?**	☐Yes ☒ No ☐ N/A	**If no, why?** Resolution and accuracy of data available from Landbase
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒		**Larger than the area of interest** ☐		**Downstream** ☐
Comments:					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes ☐ No **List (units):** $/$m^3$	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☒Yes	☐ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:	☒Include	☐Exclude			
Reason for In/exclusion: Easily measurable and an important ES to stakeholders. Data and models available and commonly used					
Stakeholder Approval:	☒Yes	☐No			
Include as final indictor for the ES?	☒Yes	☐No			

Table A-0-18. Ecological Indicator Selection Criteria – Forest Biomass Production

Indicator Characteristics					
Ecological Indicator:	Forest biomass production				
Description	Amount of biomass added to the landbase through restoration activities	**Units:** ODT			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** BRIMS Methodology	
Owner: N/A					
Model Use Agreement: N/A					
Is there available input data?	☒Yes ☐ No	**Required Inputs:** Forest growth curves			
Name: Linear Restoration Inventory, AVI	**Version:** RLI 2015, AVI 2.1.1	**Coverage:** Algar, Alberta	**Acquired from:** AltaLIS		
Is there an ABMI ESA model available?	☒Yes ☐ No ☐ N/A	**Is the ABMI ESA model being used?**	☐Yes ☒ No ☐ N/A	**If no, why?** Model developed in house, higher resolution and internal linear restoration inventory data	
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒	**Larger than the area of interest** ☐	**Downstream** ☐		
Comments: Measures change in capacity to sequester carbon on the seismic line restored and for the Algar region as the forest changes					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes ☐ No	**List (units):** $/tonne/year
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☒Yes	☐ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:	☐Include	☒Exclude			
Reason for In/exclusion: The change in biomass will also be captured in the measurement of timber supply (m^3) as this would be an input for the biomass calculation; biomass increases do not directly link to climate regulation					
Stakeholder Approval:	☐Yes	☒No			
Include as final indictor for the ES?	☐Yes	☒No			

Table A-0-19. Ecosystem Service Selection Criteria – Provision of Wild Foods

Ecosystem Service Characteristics	
Ecosystem Service:	Provision of Wild Foods
Stakeholder Value:	Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants[100]; sustain healthy populations of native wildlife[101]; sustain fish populations[102]; and maintain opportunities for traditional land use[103].
Description:	Includes the vast range of food products derived from plants, animals, and microbes.

Stakeholders			
Are there stakeholders within the defined region?	☒**Yes**	☐ **No** ☐**Unconfirmed**	• General Public • First Nations

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** ☐	**Downstream** ☐

Ecosystem Service Selection Criteria			
How many times the stakeholder value was identified (literature review or consultation)	**20**	**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: Hunting regulations, Land Use Framework, etc.		**Is the model transparent and easy to understand?**	☒ **Yes** ☐ **No**
Additional comments:			

Approvals			
Include on Final ES List:	☒**Yes**	☐ **No**	**If yes, continue to next section**
Reason for in/exclusion:	Links to ES values, Transparent and easy to understand. Can be seen as provisioning service as well as cultural.		

[100] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework Prepared for the Regional Municipality of Wood Buffalo.
[101] Ibid
[102] Ibid
[103] Alberta Government (2014). Lower Athabasca Region, Biodiversity Management Framework, Version 1.0, Draft

Table A-0-20. Indicator Selection Criteria – Animals Available for Hunting (moose)

Indicator Characteristics					
Ecological Indicator:	Moose available to hunt				
Description	Area of suitable habitat available for moose in Algar after restoration may affect species populations	**Units:** Number of moose available for hunting			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** Tolko Habitat Requirements for Moose, Mistik FMA Area Moose Winter Habitat Determination Model	
Owner: N/A					
Model Use Agreement: N/A					
Is there available input data?	☒Yes	☐ No	**Required Inputs:** Landbase, AVI		
Name: Silvacom Landbase (COSIA), AVI	**Version:** 2014, 2.1.1	**Coverage:** Algar, Alberta		**Acquired from:** AltaLIS, Silvacom (COSIA)	
Is there an ABMI ESA model available?	☐Yes ☒ No ☐ N/A	**Is the ABMI ESA model being used?**	☐Yes ☐ No ☒ N/A	**If no, why?**	
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒	**Larger than the area of interest** ☐		**Downstream** ☐	
Comments: Note: habitat models were used, then using assumptions population density estimates were made for the region					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes	☐ No
				List (units): $/moose	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☒Yes	☐ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:	☒Include	☐Exclude			
Reason for In/exclusion: Moose is an important cultural and key stone species for the boreal forest					
Stakeholder Approval:	☒Yes	☐No			
Include as final indictor for the ES?	☒Yes	☐No			

Table A-0-21. Indicator Selection Criteria – Offtake of a Given Species (Moose)

Indicator Characteristics					
Ecological Indicator:	Offtake of moose				
Description	Offtake of moose in WMU 519		**Units:** Number of moose tags filled in WMU 519		
Scientific Foundation					
Is the indicator measured or modelled?	☒Measured ☐Modelled	**Is there an available model:**	☐Yes ☐ No ☒ N/A	**Name:**	
Owner:					
Model Use Agreement:					
Is there available input data?	☒Yes	☐ No	**Required Inputs:** tags filled in WMU 519		
Name:	**Version:**		**Coverage:**		**Acquired from:**
Is there an ABMI ESA model available?	☐Yes ☒ No ☐ N/A		**Is the ABMI ESA model being used?**	☐Yes ☐ No ☒ N/A	**If no, why?**
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☐		**Larger than the area of interest** ☒		**Downstream** ☐
Comments:					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes	☐ No
				List (units): $/tag	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☒Yes	☐ No
Can the indicator be scaled up/down?	☐Yes	☒ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:			☐Include	☒Exclude	
Reason for In/exclusion: WMU larger than Algar area, tags filled reflects many variables, including effort, assumptions made about where the moose are, where people are hunting, etc.					
Stakeholder Approval:		☐Yes	☒No		
Include as final indictor for the ES?		☐Yes	☒No		

Table A-0-22. Indicator Selection Criteria – Plant Biomass/ha

Indicator Characteristics					
Ecological Indicator:	Biomass/ha				
Description	Amount of edible plants added through restoration	**Units:** Biomass/ha			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** BRIMS methodology	
Owner: N/A					
Model Use Agreement: N/A					
Is there available input data?	☒Yes ☐ No	**Required Inputs:** Landbase, AVI			
Name: Silvacom Landbase (COSIA), AVI	**Version:** 2014, 2.1.1	**Coverage:** Algar, Alberta		**Acquired from:** AltaLIS, Silvacom (COSIA)	
Is there an ABMI ESA model available?	☐Yes ☒ No ☐ N/A	**Is the ABMI ESA model being used?**	☐Yes ☐ No ☒ N/A	**If no, why?**	
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒	**Larger than the area of interest** ☐	**Downstream** ☐		
Comments:					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☐Yes ☒ No **List (units):**	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☐Yes	☐ No
Is the indicator transparent to calculate?	☐Yes	☒ No	**Is there a market price for the indicator?**	☐Yes	☒ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☒Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:	☐Include	☒Exclude			
Reason for In/exclusion: Not sensitive in a measurable way. Lack of use of biomass for consumption in the area. Not transparent to calculate.					
Stakeholder Approval:	☐Yes	☒No			
Include as final indictor for the ES?	☐Yes	☒No			

Table A-0-23. Ecosystem Service Selection Criteria– Air Quality Regulation

<table>
<tr><th colspan="6">Ecosystem Service Characteristics</th></tr>
<tr><td>Ecosystem Service:</td><td colspan="5">Air Quality Regulation</td></tr>
<tr><td>Stakeholder Value:</td><td colspan="5">Companies maintain their social license to operate; [104]</td></tr>
<tr><td>Description:</td><td colspan="5">Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality [105]</td></tr>
<tr><th colspan="6">Stakeholders</th></tr>
<tr><td>Are there stakeholders within the defined region?</td><td>☐Yes</td><td>☐ No
☒Unconfirmed</td><td colspan="3">• General Public
• First Nations
• Industry</td></tr>
<tr><th colspan="2">Ecosystem Service Type</th><th colspan="4">Market Prices</th></tr>
<tr><td>☐ Provisioning</td><td>☒ Regulating</td><td colspan="2">Is there a market price available?</td><td>☒Yes</td><td>☐ No
☐Unknown</td></tr>
<tr><td>☐ Cultural</td><td>☐ Supporting</td><td colspan="2">If no, can a market price be created?</td><td>☐Yes</td><td>☐ No
☐Unknown</td></tr>
<tr><th colspan="2">Timeline</th><th colspan="4">Scale of Benefits</th></tr>
<tr><td>Estimated time until benefits are received:</td><td>1+ years</td><td>In-situ
☐</td><td>Larger than Area of Interest
☒</td><td colspan="2">Downstream
☐</td></tr>
<tr><th colspan="6">Ecosystem Service Selection Criteria</th></tr>
<tr><td>How many times the stakeholder value was identified (literature review or consultation)</td><td>2</td><td colspan="3">Can we model a change in defined indicators for the ES?</td><td>☒ Yes
☐ No</td></tr>
<tr><td>Does the ES clearly link to the stakeholder value?</td><td>☒ Yes
☐ No</td><td colspan="3">Is there available input data for the model?</td><td>☒ Yes
☐ No</td></tr>
<tr><td>Is the ES currently relevant to policy (current or upcoming)</td><td>☒ Yes
☐ No</td><td colspan="3">If yes, is the data freely available?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="2">If yes, specify which policy: Alberta Ambient Air Act, Clean Air Strategy</td><td colspan="3">Is the model transparent and easy to understand?</td><td>☒ Yes
☐ No</td></tr>
<tr><td colspan="6">Additional comments:</td></tr>
<tr><th colspan="6">Approvals</th></tr>
<tr><td>Include on Final ES List:</td><td>☐Yes</td><td>☒ No</td><td colspan="3">If yes, continue to next section</td></tr>
<tr><td>Reason for in/exclusion:</td><td colspan="5">Not enough stakeholders in the region to see a meaningful change in the ES from linear restoration; there remains the potential to double count ES, depending on the indicator chosen for Air Quality (cannot be a CO2e)</td></tr>
</table>

[104] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[105] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Table A-0-24. Ecosystem Service Selection Criteria – Regulation of Pest Outbreaks

Ecosystem Service Characteristics					
Ecosystem Service:	Regulation of pest outbreaks				
Stakeholder Value:	Sustain a land base for timber harvest ;[106] Sustain successional patterns and ecological processes; [107]				
Description:	With climate change we are seeing more pest outbreaks, including spruce budworm and mountain pine beetle in the boreal forest				
Stakeholders					
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• 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:	Unknown		**In-situ** ☐	**Larger than Area of Interest** ☒	**Downstream** ☐
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)	8		**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: Weed Control Act, Forest and Prairie Protection Act, Environmental Protection and Enhancement Act, etc.			**Is the model transparent and easy to understand?**	☐ Yes ☐ No	
Additional comments:					
Approvals					
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**		
Reason for in/exclusion:	No indicators sensitive to change				

[106] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[107] Ibid

Table A-0-25. Ecosystem Service Selection Criteria – Regulation of Water Quality

Ecosystem Service Characteristics	
Ecosystem Service:	Regulation of Water Quality
Stakeholder Value:	Maintain opportunities for consumptive non-commercial use of fish, wildlife and plants; [108] Sustain fish populations; [109] Water quality for communities [110]
Description:	The purification of water supplies through natural processes

Stakeholders			
Are there stakeholders within the defined region?	☐Yes	☐ No ☒Unconfirmed	• General Public • 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** ☐	**Downstream** ☒

Ecosystem Service Selection Criteria			
How many times the stakeholder value was identified (literature review or consultation)	**12**	**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: Water Act, Water for Life, etc.		**Is the model transparent and easy to understand?**	☒ Yes ☐ No
Additional comments:			

Approvals			
Include on Final ES List:	☒Yes	☐ No	**If yes, continue to next section**
Reason for in/exclusion:	Globally accepted ES, important to industry to include, may have lessons learned when transferring to a different site.		

[108] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[109] Ibid
[110] Phase 1 Advisory Committee

Table A-0-26. Indicator Selection Criteria – Downstream N, P, TSS

Indicator Characteristics					
Ecological Indicator:	Downstream N, P, TSS				
Description	The quantity of nitrogen, phosphorous and total suspended solids in water used by communities.	**Units:** kg/year			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** ABMI water model	
Owner: ABMI					
Model Use Agreement: Open					
Is there available input data?	☒Yes	☐ No	**Required Inputs:** Precipitation, landbase		
Name: Environment Canada data	**Version:** 2014	**Coverage:** Alberta	**Acquired from:** N/A		
Name: Silvacom Landbase (COSIA)	**Version:** 2014	**Coverage:** Algar	**Acquired from:** Silvacom (COSIA)		
Is there an ABMI ESA model available?	☒Yes ☐ No ☐ N/A	**Is the ABMI ESA model being used?**	☒Yes ☐ No ☐ N/A	**If no, why?**	
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☐	**Larger than the area of interest** ☒	**Downstream** ☐		
Comments:					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes	☐ No
				List (units): $/kg removed	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☒Yes	☐ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☐Yes	☒ No	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:	☒Include	☐Exclude			
Reason for In/exclusion: Important to stakeholders, commonly assessed and valued ES, scientifically sound model					
Stakeholder Approval:	☒Yes	☐No			
Include as final indictor for the ES?	☒Yes	☐No			

Table A-0-27. Indicator Selection Criteria – Water Quality Ladder

<table>
<tr><th colspan="6">Indicator Characteristics</th></tr>
<tr><td>Ecological Indicator:</td><td colspan="5">Water quality ladder</td></tr>
<tr><td>Description</td><td colspan="2">Looks at various attributes including fish life, aquatic vegetation, river bank vegetation, and water clarity</td><td colspan="3">Units: generic score (e.g. blue, green, yellow, red)</td></tr>
<tr><th colspan="6">Scientific Foundation</th></tr>
<tr><td>Is the indicator measured or modelled?</td><td>☐Measured
☒Modelled</td><td>Is there an available model:</td><td>☒Yes
☐ No
☐ N/A</td><td colspan="2">Name: ABMI water model</td></tr>
<tr><td colspan="6">Owner: ABMI</td></tr>
<tr><td colspan="6">Model Use Agreement: Open</td></tr>
<tr><td>Is there available input data?</td><td>☒Yes</td><td>☐ No</td><td colspan="3">Required Inputs: Precipitation, landbase</td></tr>
<tr><td>Name: Environment Canada data</td><td colspan="2">Version: 2014</td><td colspan="2">Coverage: Alberta</td><td>Acquired from: N/A</td></tr>
<tr><td>Name: Silvacom Landbase (COSIA)</td><td colspan="2">Version: 2014</td><td colspan="2">Coverage: Algar</td><td>Acquired from: Silvacom (COSIA)</td></tr>
<tr><td>Is there an ABMI ESA model available?</td><td colspan="2">☒Yes
☐ No
☐ N/A</td><td>Is the ABMI ESA model being used?</td><td>☒Yes
☐ No
☐ N/A</td><td>If no, why?</td></tr>
<tr><th colspan="6">Model Output Scale</th></tr>
<tr><td colspan="6">The scale in which you model outputs are summarized</td></tr>
<tr><td>Smaller than the area of interest
☐</td><td colspan="2">In-situ
☐</td><td colspan="2">Larger than the area of interest
☒</td><td>Downstream
☐</td></tr>
<tr><td colspan="6">Comments:</td></tr>
<tr><th colspan="6">Indicator Selection Criteria</th></tr>
<tr><td>Does the indicator measure the appropriate stakeholder value?</td><td>☒Yes</td><td>☐ No</td><td colspan="2">Is there a valuation indicator available?</td><td>☒Yes ☐ No
List (units): WTP for improved water quality</td></tr>
<tr><td>Is the indicator sensitive to change?</td><td>☒Yes</td><td>☐ No</td><td colspan="2">Does the valuation indicator link to the ES?</td><td>☒Yes ☐ No</td></tr>
<tr><td>Is the indicator transparent to calculate?</td><td>☒Yes</td><td>☐ No</td><td colspan="2">Is there a market price for the indicator?</td><td>☒Yes ☐ No</td></tr>
<tr><td>Can the indicator be scaled up/down?</td><td>☒Yes</td><td>☐ No</td><td colspan="2">If no, can a market price be created?</td><td>☐Yes ☐ No</td></tr>
<tr><td>Is the indicator a species at risk?</td><td>☐Yes</td><td>☒ No</td><td colspan="3">Additional Comments:</td></tr>
<tr><th colspan="6">Approvals</th></tr>
<tr><td colspan="3">Internal recommendation to include in analysis:</td><td colspan="3">☒Include ☐Exclude</td></tr>
<tr><td colspan="6">Reason for In/exclusion: The ABMI model outputs do not allow for a water quality ladder to be developed transparently</td></tr>
<tr><td colspan="2">Stakeholder Approval:</td><td>☐Yes</td><td colspan="3">☐No</td></tr>
<tr><td colspan="2">Include as final indictor for the ES?</td><td>☐Yes</td><td colspan="3">☐No</td></tr>
</table>

Table A-0-28. Ecosystem Service Selection Criteria – Soil Formation

Ecosystem Service Characteristics				
Ecosystem Service:	Soil Formation			
Stakeholder Value:	Maintain soil quality			
Description:	Locally, changes in land cover can affect soil formation. Forested cover helps with soil formation.			
Stakeholders				
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• General public • Oil and gas • Forestry • Government	
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** ☐	**Downstream** ☐
Ecosystem Service Selection Criteria				
How many times the stakeholder value was identified (literature review or consultation)	1	**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: FMP Planning Process		**Is the model transparent and easy to understand?**	☒ Yes ☐ No	
Additional comments:				
Approvals				
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**	
Reason for in/exclusion:	Unknown market price, not identified by multiple stakeholders as important, not likely significantly sensitive to linear restoration			

Table A-0-29. Ecosystem Service Selection Criteria – Status of Traditional Knowledge

Ecosystem Service Characteristics			
Ecosystem Service:	Status of traditional knowledge, innovation and practices		
Stakeholder Value:	Maintain opportunities for traditional land use [111,112]		
Description:	Ecosystems influence the types of knowledge systems developed by different cultures[113]		
Stakeholders			
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• First Nations

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:	Unknown	**In-situ** ☒	**Larger than Area of Interest** ☐	**Downstream** ☐

Ecosystem Service Selection Criteria			
How many times the stakeholder value was identified (literature review or consultation)	6	**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: Land Use Framework		**Is the model transparent and easy to understand?**	☐ Yes ☐ No
Additional comments:			

Approvals			
Include on Final ES List:	☐Yes	☒ No	**If yes, continue to next section**
Reason for in/exclusion:	Indicators are not sensitive to restoration		

[111] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[112] Government of Alberta (2014). Biodiversity Management Framework, Version 1.0. Draft
[113] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Table A-0-30. Ecosystem Service Selection Criteria – Supporting Habitats

Ecosystem Service Characteristics					
Ecosystem Service:	Supporting Habitats				
Stakeholder Value:	Sustain recreational capability[114]; Sustain successional patterns and ecological processes[115]; sustain healthy populations of native wildlife[116]; and maintain opportunities for traditional land use[117].				
Description:	The indirect impact of healthy habitats on people				
Stakeholders					
Are there stakeholders within the defined region?	☒Yes	☐ No ☐Unconfirmed	• General Public • First Nations • Government • 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:	20 years		**In-situ** ☐	**Larger than Area of Interest** ☒	**Downstream** ☐
Ecosystem Service Selection Criteria					
How many times the stakeholder value was identified (literature review or consultation)		17	**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: Woodland Caribou Policy, Caribou Protection Plan, Species at Risk, etc.			**Is the model transparent and easy to understand?**		☒ Yes ☐ No
Additional comments:					
Approvals					
Include on Final ES List:	☒Yes	☐ No	**If yes, continue to next section**		
Reason for in/exclusion:	Links to ES values and is clear people in the region highly value healthy wildlife populations and sustainable habitats. It is also transparent and easy to understand and may have policy implications in the future. Can be viewed as a cultural ES				

[114] Cumulative Environmental Management Association, Sustainable Ecosystem Working Group (2008). Terrestrial Ecosystem Management Framework. Prepared for the Regional Municipality of Wood Buffalo
[115] Ibid
[116] Ibid
[117] Alberta Government (2014). Lower Athabasca Region, Biodiversity Management Framework, Version 1.0, Draft

Table A-0-31. Indicator Selection Criteria – Area of Suitable Habitat (Improved Caribou Habitat)

Indicator Characteristics					
Ecological Indicator:	Improved caribou habitat				
Description	Amount of the federal disturbance layer removed from the landbase due to restoration	**Units:** Hectares of intact forest			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☒Yes ☐ No ☐ N/A	**Name:** Modelled landbase changes	
Owner: N/A					
Model Use Agreement: N/A					
Is there available input data?	☒Yes	☐ No	**Required Inputs:** Disturbance on landbase		
Name: Federal disturbance layer	**Version:** 2008	**Coverage:** Canada	**Acquired from:** Environment Canada		
Is there an ABMI ESA model available?	☐Yes ☒ No ☐ N/A	**Is the ABMI ESA model being used?**	☐Yes ☐ No ☒ N/A	**If no, why?**	
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒	**Larger than the area of interest** ☒	**Downstream** ☐		
Comments: *Changes are modelled for the East Side Athabasca Herd Range, this can be scaled down to Algar.*					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes	☐ No
				List (units): WTP/sustainable herd	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☒Yes	☐ No	**Is there a market price for the indicator?**	☐Yes	☒ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☒Yes	☐ No	**Additional Comments:** Unclear if market price could be created		
Approvals					
Internal recommendation to include in analysis:	☒Include	☐Exclude			
Reason for In/exclusion: Caribou is an important keystone species for the region, it is important to stakeholders, and policy relevant					
Stakeholder Approval:	☒Yes	☐No			
Include as final indictor for the ES?	☒Yes	☐No			

Table A-0-32. Indicator Selection Criteria – Population Trends of a Given Species (Caribou)

Indicator Characteristics					
Ecological Indicator:	Population trends of caribou for the ESAR				
Description	As fragmentation decreases, we should see an increase in the survival rate of caribou for the ESAR	**Units:** Survival rate			
Scientific Foundation					
Is the indicator measured or modelled?	☐Measured ☒Modelled	**Is there an available model:**	☐Yes ☒ No ☐ N/A	**Name:** N/A	
Owner: N/A					
Model Use Agreement: N/A					
Is there available input data?	☐Yes	☒ No	**Required Inputs:** N/A		
Name: N/A	**Version:** N/A	**Coverage:** N/A	**Acquired from:** N/A		
Is there an ABMI ESA model available?	☐Yes ☒ No ☐ N/A	**Is the ABMI ESA model being used?**	☐Yes ☐ No ☒ N/A	**If no, why?**	
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☐	**Larger than the area of interest** ☒	**Downstream** ☐		
Comments: *Changes are modelled for the East Side Athabasca Herd Range, this can be scaled down to Algar.*					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒Yes	☐ No	**Is there a valuation indicator available?**	☒Yes	☐ No
				List (units): WTP/sustainable herd	
Is the indicator sensitive to change?	☒Yes	☐ No	**Does the valuation indicator link to the ES?**	☒Yes	☐ No
Is the indicator transparent to calculate?	☐Yes	☒ No	**Is there a market price for the indicator?**	☐Yes	☒ No
Can the indicator be scaled up/down?	☒Yes	☐ No	**If no, can a market price be created?**	☐Yes	☐ No
Is the indicator a species at risk?	☒Yes	☐ No	**Additional Comments:** Unclear if market price could be created		
Approvals					
Internal recommendation to include in analysis:	☐Include	☒Exclude			
Reason for In/exclusion: There are currently no models in development to estimate population trends based on restoration efforts that are transparent to calculate with all input data readily available					
Stakeholder Approval:	☐Yes	☒No			
Include as final indictor for the ES?	☐Yes	☒No			

Table A-0-33. Indicator Selection Criteria – Biodiversity Intactness Measure

Indicator Characteristics					
Ecological Indicator:	Biodiversity intactness				
Description	Represents the difference in species abundances between current landscape conditions and reference conditions (i.e. if no footprint were present)		**Units:** % intact		
Scientific Foundation					
Is the indicator measured or modelled?	☐**Measured** ☒**Modelled**	**Is there an available model:**	☒**Yes** ☐ **No** ☐ **N/A**	**Name:** ABMI Biodiversity Intactness model	
Owner: ABMI					
Model Use Agreement: Free, open					
Is there available input data?	☒**Yes**	☐ **No**	**Required Inputs:** Landcover, abundance index		
Name: Landbase	**Version:** N/A		**Coverage:** Southern Athabasca Oil Sands Area	**Acquired from:** COSIA landbase, developed by Silvacom	
Is there an ABMI ESA model available?	☒**Yes** ☐ **No** ☐ **N/A**		**Is the ABMI ESA model being used?**	☒**Yes** ☐ **No** ☐ **N/A**	**If no, why?**
Model Output Scale					
The scale in which you model outputs are summarized					
Smaller than the area of interest ☐	**In-situ** ☒		**Larger than the area of interest** ☐	**Downstream** ☐	
Comments: *Model can be run to estimate local intactness*					
Indicator Selection Criteria					
Does the indicator measure the appropriate stakeholder value?	☒**Yes**	☐ **No**	**Is there a valuation indicator available?**	☐**Yes** ☒ **No** **List (units):**	
Is the indicator sensitive to change?	☒**Yes**	☐ **No**	**Does the valuation indicator link to the ES?**	☐**Yes** ☐ **No**	
Is the indicator transparent to calculate?	☒**Yes**	☐ **No**	**Is there a market price for the indicator?**	☐**Yes** ☐ **No**	
Can the indicator be scaled up/down?	☒**Yes**	☐ **No**	**If no, can a market price be created?**	☐**Yes** ☐ **No**	
Is the indicator a species at risk?	☐**Yes**	☒ **No**	**Additional Comments:**		
Approvals					
Internal recommendation to include in analysis:			☐**Include** ☒**Exclude**		
Reason for In/exclusion: This indicator better reflects the genetic diversity ES					
Stakeholder Approval:		☐**Yes**	☒**No**		
Include as final indictor for the ES?		☐**Yes**	☒**No**		

Appendix B

Below is a summary of the models (biophysical and economic) that were used to assess the benefits of the COSIA LEAP program.

Timber Supply Model

Model Assumptions

The model used to estimate future growing stock does not anticipate or account for future natural disturbances including fires or pest outbreaks. It also assumes no new anthropogenic footprint will be added to the region. While no new anthropogenic footprint is likely because Algar falls in a remote region in northeast Alberta, this assumption would have to be reviewed if a similar assessment was to be completed in a different, more accessible region.

Furthermore, restoration is deemed a benefit to the timber supply because without intervention, it would take a significant amount of time for the lines to regenerate naturally. To allow for this assumption to hold in the model, the baseline (no intervention) assumes the seismic lines will begin to regenerate following a 25 year lag for black spruce species and a 15 year lag for all other species in the growth of the trees. This assumption may differ from physical responses, where some studies have shown seismic lines fail to recover even 50 years post disturbance.[118] Forest growth curves do however account for shading effects from the adjacent forest.

Lastly, to value the benefits of additional growing stock on the landscape, TDA tables were used, assuming the values will be the same 30 years into the future. TDA tables are updated annually, and their values can vary significantly between years (Table B-0-1).[119]

Table B-0-1: TDA Table Inputs

Alpac TDA Table	Coniferous Standing Timber Value ($/m^3)	Deciduous Standing Timber Value ($/m^3)
2014/15	6.67	2.72
2015/16	7.11	2.02
Difference	***+0.44***	***-0.70***

[118] Cassidy Van Rensen (2014). Predicting Patterns of Regeneration on Seismic Lines to Inform Restoration Planning in Boreal Forest Habitats. Department of Renewable Resources, University of Alberta.
[119] Alberta Environment and Parks. http://aep.alberta.ca/lands-forests/forest-management/timber-damage-assessment/default.aspx

Table B-0-2: Model Parameters

Model Parameters	Parameter Settings
Baseline Year	2010
Area Modelled:	Algar Project Area, Treatment Lines
Extent:	Algar Project Area
Model Resolution:	1 ha
Planning Horizon:	30 years
Model Inputs:	• Linear Restoration Inventory • Alberta Vegetation Inventory • Forest Growth Curves • Treatment response curves (height) • Linear restoration treatments
Regeneration Transition:	Pre-footprint condition
Regeneration lag for planted sites:	0 years
Regeneration lag under no treatment	25 years regeneration lag was assumed for black spruce and 15 years for all other species.
Introduce harvest/development plans:	No
Model Outputs:	• Coniferous growing stock (m^3) • Deciduous growing stock (m^3) • TDA strata (ha)
Valuation Criteria	Boreal Full Value TDA Table (2014/15)
Units:	$/ha
Year of Market Price (or Study):	2014
Year of Valuation	Time 30
Extent:	Alpac FMA
Resolution:	1 ha
Discount Rate	0%, 2%, and 4%

Interpreting Results

The timber value assigned to the restoration efforts is what Alberta-Pacific Forest Products would receive, should another company clear the area restored 30 years from today. Said differently, it is the value of timber that is harvestable in 30 years. Values were discounted by 0%, 2% and 4% to show a range of present values of this action.

While restoration adds merchantable timber to the land base, the adjacent stands are at a different age class than the treatment lines, creating operational inefficiencies that may reduce the ability to effectively harvest the timber in the future. Furthermore, due to the size of the project area and its low productivity characteristics, additional timber added to the land base may not be sufficient to increase the FMA holder's annual allowable cut. This may limit additionality, where additionality is defined as actions taken that go beyond business as usual. Under a conservation offset policy that includes additionality, the additional growing stock added to the landbase through linear restoration must be more than would be added without intervention.

Carbon Sequestration Model

Model Assumptions

The model used to estimate total ecosystem carbon stocks does not anticipate or account for future natural disturbances including fires or pest outbreaks. It also assumes no new anthropogenic footprint will be added to the region. While no new anthropogenic footprint is likely because Algar falls in a remote region in northeast Alberta, this assumption would have to be reviewed if a similar assessment was to be completed in a different, more accessible region.

Furthermore, restoration is deemed a benefit to the carbon sequestration because without intervention, it would take a significant amount of time for the lines to regenerate naturally. To allow for this assumption to hold in the model, the baseline (no intervention) assumes the seismic lines will begin to regenerate following a 25 year lag for black spruce species and a 15 year lag for all other species in the growth of the trees. This assumption may differ from physical responses, where some studies have shown seismic lines fail to recover even 50 years post disturbance.[120]

Lastly, to value the benefits of additional carbon stocks on the landscape, a carbon levy was used, assuming the levy will be the same 30 years into the future. This assumption has already been proven not to hold as the Alberta government has committed to doubling the carbon levy by 2017 to $30/tonne of CO_2e. The valuation model also assumes the carbon levy will be a lump sum payment in 30 years, rather than making annual payments for each year additional carbon is sequestered on the land base.

[120] Cassidy Van Rensen (2014). Predicting Patterns of Regeneration on Seismic Lines to Inform Restoration Planning in Boreal Forest Habitats. Department of Renewable Resources, University of Alberta.

Table B-0-3: Model Parameters

Model Parameters	Parameter Settings
Baseline Year	2010
Area modelled:	Algar Project Area, Treatment Lines
Extent:	Algar Project Area
Resolution:	1 ha
Planning Horizon:	30 years
Model Inputs:	• Linear Restoration Inventory • Alberta Vegetation Inventory • Forest Growth Curves • Total Ecosystem Carbon Curves • Linear restoration treatments
Regeneration Transition:	Pre-footprint condition
Regeneration lag for planted sites:	0 years
Regeneration lag under no treatment	25 years regeneration lag was assumed for black spruce and 15 years for all other species.
Introduce harvest/development plans:	No
Model Outputs:	Total Ecosystem Carbon (tonnes of CO_2e)
Valuation Criteria	• Alberta's Emission Reduction Regulations for Large Industrial Emitters (2014) • Environment Canada's Regulatory Impact Analysis Statement on the Renewable Fuels Regulation (2010)
Units	$/tonne of CO_2e
Year of Market Price (or Study):	2014
Year of Valuation	Time 30
Extent:	Alberta (Canada)
Resolution:	N/A
Discount Rate	0%, 2%, and 4%

Interpreting Results

Assigning a value to carbon sequestration is straightforward as a market price has already been defined by government agencies. Currently there is no federal carbon tax that is imposed on Albertan emitters, therefore the results of this analysis use the Environment Canada social cost of carbon estimation as a proxy to what the federal government may impose in the future.

Because the CBM-CFS3 model does not accurately account for soil carbon in peatlands, the carbon estimates may be lower than physical results.[121]

Lastly, this ES is closely tied to the timber supply in the region. As more trees are added to the land base through restoration, more carbon is sequestered. If those trees were harvested, the amount of carbon

[121] Personal communications with Stephen Kull

predicted to be sequestered would no longer be available. Because of this tradeoff, the benefits of restoration to climate regulation and timber supply cannot be combined and must be looked at independently.

Caribou Intactness Model

Model Assumptions

The model used to estimate the future state of caribou habitat does not anticipate or account for future natural disturbances including fires or pest outbreaks. It also assumes no new anthropogenic footprint will be added to the region. While no new anthropogenic footprint is likely because Algar falls in a remote region in northeast Alberta, this assumption would have to be reviewed if a similar assessment was to be completed in a different, more accessible region.

For this analysis it was assumed restored linear features that reach a height of 1.2m will no longer be visible at a scale of 1:50,000 and active footprint features will remain visible at a scale of 1:50,000. Furthermore, footprint that was not captured in the Federal Disturbance Layer, and consequently not visible using 1:50,000 Landsat imagery, was assumed to be recovered.

To assign a monetary value to the benefits of habitat improvements, two methods were used. The first approach used 2012 study which estimated the amount, per year, Albertan's were willing to pay to move from two to three self-sustaining caribou herds in Alberta. [122] To apply this approach to the Algar case study, a number of assumptions were applied. First it was assumed the restoration efforts in Algar created enough functional habitat to improve the ESAR range status to self-sustaining. Second, 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. Third, because it takes time for the planted trees to reach a height of 1.2m, at which they are considered restored, payments did not begin until year 30. Lastly, units were converted to willingness to pay per hectare (rather than WTP/sustainable herd), creating an unknown conversion error.

The second approach applied the opportunity cost of development to the restored area. In this analysis, the net present value (NPV) of resources on the land represents the opportunity cost of conserving habitat. This approach leveraged a study by Hauer et al., where the NPV per township was calculated taking into consideration the total value of all resources (gas, oil, bitumen, and forestry).[123] To apply this approach to the Algar case study, it was assumed that 25% of the NPV of the townships in the Algar region would reflect a more realistic estimate of the value of resources on the land at any given time, adjusting for technology and processing capacities. It was also assumed that development would begin immediately. Even though values assume that extraction begins immediately, the model does not assume all resources are taken in one year. Rather, resources are extracted over a period of time according to a production curve. [124]

The NPV/township was converted to NPV/ha and applied to the additional intact caribou habitat (ha). While this approach may seem more straightforward than the first approach, which applies a hypothetical

[122] Harper, Dana (2012). Analyzing the economic benefits of woodland caribou conservation in Alberta. MSc Thesis. University of Alberta.
[123] Hauer, G. et al. (2010). A net present value model of natural gas exploitation in northern Alberta: An analysis of land values in woodland caribou ranges. Rural Economy: Project Report. University of Alberta.
[124] Hauer, G. et. al. 2010. "A Net Present Value Model of Natural Gas Exploitation in Northern Alberta: An Analysis of Land Values in Woodland Caribou Ranges". Rural Economy: Project Report. University of Alberta.

monetary value to caribou, using the opportunity cost as a method to valuing *benefits* may not be appropriate. Many see the opportunity cost of development as a cost to restoration, because industry is forgoing development in the name of conservation. Arguably, this approach can be used in the Algar region because it was agreed upon by industry members that no development is likely to occur in the foreseeable future.

Table B-0-4 Model Parameters

Model Parameters	Parameter Settings
Baseline Year	2010
Area Modelled:	Algar Project Area, Treatment Lines
Extent:	Algar Project Area
Resolution:	1 ha
Planning Horizon:	30 years
Model Inputs:	• Linear Restoration Inventory • Alberta Vegetation Inventory • Forest Growth Curves • Treatment Response Curves (height) • Linear restoration treatments • Caribou Recovery Strategy Anthropogenic Disturbance Layer
Regeneration Transition:	Pre-footprint condition
Regeneration lag for planted sites:	0 years
Regeneration lag under no treatment	25 years regeneration lag was assumed for black spruce and 15 years for all other species.
Introduce harvest/development plans:	No
Model Outputs:	• Caribou range restored area (ha) • Caribou range intactness (ha)
Valuation Criteria	• Willingness to Pay ($)/self-sustaining herd • Net Present Value ($)/ha
Units	• $/self-sustaining herd • $/ha
Year of Market Price (or Study):	• 2011 (WTP Study) • 2010 (NPV Study)
Year of Valuation	Time 30
Extent:	• Alberta (WTP Study) • Green Zone (NPV Study)
Resolution:	• Caribou Range (WTP Study) • TWP (NPV Study)
Discount Rate	0%, 2%, 4%, and 8%

Interpreting Results

There is considerable controversy over whether contingent valuation studies, such as the Harper study cited above, adequately measure an individual's willingness to pay for changes in ES. Researchers argue that there is a fundamental difference in the way that people make hypothetical decisions relative to the way they make actual decisions and that the estimates such as WTP are consistently high. Furthermore, researchers have argued that the opportunity cost of development should be a considered a cost to restoration, rather than a benefit.

In the absence of a market price, using a WTP estimate is a reasonable approach to approximate the value of restored caribou habitat in the Algar region, however its estimation may be high compared to what society is realistically willing to pay. For more information on hypothetical bias in willingness to pay studies, refer to Carson et al. (2000).[125]

Biodiversity Intactness Model

Model Assumptions

The biodiversity intactness model is not bound by temporal parameters, creating model outputs that are a snap shot in time before and after restoration. Because the model isn't bound by temporal parameters, the surrounding forest characteristics are not aged. The model only assumes seismic lines are erased from the landbase completely following restoration. It also does not anticipate or account for future natural disturbances including fires or pest outbreaks. Likewise, it assumes no new anthropogenic footprint will be added to the region. While no new anthropogenic footprint is likely because Algar falls in a remote region in northeast Alberta, this assumption would have to be reviewed if a similar assessment was to be completed in a different, more accessible region.

The results of this analysis also assume important habitat variables for each species are included in the statistical model. The model has been peer reviewed before use, negating some of this uncertainty; however, as more field data is collected by ABMI, there is an opportunity to update the models as needed in the future.

The economic valuation approach assumes the opportunity cost of development is a benefit to restoration. It also assumes there is a linear relationship between the biodiversity value ($) and the intactness measure (%). If diminishing marginal returns exist (e.g. the value of one more unit of intactness is less than the previous), the benefits may be overstated using this approach.

Lastly, it was assumed that 25% of the NPV of the townships in the Algar region would reflect a more realistic estimate of the value of resources on the land at any given time, adjusting for technology and processing capacities. It was also assumed that development began immediately. Even though values assume that extraction begins immediately, the model does not assume all resources are taken in one year. Rather, resources are extracted over a period of time according to a production curve. [126]

[125] Carson, Richard et al. (2000). "Contingent Valuation: Controversies and Evidence". Department of Economics, University of California, San Diego.
[126] Hauer, G. et. al. 2010. "A Net Present Value Model of Natural Gas Exploitation in Northern Alberta: An Analysis of Land Values in Woodland Caribou Ranges". Rural Economy: Project Report. University of Alberta.

Table B-0-5 Model Parameters

Model Parameters	Parameter Settings
Baseline Year	2010
Area modelled:	Algar Project Area
Extent:	Alberta
Resolution:	64 ha (approx. quarter section)
Planning horizon:	N/A
Model Inputs:	• Linear Restoration Inventory • Alberta Vegetation Inventory • Individual species equations relating abundance to footprint and landscape • Pre-restoration landbase • Post-restoration landbase • Pre-disturbance landbase
Regeneration transition:	Pre-footprint condition
Regeneration lag for planted sites:	N/A
Regeneration lag under no treatment	N/A
Introduce harvest/development plans:	No
Model Outputs:	• Biodiversity Index value, scaled from 0 – 100%. 100% represents no change from reference conditions.
Valuation Criteria	• Net Present Value
Units:	($)/ha
Year of Market Price (or Study):	2010
Year of Valuation	Time 30
Extent:	Green Zone of Alberta
Resolution:	TWP
Discount Rate	0%, 2%, 4%, and 8%

Interpreting Results

The economic valuation of biodiversity remains a controversial topic, both in terms of methodology and in some cases morally, where people argue the presence of biodiversity is *priceless.* Where consensus can be found is that biodiversity is an important attribute to the boreal forest and the benefits gained through restoration efforts should not go unnoticed. Should the economic valuation be used from the results of this analysis, the results should be interpreted with care. Due to the assumptions used, most notably that the opportunity cost of development is a benefit of restoration, rather than a cost, and no diminishing marginal returns exist, there is the potential benefits of linear restoration to biodiversity are overstated. Furthermore, the same economic valuation approached was used to estimate the value of caribou to Albertans. Should that approach be used for the calculation of caribou benefits, the caribou and biodiversity benefit estimates should not be considered additive. Land can only be put into a conservation area once, therefore adding the values twice for two ecosystem services would overstate benefits. That being said, there is the potential that Albertan's value caribou above and beyond the land being set aside to protect the area's biodiversity. The willingness to pay study that was used as an alternative approach to estimate the value Albertan's place on the species addresses this.

Water Purification Model

Model Assumptions

The model used to estimate water pollutants is not bound by temporal parameters, creating model outputs that are a snap shot in time: before and after restoration. The model also does not anticipate or account for future natural disturbances including fires or pest outbreaks. It also assumes no new anthropogenic footprint will be added to the region. While no new anthropogenic footprint is likely because Algar falls in a remote region in northeast Alberta, this assumption would have to be reviewed if a similar assessment was to be completed in a different, more accessible region.

Additionally, the model used a DEM to derive a stream network, meaning no in-stream processes are used in the model; once pollutants reach surface water (i.e. a river), they will be carried downstream. The model also ignores other aspects of hydrology including evapotranspiration, infiltration, and groundwater flow.

Lastly, the economic valuation approach assumes there are beneficiaries downstream to enjoy the improvement in water quality. Because Algar is in a remote region of northeast Alberta, the closest population base downstream is Fort McMurray, which is approximately 70km as the crow flies from the restoration site. The model also assumes restoration costs are linear in relation to a reduction in pollutants.

Table B-0-6 Model Parameters

Model Parameters	Parameter Settings
Baseline Year	2010
Area Modelled:	Algar Project Area
Extent:	Major watershed region (i.e. Lower Athabasca)
Resolution:	64 ha (approx. quarter section)
Planning Horizon:	N/A
Model Inputs:	• Linear Restoration Inventory • Alberta Vegetation Inventory • Digital elevation model (to derive stream network) • Annual precipitation data • Nutrient export coefficients for landcover types (Donahue 2013) • Runoff coefficients for landcover types • Nutrient retention coefficients for landcover types
Regeneration Transition:	Pre-footprint condition
Regeneration lag for planted sites:	N/A
Regeneration lag under no treatment	N/A
Introduce harvest/development plans:	No
Model Outputs:	• kg/y of N, P, and TSS exported and retained by each cell of the landscape • Annual loading of N, P, and TSS to waterbodies of interest
Valuation Criteria	• Replacement Cost
Units:	$/kg
Year of Market Price (or Study):	Literature review of 14 studies
Year of Valuation	Time 30
Extent:	North America
Resolution:	N/A
Discount Rate	0%, 2%, and 4%

Interpreting Results

The model was developed to estimate pollutant concentrations at a regional scale (e.g. watershed scale), therefore when employing the model for smaller regions, the benefits may be overstated. The model was also developed to estimate the flow of pollutants over the landscape, therefore it cannot provide accurate information of the concentration of pollutants in waterbodies. It is calibrated to estimate where pollutant source and sinks are on the landscape.

Additionally, because there is not a population base in close proximity to the restoration site to benefit from the improvement in water quality, the economic valuation is likely overstated. That said, it is possible there are indirect beneficiaries who would receive value from the existence of purified water or the existence of the plants and animals present in the area that depend on the purified water for their survival. Thus it is safe to assume that the value of the purified water provided by the Algar restoration is not zero.

Lastly, when using a replacement cost approach to estimate the economic benefit to the ecosystem service change, the model should reflect the similar cost curves to the market. In terms of water quality treatment costs, treatment costs are typically non-linear; a pollutant concentration threshold needs to be crossed to see an increase in water quality treatment costs. Similarly, a reduction in pollutant concentrations would need to go below that threshold to see a reduction in costs.

Mistik FMA Area Moose Winter Habitat Determination Model

Model Assumptions

The Mistik habitat suitability model does not anticipate or account for future natural disturbances including fires or pest outbreaks. It also assumes no new anthropogenic footprint will be added to the region. While no new anthropogenic footprint is likely because Algar falls in a remote region in northeast Alberta, this assumption would have to be reviewed if a similar assessment was to be completed in a different, more accessible region.

The model also assumes a total softwood component of at least 18% is required to sustain moose in the winter months. It also assumes moose do not select treed muskeg as preferred habitat, making the Algar region an area with minimal high quality habitat. Canopy closure and vertical structure are also important deciding factors for moose according to the model. Furthermore, adjacency to early seral stages, access to aquatic vegetation and rivers/streams are also considered.

The valuation metrics used were from a 2006 study conducted in Alaska.[127] The study estimated the value of Alaskan moose populations. To employ this study in the Algar region, it was assumed that linear restoration *reduced* the amount of high quality habitat, thus reducing moose populations based on estimated WMU densities and the change in habitat suitability from restoration.

The valuation study assumed a pound of moose meat displaced a pound of other meat, and in the study beef prices were used. Using the average moose harvest and the total values provided in the study spent on moose hunting, a dollar value per moose hunted was derived. It was further assumed that the small changes in habitat availability would change the population of moose in the area, and thus the moose available for hunting. Time lags in moose populations based on the habitat changes were not accounted for. It was also assumed that any habitat, whether it be low, medium or high quality, is considered on the same level. So an increase in low habitat quality coinciding with the same decrease in high quality habitat would have no effect on overall habitat. Lastly, hunting success rates were not included in the analysis.

[127] Northern Economics Inc. 2006, The Value of Alaska Moose, Prepared for Anchorage Soil and Water Conservation District and the Alaska Soil and Water Conservation District.

Table B-0-7. Model Parameters

Model Parameters	Parameter Settings
Baseline Year	2010
Area Modelled:	Algar Project Area
Extent:	Algar Project Area
Resolution:	1 ha
Planning Horizon:	30 years
Model Inputs:	• Linear Restoration Inventory • Alberta Vegetation Inventory • Forest Growth Curves • Treatment Response Curves (height) • Linear restoration treatments
Regeneration Transition:	Pre-footprint condition
Regeneration lag for planted sites:	0 years
Regeneration lag under no treatment	25 years regeneration lag was assumed for black spruce and 15 years for all other species.
Introduce harvest/development plans:	No
Model Outputs:	• Amount of high, medium, and low quality habitat (ha)
Valuation Criteria	• Benefits Transfer: Replacement Cost
Units:	$/moose hunted
Year of Market Price (or Study):	2005
Year of Valuation	Time 30
Extent:	Alaska
Resolution:	N/A
Discount Rate	0%, 2%, and 4%

Interpreting Results

The moose habitat model was developed with state-of-the-art scientific information on species habitat requirements. However, the model has not yet been field validated for the Algar region. To assess the ability the model has to predict the distribution of species, sound presence/absence field inventories must first be completed. [128] The model was not developed to estimate population changes as a result of habitat quality. As such it remains difficult to estimate the dollar value of the indicator.

There is no change in the total moose habitat available between the no treatment and the treatment scenario in the Algar region after 30 years. The model, however, predicts an overall reduction in the quality of habitat following restoration. Because linear restoration adds trees back to the landbase faster than when left to naturally regenerate, and according to the habitat model, moose depend on early seral stage forests to forage, the treated lines are no longer considered high quality habitat 30 years following restoration. However, when the legacy lines are left untreated, the age of the forest remains ideal moose habitat. These results indicate that the treatment of the lines in Algar will not generate a significant impact on moose populations. This trade-off was expected, as linear restoration was aimed at improving caribou habitat, not moose habitat.

Moose densities estimations for WMU 519, which the Algar region falls within, in the winter of 1993 and 1994 were approximately 0.11 moose/km^2. [129] Based on the assumption that improved habitat suitability would allow for more animals, it is estimated that there would be fewer moose in the Algar area with treatment according to the model. This further assumes the density is affected by habitat quality and nothing else (predation, hunting, climate, etc.).

Because the model estimates slight population changes (less than one animal), the valuation results are difficult to defend. Nonetheless, moose was identified by stakeholders as an important ES indicator and should be recognized in the analysis. The Alaskan study provides some justification of the values associated with moose hunting, and the results may differ if the study was moved to a different or larger region, where changes in moose habitat may be more prevalent.

Lastly, it is important to note different groups of resource users will value moose differently and regional differences may skew results significantly (e.g. cultural biases between Alaska and Alberta). Furthermore, because moose was used as an indicator for the provision of wild foods, non-consumption values (such as tourism created through wildlife viewing) were not accounted for. Should moose be used as an indicator for a different ES in the future, this assumption should be revisited.

Tolko Habitat Requirements for Moose

Model Assumptions

The habitat suitability model does not anticipate or account for future natural disturbances including fires or pest outbreaks. It also assumes no new anthropogenic footprint will be added to the region. While no new anthropogenic footprint is likely because Algar falls in a remote region in northeast Alberta, this

[128] Proulx, G. (2006). Development of queries and predictive distribution maps for wildlife indicator species, species of concern, and species at risk for the current (2006) forest condition in the Mistik FMA area.
[129] CEMA (2002), A Review and Assessment of Existing Information for Key Wildlife and Fish Species in the Regional Sustainable Development Strategy Study Area – Volume 1: Wildlife

assumption would have to be reviewed if a similar assessment was to be completed in a different, more accessible region.

Habitat quality in the Tolko Habitat Requirements for Moose model was determined by cover group and forested age class. The model assumes moose prefer conifer dominated mixedwood forests the most, specifically between 50 and 100 years old. Deciduous dominated forests are considered unsuitable for moose according to the model.

Table B-0-8: Model Parameters

Model Parameters	Parameter Settings
Baseline Year	2010
Area Modelled:	Algar Project Area
Extent:	Algar Project Area
Resolution:	1 ha
Planning Horizon:	30 years
Model Inputs:	• Linear Restoration Inventory • Alberta Vegetation Inventory • Forest Growth Curves • Treatment Response Curves (height) • Linear restoration treatments
Regeneration Transition:	Pre-footprint condition
Regeneration lag for planted sites:	0 years
Regeneration lag under no treatment	25 years regeneration lag was assumed for black spruce and 15 years for all other species.
Introduce harvest/development plans:	No
Model Outputs:	• Amount of high, medium, and low quality habitat (ha)
Valuation Criteria	• Benefits Transfer: Replacement Cost
Units:	$/moose
Year of Market Price (or Study):	2005
Year of Valuation	Time 30
Extent:	Alaska
Resolution:	N/A
Discount Rate	0%, 2%, and 4%

The valuation metrics used were from a 2006 study conducted in Alaska.[130] The study estimated the value of Alaskan moose populations. To employ this approach in the Algar region, habitat suitability was converted to population estimates. Based on estimated WMU densities and the change in habitat suitability from restoration, an increase in moose populations was estimated.

[130] Northern Economics Inc. 2006, The Value of Alaska Moose, Prepared for Anchorage Soil and Water Conservation District and the Alaska Soil and Water Conservation District.

The valuation study assumed a pound of moose meat displaced a pound of other meat, and in the study beef prices were used. Using the average moose harvest and the total values provided in the study spent on moose hunting, a dollar value per moose hunted was derived. It was further assumed that the small changes in habitat quality would change the population of moose in the area, and thus the moose available for hunting. Time lags in moose populations based on the habitat changes were not accounted for. It was also assumed that any improvement in habitat quality, whether it be low to medium or medium to high quality would improve populations. Lastly, hunting success was not accounted for in this analysis.

Interpreting Results

The moose habitat model was developed with a significant contribution of scientific research on moose habitat requirements. However, the model has not been field validated for the Algar region. The model was not developed to estimate population changes as a result of habitat quality.

The difference in total moose habitat between the no treatment and the treatment scenario in the Algar region after 30 years did not change. Rather, under the treatment scenario 21 ha of habitat improved from low quality to medium quality. As the forest continues to age past the 30 year timeframe of the model, low quality habitat will continue shift into higher quality.

To estimate changes in population, the model assumes the population density will be affected by habitat quality and nothing else (predation, hunting, climate, etc.). Without accounting for other externalities (e.g. predation), and the small estimated change in population (less than one animal), the valuation results are difficult to defend. Nonetheless, moose was identified by stakeholders as an important ES indicator and should be recognized in the analysis. The Alaskan study provides some justification of the values associated with moose hunting, and the results may differ if the study was moved to a different or larger region, where changes in moose habitat may be more prevalent.

Lastly, it is important to note different groups of resource users will value moose differently and regional differences may skew results significantly (e.g. cultural biases between Alaska and Alberta). Furthermore, because moose was used as an indicator for the provision of wild foods, non-consumption values (such as tourism created through wildlife viewing) were not accounted for. Should moose be used as an indicator for a different ES in the future, this assumption should be revisited.

Appendix C

Moose Habitat Assessment Results

Two models were employed to assess habitat changes following restoration, with varying results. Both models assessed the available habitat 30 years into the future, under two scenarios: with and without treatment.

Using the Mistik Winter Habitat Determination model, linear restoration treatments also do not increase the amount of habitat available for moose. This model depends heavily on early seral stage forests (less than 25 years old) to provide suitable habitat for moose. Different than the above model, the Mistik model estimates a reduction in high quality habitat following restoration. This result is expected because linear restoration improves how fast the forest can regenerate, causing the legacy seismic lines to move into a later seral stage faster than left to naturally regenerate on their own.

Table C-0-1 Mistik Winter Habitat Assessment Results

Habitat Quality	Control Scenario (ha)	Treatment Scenario (ha)
High	11,961	10,032
Medium	34,510	36,437
Low	3,619	3,621
Unsuitable [131]	6,825	6,825

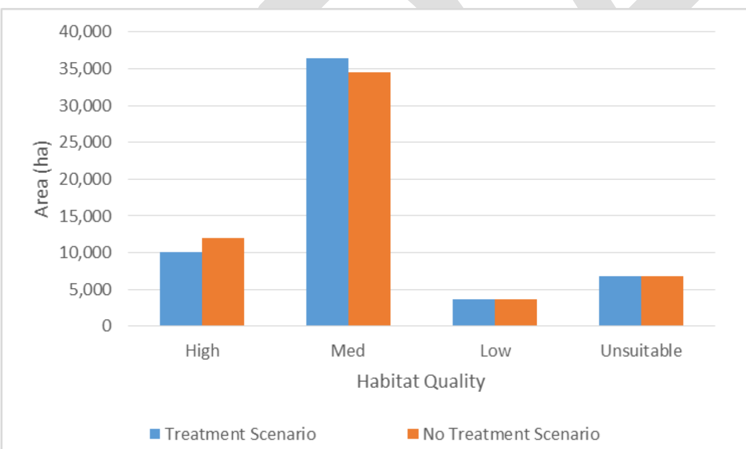

Figure 14 Mistik Winter Habitat Assessment Results

Using the Tolko Habitat Requirements for Moose, linear restoration treatments do not increase the amount of habitat available for moose, but it does improve the quality by 21 ha. Linear restoration promotes the regeneration of forest faster than if left to regenerate naturally, moving some of the treated lines into "medium habitat quality" faster than under the control scenario. As the forest continues to age,

[131] The model considers deciduous dominated forested stands, non-forested stands, and anthropogenic footprint are unsuitable habitat

the natural succession of the region will improve/diminish habitat quality depending on the current age of the forest and habitat preferences.

Table C-0-2 Tolko Habitat Assessment Results

Habitat Quality	Control Scenario (ha)	Treatment Scenario (ha)
High	1,570	1,570
Medium	41,967	41,988
Low	293	272
Unsuitable [132]	13,084	13,084

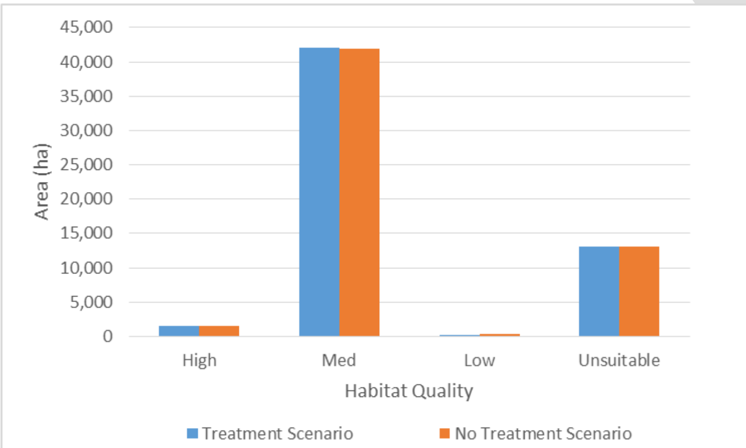

Figure 15 Tolko Habitat Assessment Results

Both habitat models results differ significantly from one another. The Tolko Habitat Requirements focus on overall habitat requirements at a very high level, where the Mistik Winter Habitat Requirements focus on moose requirements to survive winter. As such, it was not expected that the results would be the same. However, both models show relatively little change in moose habitat quality following restoration. These results were expected as the Algar Linear Restoration Project was not focused on improving moose habitat in the region. To see a larger improvement in moose habitat, restoration would have to be focused close to rivers and streams, but away from treed muskeg (which dominates the Algar region).

Nonetheless, moose was identified by stakeholders as an important ES indicator and should be recognized in the analysis. To have a complete ES assessment, it is important to address any trade-offs between highly valued indicators stakeholders have identified that may be affected through a management alternative.

Moose Habitat Valuation Results

The Algar restoration project treated approximately 211 ha of seismic line over four years. While the project focused on improved intactness for caribou, stakeholders had identified moose as another species of interest. In 30 years, moose habitat improvements following restoration are not significant. However,

[132] The model considers deciduous dominated forested stands, non-forested stands, and anthropogenic footprint are unsuitable habitat

changes in population densities were estimated to attempt to value the change in the provision of wild foods from linear restoration.

Current moose densities are estimated to be $0.11/km^2$ (0.000011 ha) for the WMU of which the Algar region falls within.[133] Using the changes in habitat suitability and current density estimates, population changes in the Algar region following restoration are estimated to be less than one moose.

The estimated value of a moose hunted, following a 2006 Alaskan study, is approximately $5,000 CDN (2010). When this value is applied to the number of moose added to the landbase, a total value of restoration for the provision of wild foods is $0.

Because the estimations are occurring 30 years into the future, discount rates of 0%, 2%, and 4% were applied to estimate the net present value (NPV).

Table C-0-3 Future State Moose Habitat Benefits (NPV)

Discount Rate	Value of Moose Habitat Improvements	
	Lower Limit (Mistik Model)	Upper Limit (Tolko Model)
0%	-$ 0.13	$ 1.52
2%	-$ 0.07	$ 0.84
4%	-$ 0.04	$ 0.47

[133] CEMA (2002), A Review and Assessment of Existing Information for Key Wildlife and Fish Species in the Regional Sustainable Development Strategy Study Area – Volume 1: Wildlife